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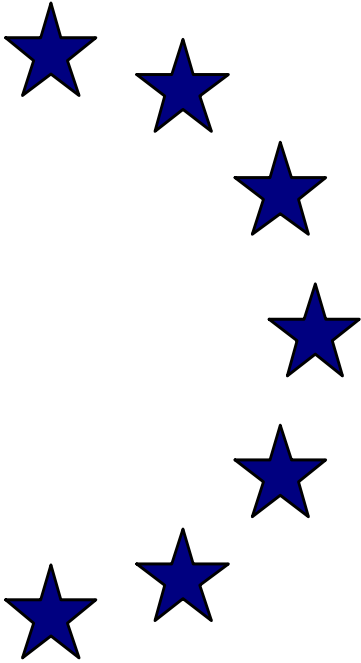
**Proceedings of the 2004 First
Annual DG ECFIN Research Conference on
"Business Cycles and Growth in Europe"**

Edited by Lars Jonung
Directorate-General for Economic and Financial Affairs

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Introduction

In October 2004, DG ECFIN held its first annual research conference. The theme of the conference was "Business Cycles and Growth in Europe". The thirteen papers presented are collected here in revised form in two volumes as Economic Paper number 227, 1/2 and 2/2. Some of the contributions are followed by comments made by the discussants.

The aim of the conference was to bring together academics and policy-makers interested in recent work on the theory and empirics of business cycles and growth with a focus on European developments.

The conference took as its starting point the creation and impact of the euro. The common currency and the Economic and Monetary Union have changed and continue to change the economic landscape of Europe in many ways. A single monetary policy has been in place in the euro area for over six years and a framework for economic policy co-ordination is evolving. With the recent enlargement of the EU, the whole of Europe is gradually being transformed into one large common market.

These historic processes are having far-reaching consequences for business cycles and growth in Europe. As a result, policy-makers and academic researchers are facing new and challenging issues such as:

1. When, if ever, will one common euro-area business cycle emerge? Has it already emerged? How rapidly are the cycles of the Member States converging?

2. What will the relationship between the euro-area business cycle and the world business cycle be?

3. To what extent has the introduction of the euro influenced the characteristics of the business cycle in Europe? Have the cycles of the Member States become more synchronised over time?

4. Following the enlargement that took place in the spring of 2004, the EU is now trying to integrate the new Member States in the East with the old members of the West. This process raises many issues such as: how rapidly will the business cycles of the new Member States converge with the cycles of Western Europe? What are the sources of economic volatility in the new Member States compared to those in the old Member States? Are the macroeconomic disturbances in the new Member States due to specific problems during the transition phase? Or are they caused by "normal" business cycle fluctuations?

The conference was subdivided into four main sessions (see the enclosed conference programme).

1. Differences and commonalities in business cycles and growth: Evidence from the EU and US.
2. International transmission of business cycles.
3. Business cycles in Europe.
4. Business cycles and growth: Theory and evidence from old and new Member States.

The papers presented here are printed in the order of the programme. All sessions covered issues relating to business cycles and growth. Some papers have a specific European perspective, incorporating empirical and applied analyses, while others have a more worldwide perspective. Yet another group of papers are more theoretical or combine theory with empirical applications. Of course, there is considerable overlap between the four sessions.

The conference was organised by Lars Jonung and Klaus Wälde, both research advisers at DG ECFIN, and was designated as the first annual DG ECFIN research conference. It was preceded by a conference held in 2003 on "Who will own Europe? The internationalisation of asset ownership in the EU today and in the future". (The proceedings from this conference will be published by Cambridge University Press in October 2005 as *The Internationalisation of Asset Ownership in Europe*, edited by Harry Huizinga and Lars Jonung.) The next annual conference, in 2005, will be on "Financial stability and the convergence process in Europe".

Lars Jonung

DG ECFIN Research Conference
"Business Cycles and Growth in Europe"
Thursday 7th and Friday 8th October, 2004
Charlemagne building, Room S4, Rue de la Loi 170, 1040 Brussels (next to metro stop Schuman)

Thursday

8:50	Klaus Regling (ECFIN): Welcome Address

Session 1 — **Differences and commonalities in business cycles and growth: Evidence from the EU and US**
Chair: Lars Jonung (ECFIN)

9:00 to 10:00   Michael Bergman (Lund University): How Similar Are European Business Cycles?
Discussant: Marianne Baxter (Boston University)

10:00 to 11:00   Thomas F. Helbling (IMF): International Business Cycle Synchronization in Historical Perspective
Discussant: Matteo Ciccarelli (ECB)

11:00 to 11:15   Coffee break

11:15 to 12:15   Michael Artis (European University Institute): Business Cycle Affiliations and Their Determinants: Where Do We Stand?
Discussant: Jesper Hansson (National Institute of Economic Research, Stockholm)

12:30 to 14:00   Lunch buffet

Session 2 — **International transmission of business cycles**
Chair: Marianne Baxter (Boston University)

14:00 to 15:00   Ian Babetskii (Czech National Bank): EU Enlargement and Endogeneity of some OCA Criteria: Evidence from the CEECs
Discussant: Zsolt Darvas (Magyar Nemzeti Bank - Central Bank of Hungary)

15:00 to 16:00   Maria Olivero (Duke): Trade, Non-Competitive Banking and the International Transmission of Business Cycles
Discussant: Patrick Francois (University of British Columbia)

16:00 to 16:15   Coffee break

16:15 to 17:15   Pedro Cerqueira (European University Institute and Coimbra University): How Pervasive is the World Business Cycle?
Discussant: Sandra Eickmeier (Bundesbank)

| 17:15 to 18:15 | Marianne Baxter (Boston University): Determinants of Business Cycle Comovement: A Robust Analysis |
| | Discussant: Patrick Fève (University of Toulouse I) |

20:00   Conference dinner (speakers and discussants)

Friday

| Session 3 | **Business cycles in Europe** |
| | **Chair: Lucrezia Reichlin (Free University of Brussels)** |

| 9:00 to 10:00 | Apostolis Philippopoulos (Athens University of Economics and Business): Electoral Uncertainty, Fiscal Policies and Growth: Theory and Evidence from Germany, the UK and the US |
| | Discussant: Diego Comin (New York University) |

| 10:00 to 11:00 | Gabriel Perez-Quiros (Banco de España): Are European Business Cycles Close Enough to be Just One? |
| | Discussant: Michael Bergman (Lund University) |

| 11:00 to 11:15 | Coffee break |

| 11:15 to 12:15 | Lucrezia Reichlin (Free University of Brussels): Dating the Euro Area Business Cyle |
| | Discussant: Michael Binder (University of Frankfurt) |

| 12:30 to 14:00 | Lunch buffet |

| Session 4 | **Business cycles and growth: Theory and evidence for old and new member states** |
| | **Chair: Patrick Francois (University of British Columbia)** |

| 14:00 to 15:00 | Francesco Caselli (Harvard University): Is Poland Next Spain? |
| | Discussant: Werner Roeger (ECFIN) |

| 15:00 to 16:00 | Klaus Wälde (ECFIN and University of Würzburg): Volatility, Welfare and Taxation |
| | Discussant: Romain Ranciere (Universitat Pompeu Fabra) |

| 16:00 to 16:15 | Coffee break |

| 16:15 to 17:15 | Patrick Francois (University of British Columbia): Investment Cycles |
| | Discussant: Raouf Boucekkine (Louvain-La-Neuve) |

| 17:30 | Concluding remarks |

| 18:00 | Informal get-together |

How Similar Are European Business Cycles?[*]

U. Michael Bergman

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March, 2005

Abstract

In this paper, we focus on how European economic integration has affected the synchronization and the magnitude of business cycles among participating countries. We measure, based on bandpass filtered data, the characteristics of European business cycles analyzing to what extent they have become more similar over time. We also consider the role of other factors such as differences in fiscal and monetary policy, border effects, and trade intensity. Our main finding is that European business cycles are highly synchronized, although we also find that synchronization was higher during periods with highly flexible exchange rates. In addition we find a positive tradeoff between timing and magnitude such that more synchronization coincides with larger relative magnitude. These results raise concern about the consequences of a common monetary policy within EMU.

JEL Classification: E32, F15

Keywords: Business cycles; symmetry and co–movement of cycles, magnitude of cycles, economic integration, monetary union.

1 Introduction

Linkages between European countries have become more prevalent in the postwar period as a result of the efforts of integrating national markets. These efforts include the removal

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of trade barriers, the implementation of the Single European Act in 1986, the Maastricht Treaty in 1992, the introduction of the Single European Market in 1993, the Stability and Growth Pact in 1997, and the creation of the Economic and Monetary Union with a common currency and monetary policy. An important question is whether these efforts of economic and monetary integration have led to a higher degree of similarity of European business cycles in recent years.

Such a development is also desirable since the loss of the option of using an independent monetary policy and giving up the value of changing the exchange rate when desired would otherwise constitute a major cost for the EMU countries. These options are especially important if countries are facing asymmetric shocks, in which case exchange rate adjustments and separate monetary policies could help to stabilize nation–specific aggregate fluctuations. A common monetary policy therefore requires that the timing of business cycles is similar among the members of the monetary union. However, even if the timing of business cycles is similar, the magnitude may differ, in which case the intensity of policies may have to be different. Therefore, a common monetary policy requires that business cycles in member states are highly synchronized and have small differences in the magnitude.

There are theoretical reasons for both the view that economic integration will lead to more synchronized business cycles and the opposite view that increased economic integration will lead to less synchronized business cycles. Kalemli–Ozcan, Sørensen and Yosha (2001) argue that increased economic integration leads to better income insurance through greater capital integration which in turn will lead to a more specialized production structure and an increase in trade and therefore less synchronized business cycles. A similar argument, although using different mechanisms, has also been proposed by Krugman (1993). Alternatively, it could be argued, as Coe and Helpman (1995) and Frankel and Rose (1998) suggest, that the removal of trade barriers will lead to more trade such that demand shocks are more easily transmitted across national borders. Economic and monetary integration, will according to this view, lead to more symmetry of structural shocks and knowledge and technology spillovers which will lead to a higher degree of synchronization of national business cycles.

Given these theoretical ambiguities over the effects of economic and monetary integration on the behavior of business cycles, empirical evidence must be brought to bear on the issue. Indeed, there are several papers suggesting that business cycles are more synchronized when exchange rate variability is low (Fatás (1997), Artis and Zhang (1997, 1999), Dickerson, Gibson and Tsakalotos (1998) and Rose and Engel (2002)). However, there are also papers suggesting the opposite, that business cycles are more synchronized during periods with higher exchange rate volatility (Gerlach (1988), Inklaar and De Haan (2001) and De Haan, Inklaar and Sleijpen (2002)). A few authors report evidence suggesting no relationship between exchange rate regime and business cycle synchronization

(Baxter and Stockman (1989), Sopraseuth (2003), Baxter and Kouparitsas (2004)).[1] In addition, there seems to be at most only weak evidence supporting the view that increased economic integration leads to a higher degree of synchronization. Indeed, Doyle and Faust (2002) and Kose, Prasad and Terrones (2003) find no strong evidence supporting this idea whereas Imbs (2003) supports the view that financial liberalization is significantly related to a higher degree of synchronization.

One approach in the literature is to distinguish between core and periphery European countries, where the core countries have highly synchronized business cycles. Countries identified as core EU have closer links and are expected to benefit from the common monetary policy and the common currency without sacrificing national macroeconomic stabilization objectives. On the other hand, countries identified as in the periphery are not expected to gain from being members of a monetary union. There is a large literature attempting to classify European countries into a core and a periphery, see, e.g., Artis and Zhang (1997,1999), Artis, Kontolemis and Osborn (1997), Christodoulakis, Dimelis and Kollintzas (1995), and Dickerson, Gibson and Tsakalotos (1998). These studies vary in their classification but a general result is that the long–standing members of the EU often are classified as being in the core with Germany as an attractor. Camacho, Quirós and Saiz (2004), however, cannot find strong evidence supporting the core/periphery distinction and suggest that there is no distinct euro economy attractor. They also show that European business cycles have become less synchronized after the establishment of the EMU, a result that raises concern about the future of EMU.

With few exceptions, earlier papers focus on the relationship between exchange rate regimes and the timing of European business cycles disregarding any effects of the magnitude of cycles.[2] This is in part surprising since there is a direct relationship between the correlation and the variance. For example, holding everything else constant, a lower variance would imply a higher correlation coefficient. Dickerson, Gibson and Tsakalotos (1998) find that the magnitude of business cycles in general is lower for core EU countries but they provide no analysis of the relationship between magnitude and exchange rate regimes. Sopraseuth (2003), however, found that the magnitude of European business cycles was unrelated to membership of the EMS.

The purpose of this paper is to shed light on the question whether European busi-

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[1]Baxter and Stockman (1989) found that synchronization and monetary regimes were unrelated for linear trend adjusted data but not for first log difference data where synchronization was higher when exchange rate volatility was low. Sopraseuth (2003) also found that even though membership of the EMS did not result in a higher degree of synchronization, business cycles in EMS countries became more synchronized to the German cycle and less synchronized to the US cycle.

[2]The literature usually focuses on the G–7 countries documenting shifts in the volatility and in the synchronization of cycles, see e.g. Doyle and Faust (2002), van Dijk, Osborn and Sensier (2002) and Stock and Watson (2003). The consensus from this literature is that the business cycle has been dampened recently but there is disagreement on the number of shifts, the dates of the breaks and the magnitude of these breaks.

ness cycles have become more similar as a result of economic and monetary integration. We measure, based on bandpass filtered data, the characteristics of European business cycles analyzing to what extent they have become more synchronized over time and test whether, for example, EU membership and the Single Market program can account for a higher degree of synchronization. We then consider the role of other factors that have received considerable attention in the literature such as differences in fiscal and monetary policy, border effects, and trade intensity. Can these factors explain the lack of full synchronization among European business cycles?

Next, we turn our attention to the relative magnitude of national business cycles and the question whether the amplitude of business cycles across Europe has become more similar over time. Finally, we consider the linkage between synchronization and the relative magnitude of business cycles.

The paper extends the earlier literature in at least two different directions. First, we consider the role of exchange rate fluctuations in two ways, by decomposing the sample into sub–samples reflecting different exchange rate regimes and by considering the direct role of exchange rate volatility on the degree of synchronization. Second, we analyze the tradeoff between synchronization or the timing of business cycles and the relative magnitude of business cycles. This is particularly important from a European perspective since the success of the common monetary policy and the common currency in Europe rests on the similarity of both the timing and the magnitude of business cycles in member states.

The paper is organized in the following manner. In section 2 we describe the method used to extract the business cycle component from the data and perform a first preliminary analysis of the data. Section 3 contains the empirical analysis. Section 4 summarizes the main findings.

2 METHODOLOGY

2.1 DATA

The data set consists of quarterly observations on industrial production for the EU–14 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom) and five non–EU countries (Canada, Japan, Norway, Switzerland and the US) for the sample 1961:1 to 2001:4.[3] The data are taken from IFS CD–Rom except for industrial production for Ireland and Portugal that have been taken from OECD Main Economic Indicators, see Appendix A.

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[3]We use industrial production as our business cycle indicator rather than GDP since quarterly GDP data for all these countries is only available for a shorter sample period making it difficult to study changes in business cycle behavior over time.

2.2 Measuring domestic business cycles

Prior to our empirical analysis we must extract the cyclical component from the macro-economic time series, i.e., the natural logarithm of industrial production. Recently, Baxter and King (1999) have developed a bandpass filter that isolates cyclical components of economic time series. This filter can be designed to isolate cyclical components of economic time series conforming to a certain definition of business cycles.[4] In particular, we isolate cyclical components of the data with durations conforming to the Burns–Mitchell definition of the business cycle.[5] We use a 12–order two–sided filter following Baxter and King (1999) to extract all fluctuations at frequencies between 6 and 32 quarters (1.5 year and eight years) from the logarithm of industrial production in each country.[6] When applying this filter, we lose observations at both ends of our sample. We use forecasts and backcasts based on a twelfth order univariate autoregressive model to add these observations to the sample prior to applying the bandpass filter. This same method is used by Stock and Watson (1999) and Bergman, Bordo and Jonung (1998) amongst others.

In Appendix B, we show plots of the extracted business cycles as well as plots of the raw data and the implied trend, i.e., the difference between the actual data and the cyclical component. A striking feature of these graphs is the regularity of national business cycles and the co–movements of downturns and upturns, in particular between the EU–14 countries. The overall impression is that cyclical fluctuations in industrial production in this sample of countries display a relatively high degree of synchronization. It is also interesting to note that the severity of business cycles has declined in the latter part of our sample for some countries (Denmark, France and Greece) while the amplitude seems to be relatively unchanged over time for other countries. The effects of the oil price shock during the second half of the 1970's and in the beginning of the 1980's are also evident for most countries as are the banking and currency crises in Finland and Sweden in the early 1990's.

3 Empirical work

3.1 Country–specific co–movements

In Figure 1 we study the co–movements between EU–14 and non–EU countries and the co–movements between EU–14 countries before and after the particular country became

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[4]Baxter and King (1999) compare the properties of cyclical components of US GNP generated by different detrending techniques and find that the bandpass filter usually is superior to other filters in isolating cyclical variation within certain frequency bands.

[5]They define business cycles as recurrent, but not strictly periodic, fluctuations in economic activity with a duration usually between one and ten years, the average length varying over time.

[6]The results below are essentially unaffected when using the Hodrick–Prescott filter to extract the business cycle component of industrial production instead of the Baxter–King filter.

a member of the EU. To construct the graph in the upper panel we use the full sample and compute the average of bilateral contemporaneous cross–correlation between EU–14 and non–EU countries for each country in our sample, i.e., the average of the cross–correlations between, say, Germany and each European country and between Germany and the five non–EU countries. On the vertical axis we measure cross–correlations with non–EU countries whereas we measure cross–correlations with EU–14 countries on the horizontal axis. As can be seen in this graph, there is a tendency that business cycles in non–EU countries are more correlated to business cycles in non–EU countries than to business cycles in the EU–14 countries with the exception of Austria and Switzerland. The EU–14 countries seem to be more correlated to other EU–14 countries. However, the differences are not substantial according to this plot.

The lower graph in Figure 1 shows the average of contemporaneous cross–correlations between EU member states excluding the six original members prior to (vertical axis) and after (horizontal axis) the particular country became a member of the EU. There is no clear–cut pattern evident in this graph. Some countries have become more correlated to other EU–countries after entering the EU (Ireland and the UK) while business cycles in other countries were more synchronized prior to their EU–membership (Austria, Greece and Portugal). Again there is no uniform evidence pointing in any particular direction for these nine countries. The graphs in Figure 1 suggest that business cycles in the EU–14 countries are somewhat more synchronized to business cycles in other EU–14 countries than with non–EU countries whereas EU membership seems to have had only marginal effects on the degree of synchronization for most European countries.

3.2   Has the degree of synchronization changed over time?

It may well be the case that the degree of synchronization has changed over time and that these changes are related to other developments than the timing of EU–membership, for example, the exchange rate regime. Therefore we now divide our sample into five sub–samples reflecting different monetary regimes and different degrees of economic integration: the Bretton–Woods period 1961:1–1973:1, the flexible exchange rate regime 1973:2–1978:4, the EMS period 1979:1–1987:2, the implementation of the Single European Act and the hard ERM period 1987:3–1992:4, and the implementation of the common market and preparations for monetary union 1993:1–2001:4.[7] In addition, we will from now on focus on the general pattern, i.e., we distinguish between groups of countries instead of differences between countries. This allows us to distinguish between EU member states, non–EU member states and the role played by the monetary regime and

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[7]It would have been interesting to divide the last period into two sub–periods allowing us to also study the effects of EMU. This is, unfortunately, not possible since our estimates of co–movements would be highly uncertain given the few available observations on industrial production and other variables used in the analysis below for the EMU–period. The sub–samples we use roughly correspond to the ones used in the earlier literature.

Figure 1: Cross–correlations.

(a) Average cross–correlation with EU and non–EU countries.
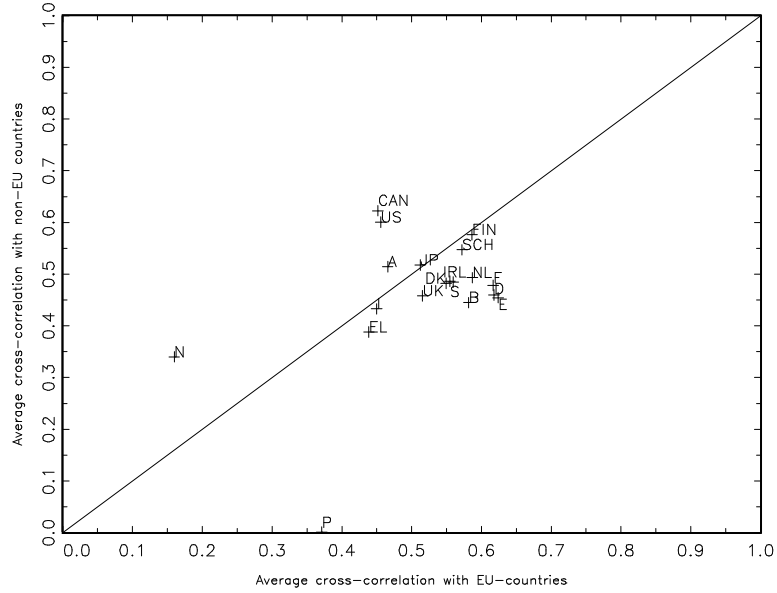
(b) Average cross–correlation with EU countries before and after EU membership.
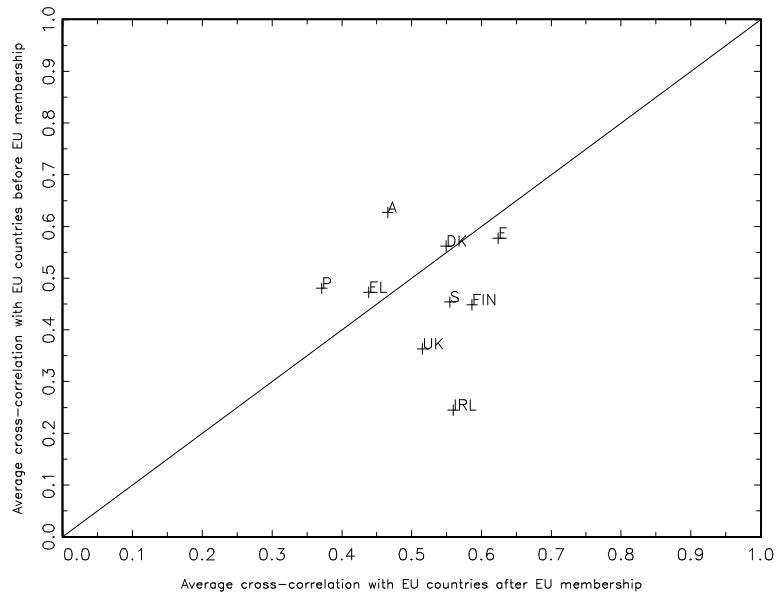
Note: The average cross–correlations for non–EU countries shown in subfigure 1(a) are computed using the full sample whereas the cross–correlations for EU countries are computed using data when they are members of the EU. In subfigure 1(b) we show the average cross–correlation between a EU country and other EU member states before and after the particular country entered the EU.

the degree of economic integration.

In Table 1 we present the average cross–correlations between all countries, between EU–14 countries, between non–EU countries and finally between EU–14 and non–EU countries for the full sample and the five sub–samples. To measure these averages, we first compute the bilateral cross–correlations between country i and j (ρ_{ij}) for each sub–sample and stack the unique cross–correlations in the vector ρ. This leads to a vector with 855 unique cross–correlations for the 19 countries (for each sample we have $19(19-1)/2$ unique cross–correlations). The average of cross–correlations between, say, the EU–14 countries over the full sample is then a linear combination of these unique cross–correlations of the form $\rho = \delta' \rho$. To measure the standard error of these averages we use the Newey–West heteroscedastic and autocorrelated corrected variance estimator (HAC).[8]

Looking first at the first row of Table 1 where we report estimates of the average cross–correlations (ρ) for all countries. As can be seen from this row, the point estimates of the degree of synchronization change over time, it is highest during the flexible exchange rate period and lowest during the Bretton–Woods period. There is also a clear cycle in the degree of synchronization. It is increasing between the first two sub–samples, decreasing during the next two and then finally increasing again.

This pattern is also evident in the next row reporting the average cross–correlations between EU member states, ($\rho_{\mathrm{EUM}}^{\mathrm{EUM}}$). These averages are based on the sample of countries that were members of the EU during the particular sub–sample, Denmark and Ireland joined in 1973, Greece in 1981, Portugal and Spain joined in 1986 whereas Austria, Finland and Sweden joined in 1995.[9] The synchronization of business cycles between EU–member states are highest during the flexible exchange rate period and higher during the most recent period compared to the earlier two sub–samples.

A different pattern is evident for the sample of non–EU member states. Note that these cross–correlations ($\rho_{\mathrm{NEU}}^{\mathrm{NEU}}$) are computed for all countries that were not members of the EU during the particular sub–sample. For these countries we observe a downward trend (according to the point estimates) in the degree of synchronization over time. As for the earlier two groups of countries, business cycles were strongly synchronized during the flexible exchange rate period.

In the last row of the upper part of Table 1 we show the estimates of the average degree of synchronization between EU–member states and non–EU member states ($\rho_{\mathrm{EUM}}^{\mathrm{NEU}}$).

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[8]It may be the case that the cross–correlations in ρ are correlated, the cross–correlation between Sweden and Belgium and between Sweden and Denmark is correlated to the cross–correlation between Denmark and Belgium. This potential problem gives rise to autocorrelated residuals. Following the practice in the related literature we estimate the parameters using OLS and the standard errors using a robust estimator.

[9]Our five sub–samples do not fully correspond to the dates when these countries joined the EU. In our empirical work we, therefore, include Greece in our sample of EU countries in the sub–sample 1978–87, Portugal and Spain in the sub–sample 1987–1992 and Austria, Finland and Sweden in the last sub–sample 1993–2011. Our empirical results are essentially unaffected by these assumptions.

Table 1: Average cross–correlations in EU and non–EU countries.

	1961–2001	1961–1973	1973–1978	1979–1987	1987–1992	1993–2001
Panel A: Average cross–correlations.						
ρ	0.455	0.327	0.646	0.493	0.333	0.478
	(0.018)	(0.031)	(0.037)	(0.033)	(0.029)	(0.038)
$\rho_{\mathrm{EUM}}^{\mathrm{EUM}}$	0.543	0.300	0.824	0.517	0.345	0.567
	(0.028)	(0.174)	(0.026)	(0.040)	(0.064)	(0.030)
$\rho_{\mathrm{NEU}}^{\mathrm{NEU}}$	0.409	0.333	0.552	0.464	0.322	0.319
	(0.031)	(0.029)	(0.061)	(0.081)	(0.084)	(0.192)
$\rho_{\mathrm{NEU}}^{\mathrm{EUM}}$	0.440	0.323	0.647	0.498	0.332	0.386
	(0.024)	(0.044)	(0.051)	(0.039)	(0.036)	(0.069)
Panel B: Wald tests.						
H$_0$: $\rho_{\mathrm{EUM}}^{\mathrm{EUM}} = \rho_{\mathrm{NEU}}^{\mathrm{NEU}}$	10.373	0.035	16.559	0.353	0.052	1.620
	0.001	0.852	0.000	0.553	0.820	0.203
H$_0$: $\rho_{\mathrm{EUM}}^{\mathrm{EUM}} = \rho_{\mathrm{NEU}}^{\mathrm{EUM}}$	8.801	0.022	10.438	0.138	0.028	5.790
	0.003	0.882	0.001	0.710	0.868	0.016

Note: In Panel A we report the average of bilateral contemporaneous cross–correlations for all countries (ρ), the average of contemporaneous cross–correlation between EU member states ($\rho_{\mathrm{EUM}}^{\mathrm{EUM}}$), the average of contemporaneous cross–correlations between non–EU member states ($\rho_{\mathrm{NEU}}^{\mathrm{NEU}}$), and the average of contemporaneous cross–correlations between EU member states and non–EU members ($\rho_{\mathrm{NEU}}^{\mathrm{EUM}}$). Newey–West HAC standard errors are shown in parentheses below each cross–correlation. In Panel B we report Wald tests of the null hypothesis that the cross–correlation between EU and non–EU countries is equal (H$_0$: $\rho_{\mathrm{EUM}}^{\mathrm{EUM}} = \rho_{\mathrm{NEU}}^{\mathrm{NEU}}$) and Wald tests of the null hypothesis that the cross–correlation between EU member states is equal to the cross–correlations between EU member states and non–EU member states (H$_0$: $\rho_{\mathrm{EUM}}^{\mathrm{EUM}} = \rho_{\mathrm{NEU}}^{\mathrm{EUM}}$). These tests are χ^2 distributed with 1 degree of freedom. The total number of unique cross–correlations is 855.

The pattern is similar, but not as strong, as for the EU–member states. The degree of synchronization seems to increase somewhat in the last sub–period 1993–2001 compared to the earlier period.

Comparing the degrees of synchronization across groups of countries and across time, we find an interesting pattern. In Panel B in Table 1 we report Wald tests of the null hypothesis that the average cross–correlations across EU–members and across non–EU members are equal during each sample. These tests reveal that the degree of synchronization differs only during the flexible exchange rate period. This suggests again that the degree of synchronization has changed in a similar way for these two groups of countries over time. In the second row of Panel B, we test the null hypothesis that EU–member states synchronization with other EU–members and non–EU members are equal for each sample. These tests show that business cycles in EU–member states were more synchronized business during the flexible exchange rate period and the most recent period of deepening European integration.

The analysis above only shows the main tendencies of the data and cannot be used to argue that the attempts to bring European countries closer to each other by the implementation of the common market and the establishment of the monetary union have made business cycles more synchronized in Europe. To answer such questions, we from now on focus on the sample of EU–countries, that is we focus only on bilateral cross–correlations between EU–14 countries during each sub–sample testing for an additional EU membership effect and the role played by the monetary regime.

In Table 2 we report tests of the null hypothesis that sub–sample averages of cross–correlations between EU–member states are equal. A striking feature of these results is that the second sub–sample, the flexible exchange rate regime, stands out as different. We strongly reject the null hypothesis that business cycle synchronization during this sample is equal to the synchronization during all other sub–samples. These results support our earlier finding that business cycles were more synchronized during this sub–sample compared to the other four regimes.

It is commonly argued in the literature that flexible exchange rates tend to insulate the national economy from demand type shocks, i.e., shocks affecting the business cycle.[10] Our calculations lend support to this idea. Monetary regimes with less flexible exchange rates tend to be associated with a lower degree of synchronization.

The results in Table 2 also suggest that the degree of synchronization during the most recent sub–sample is significantly different from the co–movements during the period when the Single European Act was implemented. In this regard, it may be argued that a deepening of European integration has led to a higher degree of synchronization although business cycles were even more synchronized during the earlier flexible exchange rate

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[10]Within a Mundell–Fleming model it is possible to show that flexible exchange rates insulate the economy to aggregate demand shocks but not to money demand shocks. For a large open economy with an inflation target, a fixed exchange rate regime is optimal.

Table 2: Wald tests of EU membership effects across different monetary regimes.

		1973–1978	1978–1987	1987–1992	1993–2001
1961–73	Wald	9.045	1.512	0.061	2.336
	p–value	0.003	0.219	0.805	0.126
1973–78	Wald		43.222	48.604	44.027
	p–value		0.000	0.000	0.000
1978–87	Wald			5.303	1.052
	p–value			0.021	0.305
1987–92	Wald				10.280
	p–value				0.001

Notes: Wald tests are based on regressions with a constant and sub–sample dependent EU dummy variables and the HAC covariance matrix estimator. The degree of freedom is 2 for all tests.

period. A Wald test of the null hypothesis that cross–correlations are equal across all five subperiods strongly rejects the null, $\chi^2 = 91.978$ with p–value $= 0.000$ further supporting the conclusion that the degree of synchronization has changed over time. This result is consistent with the results provided by Massmann and Mitchell (2003) in particular but also the large body of the literature suggesting changes in the degree of synchronization across time.

Our analysis above suggests that the synchronization of business cycles among EU member states is higher than among non–EU member states. In the next subsection we turn to the question why we observe these changes in the degree of synchronization. What could explain the apparent changes in synchronization? In particular, we are interested in explaining why the degree of synchronization was so high during the period when the European countries had flexible exchange rates. It is also interesting to test whether the significantly higher degree of synchronization during the last period is explained by the increased economic integration or if other factors explain this increase.

3.3 What accounts for the EU membership effect?

In this section we examine whether the EU membership effects identified above can be explained by other factors affecting the European economies or if other developments have led to an increase in the degree of synchronization. Following Clark and van Wincoop (2001) who study the border effect on the synchronization of business cycles, we consider in addition to a border effect, the role played by trade intensity, distance between countries, the size of countries, differences in monetary and fiscal policy, exchange rate volatility and the volatility of oil price changes.

We define trade intensity (following Frankel and Rose (1998)) as the natural logarithm of the value of bilateral trade between two countries divided by sum of the value of total

trade in both countries, i.e.,

$$w_{ijt} = \ln \left(\frac{X_{ijt} + M_{ijt}}{X_{it} + M_{it} + X_{jt} + M_{jt}} \right).$$

We then take the average of these trade intensities over the five sub–samples. The distance (D) between countries is measured as the great circle between largest cities in each country according to Fitzpatrick and Modlin (1986).[11] The size is measured as the natural logarithm of the product of real GDP per capita measured in current US$.[12] To account for differences in monetary and fiscal policy, we use the standard deviation of the money market (or equivalent measures) interest rate differential (σ_{r-r^*}) and the standard deviation of the budget deficit (as a percentage of GDP) differential (σ_{D-D^*}), respectively. These measures imply that if the monetary policy (or the fiscal policy) in two countries differs substantially over a certain time period, the standard deviation is high. The larger discrepancy between monetary (and fiscal policy), the higher standard deviation. The exchange rate volatility is measured as the standard deviation of the first log difference of bilateral exchange rates ($\sigma_{\Delta s}$). Finally, we use the standard deviation of oil price changes ($\sigma_{\Delta \text{oil}}$) as an indicator of large common shocks affecting all countries at the same time. Note that all these measures are bilateral and that we take the average of annual (and monthly or quarterly) observations for each sub–sample. Data sources and sample ranges are presented in Appendix A.

In Table 3 we show the role of these factors in explaining the synchronization of business cycles within the EU–14 countries. All results are based on running the following regression

$$\rho = \alpha_0 + \alpha_1 \text{EUM} + X\beta + \varepsilon$$

where EUM is a dummy variable taking the value 1 if both countries are members of the EU at the time we measure the cross–correlation, X includes the various variables discussed above. When including trade and the policy variables, we estimate the regression using instrumental variables as discussed below.

In the first column of Table 3 we report the estimated effect of EU membership. As we already know from our earlier analysis, this parameter is significant and positive suggesting that EU member states tend to have more synchronized business cycles compared to EU–14 countries that were not members of the EU at the point in time we computed the cross–correlation. The question now is whether this positive effect disappears when including

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[11] We have also considered alternative measures of distance such as the distance in radians of the unit circle between country centroids. The empirical results below are essentially unaffected when using this measure.

[12] Another approach to measure size is to use the natural logarithm of the sum of population. In general, the significance of the parameters associated to this measure of size was lower (although statistically significant at conventional levels) compared to the significance of the log of the product of real GDP. All other results were essentially unaffected.

other variables in the regression. In other words, is this EU member effect robust or are there other explanations to the increasing synchronization that we have observed above.

The second column in Table 3 reports the results when including border, distance and size as additional explanatory variables besides the constant and the EU membership dummy. As is evident, there is a very strong border effect. Bordering EU countries tend to have more synchronized business cycles compared to non–bordering countries. This result is consistent with evidence provided by Clark and van Wincoop (2001) who report very strong border effects between France, Germany, Italy and the UK.

The distance between the countries seems to play no role in explaining synchronization, the parameter is not significantly different from zero. The size effect is highly significant suggesting that the size of the countries play an important role for explaining the degree of business cycle synchronization. The cross–correlation between large countries tends to be higher compared to cross–correlations between small countries. However, controlling for border, distance and size has some effect on the importance of EU membership. The coefficient drops from 0.090 to 0.062 and it is only statistically significant at the 10 percent level suggesting that border, distance and size explain parts of the co–movements of business cycles in EU member states. The conclusion is that controlling for a border, in particular, but also for size reduces the EU membership effect somewhat.

Next, we add trade intensity, differences in monetary and fiscal policies, exchange rate volatility and the volatility of oil price changes to the regression. To avoid multicolinearity between the regressors, we now exclude both border and distance from our regression.[13] Since trade may be endogenous (as argued by Frankel and Rose (1998)) we estimate the regression using instrumental variables. Countries that border usually trade more and therefore have more synchronized business cycles. A similar argument holds for distance, the longer the distance is between two countries, the more likely it is that the volume of trade is smaller. At the same time, as argued by both Frankel and Rose (1998) and Clark and van Wincoop (2001), countries with highly synchronized business cycles are better candidates for currency unions, which in turn could increase trade. We use instruments that often are used in gravity models: border, distance, linguistic distance, and an interaction term equal to the product of size and distance.[14]

To instrument the policy variables and exchange rate volatility, we use the absolute inflation differential, the sum of interest rates, the absolute difference between the ratios of government spending to GDP and the sum of the ratios of government spending to GDP. These same instruments were used in a similar context by Clark and van Wincoop (2001). To test whether trade, the policy variables and exchange rate volatility are endogenous we apply the Durbin–Wu–Hausman test. The result shown in the last row of Table 3 strongly

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[13]Trade, border and distance are highly correlated, the correlation coefficients are above 0.6 between trade and the other two variables.

[14]The explanatory power for trade in the first stage regression using these instruments is 0.68.

Table 3: Testing the border effect, the role of EU–membership distance, size, trade and economic policy. EU–14 countries.

Variable	OLS	IV	IV
EUM	0.090	0.062	0.054
	(0.036)	(0.037)	(0.044)
Border		0.170	0.000
		(0.052)	
Distance		0.019	
		(0.037)	
Size		0.142	0.402
		(0.065)	(0.128)
w_{ij}			0.032
			(0.016)
σ_{r-r^*}			0.194
			(0.052)
σ_{D-D^*}			-0.113
			(0.072)
$\sigma_{\Delta s}$			-0.080
			(0.069)
$\sigma_{\Delta \text{oil}}$			-0.041
			(0.017)
Durbin–Wu–Hausman test			35.953
p–value			0.000

Notes: Estimates are based on regressions of the average bilateral cross–correlations on a constant and the various variables shown in the table where w_{ij} is trade intensity, σ_{r-r^*} denotes differences in monetary policy, σ_{D-D^*} is a measure of differences in fiscal policy, $\sigma_{\Delta s}$ is the standard deviation of bilateral exchange rates and $\sigma_{\Delta \text{oil}}$ is the standard deviation of oil price changes. Instruments for trade are border, distance, language and an interaction term of distance and size. The three policy variables (σ_{r-r^*}, σ_{D-D^*} and $\sigma_{\Delta s}$) are instrumented using the absolute inflation differential, the sum of interest rates, the absolute difference between the ratios of government spending to GDP and the sum of the ratios of government spending to GDP. HAC standard errors using 4 lags are shown in parentheses below each parameter estimate. Estimates are based on 182 unique cross–correlations.

suggests a rejection of the null hypothesis that these variables are not endogenous.[15]

The result when including these explanatory variables in the regression is shown shown in the third column of Table 3. The parameter associated with the EU dummy is further reduced and is not statistically different from zero. This suggests that the higher synchronization of business cycles within EU can be explained by the variables we have included in the regression, not by the fact that these countries are members of the EU.

Trade is positively related to the synchronization of business cycles. The reason why the business cycle is more synchronized between EU member states is, according to these estimates, that they trade more. A surprising result, however, is that the two policy variables (differences in monetary and fiscal policies) exert different influences on the degree of synchronization. It is often assumed that more similar economic policy should to lead to a higher degree of business cycle synchronization. Looking at the particular estimates in Table 3, we find that larger differences in monetary policy and smaller differences in fiscal policy implies a higher degree of synchronization. Differences in monetary policy is statistically significantly different from zero at the 1 percent level whereas fiscal policy is statistically different from zero at the 10 percent level. These results are different from the evidence presented by Clark and van Winccop (2001). In their empirical application, policy variables were often found to be positively related to the degree of synchronization but very seldom statistically significant.

The volatility in exchange rates is not significant. According to our estimates there is no additional link between exchange rate volatility and the synchronization of business cycles that are not already captured by our decomposition into sub–samples. This result questions some earlier empirical evidence provided by, for example, De Haan, Inklaar and Sleijpen (2002). They show that there is a positive relationship between exchange rate volatility and business cycle synchronization. One possible explanation is that we also include differences in both monetary and fiscal policy and the effect from oil price changes in our regressions.

Experiments with alternative specifications reveal that the inclusion of differences in monetary policy explain why exchange rate volatility is not statistically significant. In regression excluding differences in monetary policy, exchange rate volatility is always significant and the point estimate is positive such that more volatility is associated with more synchronized cycles. Furthermore, when excluding the volatility of oil prices in our regressions we also obtain a positive parameter on exchange rate volatility but with a t–ratio slightly above 1. In a regression excluding differences in monetary and fiscal policy,

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[15]Gruben, Koo and Millis (2002) find that this endogeneity hypothesis is rejected in regressions similar to the ones we perform above. They suggest that instrumental variable regressions tend to overestimate the effects from trade on synchronization and suggest that OLS estimates should be used instead. However, their results based on OLS are consistent with our finding that there is a significant relationship between trade intensity and synchronization. Traistaru (2004), also studying the relationship between synchronization and trade, rejects the null of no endogeneity, the same result as we obtain in our regressions.

exchange rate volatility is significantly and positively related to business cycle synchronization. To these findings we may also add that the average exchange rate volatility for EU member states during the five sub–samples is 1.032, 1.823, 1.487, 0.997 and 1.482, respectively. There is, thus, a common pattern of synchronization and exchange rate volatility, higher exchange rate volatility is associated with a higher degree of business cycle synchronization for EU member states.

The volatility of oil price changes is negatively related to business cycle synchronization. A higher volatility (larger fluctuations in oil prices) lead to less synchronization. This result is somewhat surprising since oil price changes affect all countries at the same time and represent common shocks. It is often argued that a larger variance in common shocks relative to idiosyncratic shocks tend to increase the correlation. It may be the case that more flexible exchange rates during the 1970's compensated for the increased volatility in oil price changes such that business cycles became more synchronized. This is also confirmed in regressions of business cycle synchronization on the standard deviation of oil prices allowing the effect to vary over sub–samples. In these regressions we find that higher oil price volatility is associated with more synchronization, confirming the view that common shocks tend to increase comovements in international business cycles. This effect is also significant when adding sub–sample dependent exchange rate volatility.

The results shown in Table 3 cannot be used to draw inference about the importance of economic integration as the parameters are not allowed to vary across different sub–samples. It may well be the case that EU membership is important during, say, the last sub–period where the European countries have become more integrated. To examine whether this is the case, we now allow the EU membership dummy to vary across the five sub–samples. We still assume, however, that the influence from other explanatory variables is time invariant. The results from these estimates are shown in Table 4.

For comparison we have included in the first column estimates of sample dependent EU membership effects taken from Table 1. What is immediately evident in this table is that the parameter associated to EU membership tends to change very little for some sub–samples whereas it changes considerably for other sub–samples. The effect of the EU membership dummy variable changes considerably for the first two sub–samples but much less for the last sub–sample. Controlling for trade, differences in economic policy, exchange rate volatility and oil price volatility leads to a drop in the EU membership dummy suggesting that synchronization is explained by trade in particular but also differences in economic policy, see the last column of Table 4. Exchange rate and oil price volatility are not statistically significant in these regressions.

Similarly to our earlier results presented earlier in Table 3, there is a strong border effect and trade is always significant. This suggests that bordering countries that also trade more, will have more synchronized business cycles compared to countries located far away. The parameter associated with size is significantly different from zero all regressions. Differences in monetary policy and fiscal policy are both significant and have parameters

Table 4: Testing the border effect, the role of EU–membership distance, size, trade and economic policy. EU–14 countries.

Variable	OLS	IV	IV
EUM 1961–73	−0.152	−0.256	−0.329
	(0.167)	(0.155)	(0.158)
EUM 1973–78	0.372	0.314	0.284
	(0.037)	(0.041)	(0.054)
EUM 1979–87	0.065	0.024	0.069
	(0.047)	(0.047)	(0.078)
EUM 1987–92	−0.107	−0.152	−0.203
	(0.071)	(0.066)	(0.072)
EUM 1993–2001	0.115	0.098	0.095
	(0.040)	(0.038)	(0.037)
Border		0.178	
		(0.045)	
Distance		0.004	
		(0.035)	
Size		0.123	0.371
		(0.062)	(0.120)
w_{ij}			0.034
			(0.018)
σ_{r-r^*}			0.167
			(0.048)
σ_{D-D^*}			−0.137
			(0.059)
$\sigma_{\Delta s}$			−0.069
			(0.072)
$\sigma_{\Delta\text{oil}}$			−0.039
			(0.016)
Durbin–Wu–Hausman test			37.380
p–value			0.000

Notes: Estimates are based on regressions of the average bilateral cross–correlations on a constant and the various variables shown in the table where w_{ij} is trade intensity, σ_{r-r^*} denotes differences in monetary policy, σ_{D-D^*} is a measure of differences in fiscal policy, $\sigma_{\Delta s}$ is the standard deviation of bilateral exchange rates and $\sigma_{\Delta\text{oil}}$ is the standard deviation of oil price changes. Instruments for trade are border, distance, language and an interaction term of distance and size. The policy variables are instrumented using the absolute inflation differential, the sum of interest rates, the absolute difference between the ratios of government spending to GDP and the sum of the ratios of government spending to GDP. HAC standard errors using 4 lags are shown in parentheses below each parameter estimate. Estimates are based on 182 unique cross–correlations.

of approximately the same size regardless of whether we allow the EU membership dummy to vary across sub-samples or not.

Looking more closely at the results for the flexible exchange rate regime, we find that the effect of EU membership drops when adding the control variables. This suggests that the control variables explain parts of the very high synchronization of business cycles for this sub–sample. For the more recent sub–samples, the parameter changes very little. We can, therefore, conclude that the various control variables cannot explain the increased synchronization during this period. In this respect, the increased economic integration may have had a positive influence on business cycle synchronization. This result is consistent with the empirical evidence provided by Imbs (2003). He finds that financial integration (no capital account restrictions and a high degree of risk–sharing) has a positive and significant effect on business cycle synchronization. Even if our measurements are different from the measurements used by Imbs, our results and interpretations are consistent.

Even though there is an upward trend in synchronization, we cannot draw any strong conclusions about the future of European business cycle behavior. The reason is that synchronization depends also on trade and differences in economic policy. The empirical evidence on the relationship between exchange rate volatility and trade suggest that trade possibly will increase in the future as a result of monetary union.[16] In addition, our results suggest that common fiscal policies also increase synchronization, the parameter associated with the standard deviation of differences in budget deficits as percentage of GDP is negative. Convergence of fiscal policies within the EMU may lead to a higher degree of synchronization.

We also found a positive and significant effect between differences in monetary policy and synchronization. If this result is robust, then the common monetary policy in Europe runs the risk of increasing the divergence in business cycles counteracting the positive effects from economic integration. It is, of course, an open question whether the trade effect is stronger or weaker than the effect from differences in monetary policy. The common monetary policy will tend to decrease synchronization whereas increased trade intensity will tend to increase synchronization. If the former effect dominates, the common monetary policy would be too expansive in some countries and too restrictive in others. These potential problems will not occur to the same extent if the latter effect dominates. In addition, our results that there is a weak positive relationship between exchange rate volatility and business cycle synchronization. Our estimates cannot reveal how strong this effect is, but periods with more flexible exchange rates coincide with periods with a high degree of synchronization.

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[16]Running a regression of trade on exchange rate volatility, we find a very strong and significant effect implying that lower exchange rate volatility will tend to increase trade. This positive relationship has also been found by, e.g., Rose and Engel (2002).

3.4 THE MAGNITUDE OF BUSINESS CYCLES

The analysis above shed some light on the timing of business cycles in the EU where the main argument was that the implementation of a common monetary policy and the synchronization of fiscal policy within the EU–area is a concern if the timing of business cycles differs considerably. A similar argument holds for the magnitude of business cycles as a common economic policy could lead to too small effects in countries with highly variable cycles and too large effects in countries with less variable cycles. For countries with similar amplitudes, a common economic policy raises no such concerns. In other words, the intensity of economic policies has to differ among countries with different amplitudes of its business cycles.

An analysis and comparison of the amplitude of business cycles and its consequences for the common economic policy in Europe require a thorough analysis of each national business cycle and its relation to business cycles in all other EU countries. In this subsection, however, we continue to study the average behavior in all EU countries. There are, of course, many aspects that such analysis cannot capture, but it is nevertheless interesting to study the main tendencies, in particular to establish whether the business cycle amplitude has changed over time and if so, if these changes are related to the monetary regime.

In the upper panel of Table 5 we report estimates of the absolute difference of the standard deviation of national business cycles both for all EU–14 countries and for the EU member states.[17] According to these estimates, the amplitude for all EU–14 countries have increased considerably over the sample from 0.6 to 0.95. This suggests that the magnitude of business cycles were more similar during the Bretton–Woods period compared to all other sub–samples we examine. This result does not fully carry over to EU member states. According to the results shown in Panel A, differences in the amplitude for these countries fell somewhat during the implementation of the Single European Act period compared to the earlier EMS period.

In Panel B, we report formal tests of the hypothesis that the relative magnitude of business cycles is equal across sub–samples.[18] These results show that we can always reject the null hypothesis of equal magnitudes when comparing the last sub–sample with all other sub–samples at the 10% level. Based on this evidence, we conclude that the bilateral differences of the magnitude are larger during the most recent sub–sample. A test of the hypothesis that the average amplitude is constant over all samples is strongly rejected, $\chi^2_4 = 18.852$ with p–value $= 0.001$ suggesting that the magnitude is not constant.

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[17]There are other ways to measure the amplitude of business cycles, for example by using the mean absolute deviation as suggested by Dickerson, Gibson and Tsakalotos (1998). They report, however, that their results were unchanged when they used the standard deviation as the measure of business cycle amplitude as we use here.

[18]We only report results for EU member states in the table. We obtain similar results for the sample of all EU–14 countries and these results are available upon request from the author.

Table 5: Absolute difference between the standard deviation of the business cycle. EU–14 countries.

Panel A: Mean of absolute difference of standard deviations.						
	1961–2001	1961–1972	1973–78	1979–1987	1987–1992	1993–2001
EU–14	0.749	0.595	0.759	0.678	0.767	0.948
	(0.031)	(0.056)	(0.091)	(0.062)	(0.043)	(0.055)
EU members	0.792	0.682	0.717	0.682	0.575	0.948
	(0.043)	(0.132)	(0.118)	(0.074)	(0.077)	(0.055)

Panel B: Wald tests of equal differences in magnitude for EU–members across monetary regimes.					
		1973–1978	1978–1987	1987–1992	1993–2001
1961–73	Wald	0.040	0.000	0.488	3.484
	p–value	0.842	0.999	0.485	0.062
1973–78	Wald		0.065	1.014	3.160
	p–value		0.799	0.314	0.075
1978–87	Wald			0.997	8.465
	p–value			0.318	0.004
1987–92	Wald				15.325
	p–value				0.000

HAC standard errors using 4 lags are shown in parentheses below each parameter estimate. Wald tests are based on regressions with a constant and a EU dummy variable where all parameters are allowed to vary across the sub–samples and the HAC covariance matrix estimator. Degrees of freedom is 2 for all tests. A Wald test of the null hypothesis that cross–correlations are equal across all five subperiods strongly reject the null, $\chi^2 = 18.852$ with p–value = 0.001. Estimates are based on 182 observations of relative magnitudes.

It is surprising that the relative magnitude of European business cycles tends to increase, in particular, towards the end of our sample. Our results are, however, similar to earlier empirical findings in the literature for the US and the G–7 countries. There is a general consensus that the volatility of business cycle in these countries has been dampened even though there is a debate on the date of the structural break in the amplitude and, of course, whether there has been more than one structural break, see e.g. van Dijk, Osborn and Sensier (2002), Doyle and Faust (2002) and Stock and Watson (2003). Indeed, looking at the underlying data we use to compute the relative magnitudes, we find that the volatility of the bandpass filtered data tends to be lower for the more recent sub–samples for some countries compared to earlier periods. This can also be seen in the plots of the bandpass filtered data in Appendix B.

How should we interpret our results that both the cross–correlations and the relative magnitude have increased during the most recent period. First, we recognize that these changes are related. Holding everything else constant, an increase in the volatility implies a reduction in the co–movement of the two time series we examine. But how do increases in economic integration or a higher degree of asymmetry of nation–specific shocks affect these measures? To answer these questions it is informative to use the following model that is also used by Doyle and Faust (2002). Assume for simplicity that we only study two countries, home and foreign, and that the business cycle in each country is driven by idiosyncratic shocks and common shocks. We also allow for a direct linkage between the countries such that, say, the nation–specific foreign shocks are transmitted to the home country. Let y be the measure of the business cycle, ε_h and ε_f are the idiosyncratic shocks (they are assumed to be independent white noise sequences with variance σ_h^2 and σ_f^2 respectively), ε_c is the common shock (also white noise with variance σ_c^2) and $0 < \gamma < 1$ is a parameter determining the linkages between the two countries. We can now write the model in the following way

$$
\begin{aligned}
y_h &= \varepsilon_h + \varepsilon_c + \gamma y_f \\
y_f &= \varepsilon_f + \varepsilon_c + \gamma y_h.
\end{aligned}
$$

We have used the simple correlation coefficient to measure co–movements and the absolute value of the difference between the standard deviations of the cycles. Using the model above to compute the variance of the business cycles in the two countries and the covariance between the cycles, we obtain

$$
\begin{aligned}
\mathrm{Var}\left(y_h\right) &= \left(-\tfrac{1}{\gamma^2-1}\right)^2 \left(\sigma_h^2 + \gamma^2\sigma_f^2 + (1+\gamma)^2\sigma_c^2\right) \\
\mathrm{Var}\left(y_f\right) &= \left(-\tfrac{1}{\gamma^2-1}\right)^2 \left(\gamma^2\sigma_h^2 + \sigma_f^2 + (1+\gamma)^2\sigma_c^2\right) \\
\mathrm{Cov}\left(y_h, y_f\right) &= \left(-\tfrac{1}{\gamma^2-1}\right)^2 \left(\gamma\left(\sigma_h^2 + \sigma_f^2\right) + (1+\gamma)^2\sigma_c^2\right).
\end{aligned}
$$

The correlation coefficient is therefore

$$
\rho_{hf} = \frac{\gamma\left(\sigma_h^2 + \sigma_f^2\right) + (1+\gamma)^2\sigma_c^2}{\sqrt{\left(\sigma_h^2 + \gamma^2\sigma_f^2 + (1+\gamma)^2\sigma_c^2\right)\left(\gamma^2\sigma_h^2 + \sigma_f^2 + (1+\gamma)^2\sigma_c^2\right)}}
$$

and the relative magnitude is

$$\mid \sigma_h - \sigma_f \mid = \mid \frac{\sigma_f^2 - \sigma_h^2}{\gamma^2 - 1} \mid .$$

From these relationships we find that the correlation coefficient is increasing in γ the parameter describing the spillover effect from one country to the other and the variance of the common shock ε_c. Higher variance of the idiosyncratic shocks tends to reduce the correlation between the cycles holding everything else constant. It is also evident that the relative standard deviation of the two cycles is independent of the variance of the common shock. Unless the idiosyncratic shocks are equal across the two countries, a higher value of γ reduces the difference. If the spillover effect is stronger, the variance of the two business cycles tends to be more equal. The only case when both the correlation and the relative standard deviation increase is when the variance of the foreign idiosyncratic shock (σ_f^2) is falling. This argument is consistent with recent empirical results provided by Stock and Watson (2003) who showed that the increases in synchronization observed for G–7 countries could be explained by lower volatility in idiosyncratic shocks.

Our empirical analysis raises the question whether there is a tradeoff between co–movements and the relative magnitude and also if there are differences between EU–member states and European countries that were not members at the time we measure these indicators. To shed some light on these questions, we run a regression with the contemporaneous cross–correlations ρ as a function of a constant, the absolute difference between standard deviations of national business cycles and the corresponding measure for EU member states. It is important to notice that we are not discussing any causal relationship between these variables, we are only interested in whether synchronization and the relative magnitudes are correlated and if there is a difference between all EU countries and EU member states. These regression results are shown in Panel A of Table 6. As can be seen from these estimates, we find a negative point estimate (although not statistically significant) of the parameter associated to the absolute difference in the magnitude. What is indeed surprising is that we also obtain a positive and significant point estimate for EU members. According to this regression result, a lower absolute difference in the magnitude is associated with a lower degree of business cycle synchronization for EU members only.[19]

This result tends to be robust to changes in the specification of the regressions. The results do not change when we allow the tradeoff to be sample dependent or when we include other explanatory variables. In Panel B, we allow the tradeoff to be sample dependent. In the first two columns we report the results when allowing the tradeoff for all EU–14 countries to vary across sub–samples. In the second column, we also distinguish between EU–14 and EU members. From these estimates, we find that the overall negative and

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[19]Running a regression with cross–correlations on a constant and the relative magnitude, we find no significant relationship. But as soon as we distinguish between EU–14 countries and EU members, we obtain a positive and significant parameter.

Table 6: Tradeoff between synchronization and magnitude.

Panel A: Tradeoff between synchronization and magnitude.			
Dep.var.	const	$\mid \sigma_i - \sigma_j \mid$	$\mid \sigma_i - \sigma_j \mid .*$ EUM
ρ	0.489	-0.043	0.103
	(0.032)	(0.033)	(0.032)

Panel B: Tradeoff between synchronization and magnitude. Dependent variable: ρ.					
const	0.509	0.506	const	0.468	0.496
	(0.030)	(0.030)		(0.024)	(0.030)
$\mid \sigma_i - \sigma_j \mid .* D_1$	-0.175	-0.182	$\mid \sigma_i - \sigma_j \mid .* D_1.* EUM$	-0.150	-0.130
	(0.068)	(0.066)		(0.196)	(0.199)
$\mid \sigma_i - \sigma_j \mid .* D_2$	0.097	0.080	$\mid \sigma_i - \sigma_j \mid .* D_2.* EUM$	0.299	0.324
	(0.047)	(0.048)		(0.042)	(0.045)
$\mid \sigma_i - \sigma_j \mid .* D_3$	-0.032	-0.055	$\mid \sigma_i - \sigma_j \mid .* D_3.* EUM$	0.054	0.076
	(0.034)	(0.041)		(0.043)	(0.045)
$\mid \sigma_i - \sigma_j \mid .* D_4$	-0.110	-0.124	$\mid \sigma_i - \sigma_j \mid .* D_4.* EUM$	-0.112	-0.094
	(0.041)	(0.043)		(0.074)	(0.078)
$\mid \sigma_i - \sigma_j \mid .* D_5$	0.048	-0.026	$\mid \sigma_i - \sigma_j \mid .* D_5.* EUM$	0.079	0.107
	(0.030)	(0.053)		(0.028)	(0.034)
$\mid \sigma_i - \sigma_j \mid .* EUM$		0.076	$\mid \sigma_i - \sigma_j \mid$		-0.050
		(0.043)			(0.032)

Panel C: Can policy variables explain the trade–off? Dependent variable ρ.						
const	$\mid \sigma_i - \sigma_j \mid$	$\mid \sigma_i - \sigma_j \mid .*$ EUM	σ_{r-r^*}	σ_{D-D^*}	$\sigma_{\Delta s}$	σ_{oil}
0.494	-0.041	0.080	0.091	-0.251	0.050	0.008
(0.029)	(0.032)	(0.031)	(0.029)	(0.068)	(0.027)	(0.010)

Note: EUM denotes a EU membership dummy variable, D_i denotes a dummy variable for sub–sample i and $\mid \sigma_i - \sigma_j \mid$ is the absolute difference between the standard deviation of the business cycle in country i and j. The policy variables and exchange rate volatility are instrumented using the absolute inflation differential, the sum of interest rates, the absolute difference between the ratios of government spending to GDP and the sum of the ratios of government spending to GDP. HAC standard errors using 4 lags are shown in parentheses below each parameter estimate. Estimates are based on 182 observations of relative magnitudes.

significant relationship holds for two sub–samples, the Bretton–Woods period and during the implementation of the Single European Act 1987–1992. For one sub–sample (the flexible exchange rate period 1973–1978) we find a positive and significant relationship. This result is not dependent on a distinction between EU–14 and EU members as can be seen in the second column where we add the relative magnitude for EU member states. The parameter associated to the relative magnitude between EU members is significant at the 10% level and positive supporting our earlier result.

In the last two columns of Panel B in Table 6 we allow the tradeoff for EU members to vary across sub–samples. In the first of these two columns we find that there is a strong positive relationship during the flexible exchange rate period and the most recent sub–sample. There is no significant tradeoff during the other three sub–samples according to these estimates. This conclusion does not change if we include the magnitude for all EU–14 countries in the regression with one exception. The parameter associated to the tradeoff between EU members during the EMS period is positive and significant at the 10% level.

Our conclusion from these estimates is that there seems to be a positive tradeoff between synchronization and the relative magnitude of business cycles for the EU member states. A higher degree of synchronization is associated with larger differences in the relative magnitude as the volatility of country–specific business cycles tends to be lower in recent years for some EU member states and higher for other. A similar tradeoff is not evident for European countries that are not members of the EU at the time of measurement except for the second sub–sample with flexible exchange rates where the parameter is positive and statistically significant at the 10% level, see the two first columns in Panel B. This raises concern over the attempts of using a common monetary policy to stabilize the European economies since it suggests that it is important to vary the intensity of the policy.[20] It is possible, of course, that national fiscal policies can be used to compensate for differences in the intensity of the common monetary policy.

To answer the question of whether similarities in economic policy and whether the exchange rate regime can explain the significant EU–membership effect, we run additional regressions of the cross–correlations on a constant, the magnitude for all countries and the magnitude for EU members adding measures of the difference in economic policy, exchange rate volatility and oil price volatility. These results are shown in Panel C in Table 6. We use the same instruments for the policy variables and exchange rate volatility as in our earlier regressions. The overall impression from these tests is that the policy variables cannot explain the positive tradeoff even though three of these control variables are significant (differences in fiscal and monetary policy and exchange rate volatility).

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[20]It may be the case that the different magnitudes are the result of differences in the transmission of structural shocks. If that is the case and if the difference in the magnitude is solely attributable to monetary policy shocks, then there is no problem, the European countries would only react differently to the common monetary policy.

The parameter associated with the relative magnitude in EU members do change (from 0.103 to 0.080) but is still significantly different from zero.

To interpret these empirical results and to be able to speculate about future developments and the consequences of the common monetary policy in Europe, we have to look more closely at the exchange rate volatility we have measured for the five sub–samples. For the EU member states, exchange rate volatility was highest during the flexible exchange rate period and the most recent period. It is also for these two sub–samples we obtain a positive tradeoff between the relative magnitude and synchronization, the parameter is statistically significant at the 10% level. This implies that a higher degree of exchange rate volatility is associated with more synchronization and larger differences in the magnitude of the business cycle. If these relations are stable over time and over different monetary regimes, then business cycles in EU member states will become less synchronized but also display less differences in the magnitude which would constitute a potential problem when implementing a common monetary policy and the common currency.

4   CONCLUSIONS

It is widely argued that the success of the common currency area in Europe rests on the uniformity of business cycle fluctuations. Our results suggest that European business cycles are synchronized to a high degree but we also find that the degree of synchronization has changed considerably since the early 1960s. In particular, we find that synchronization is higher during periods with more flexible exchange rates and lower when exchange rate volatility is low. These results question earlier findings that European business cycles became more synchronized during the EMS period. Our evidence further suggests that there are several contradicting forces affecting the degree of synchronization, smaller differences in monetary policy leading to less synchronized cycles, smaller differences in fiscal policy and increases in trade leading to more synchronization. In addition, there may be positive relationship between exchange rate volatility and synchronization. As a major objective of the EU is economic and monetary integration, one would anticipate that the linkages should strengthen over time, maybe also offset the negative effects from the common monetary policy (and lower exchange rate volatility).

When adding the analysis of the magnitude of European business cycles, the picture becomes more complex. Our estimates suggest that differences in the magnitude of European business cycles have risen over time and have never been so large for EU members. This result also raises concern about the common monetary policy as it is likely that the policy will be too expansive for some member states and too restrictive for others. The tradeoff between synchronization and differences in magnitude is positive such that larger differences coincide with a higher degree of synchronization. If business cycles become more synchronized and the relative magnitude less similar, then the timing of the common

policy tends to be optimal but the intensity tends to be wrong for some member states.

A major objective of the EU is to foster stronger economic ties between members and this process will tend to increase the degree of compatibility between the member states. Whether this also leads to more synchronization and convergence of the amplitude of the business cycle in member countries is an open question and cannot be answered by looking at historical relationships. The analysis in this paper supports this view. We find that business cycle behavior changes over time in response to new economic environments. This point, which is a version of the Lucas critique, implies that it is not possible to draw too strong policy conclusions from our empirical analysis. It may well be the case that economic integration leads to more similar business cycles within the EMU area even though our empirical analysis of historical data suggests the opposite.

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Appendix A: Data sources

Industrial production To measure business cycles we use quarterly observations of industrial production taken from IFS for all countries except for Ireland and Portugal where the data is extracted from OECD Main Economic Indicators. All data are seasonally adjusted. Sample range is 1961:1–2001:4 for all countries except Belgium 1961:4–2000:4, Denmark 1968:1–2001:4 and Switzerland 1965:1–2001:4. Estimates of bilateral cross–correlations use all data available for each pair of countries.

Trade Annual bilateral trade statistics are obtained from IMF Direction of Trade Statistics. Sample range is 1961–2001.

Interest rates The following interest rates are used to measure differences in monetary policy over the sample 1980–2001: Austria – money market rate; Belgium – call money rate; Canada – overnight money market rate; Denmark – call money rate; Finland – average cost of CB debt; France – call money rate; Germany – call money rate; Greece – central bank rate; Ireland – exchequer bills; Italy – money market rate; Japan – call money rate; Netherlands – call money rate; Norway – call money rate; Portugal – up to 5 days interbank deposit; Spain – call money rate; Sweden – call money rate; Switzerland – money market rate; United Kingdom – overnight interbank rate; United States – Federal funds rate. For the period 1961–1979 we use discount rates taken from IFS except for Greece where we use central bank rate. All data are quarterly.

Consumer price index We use quarterly observations of the consumer price index taken from IFS to compute annual inflation.

Budget deficit as a fraction of GDP Annual data on net lending as a fraction of GDP for the European countries, Japan and the US during the period 1970–2001 are obtained from European Economy Tables 78A linked to data from Table 78B. Data for the period 1960–69 are obtained from IFS. Data for other non–European countries are taken from IFS. The sample range is 1961–2001 except Japan and Portugal 1970–2001.

Exchange rate volatility Monthly nominal exchange rates are obtained from IFS. Sample range is 1961:1–2001:4. Exchange rate volatility is measured as the average of log first difference of bilateral exchange rates.

Government expenditure as a fraction of GDP Annual observations of government expenditure and nominal GDP are obtained from IFS. The sample ranges are: Austria and Belgium 1961–98, Canada 1961–2000, Denmark 1961–1999, Finland 1961–1998, France 1972–1997, Germany 1961–1998, Greece 1961–1999, Ireland 1961–1999, Italy 1961–98, Netherlands 1961–98, Norway 1961–98, Portugal 1970–98, Spain
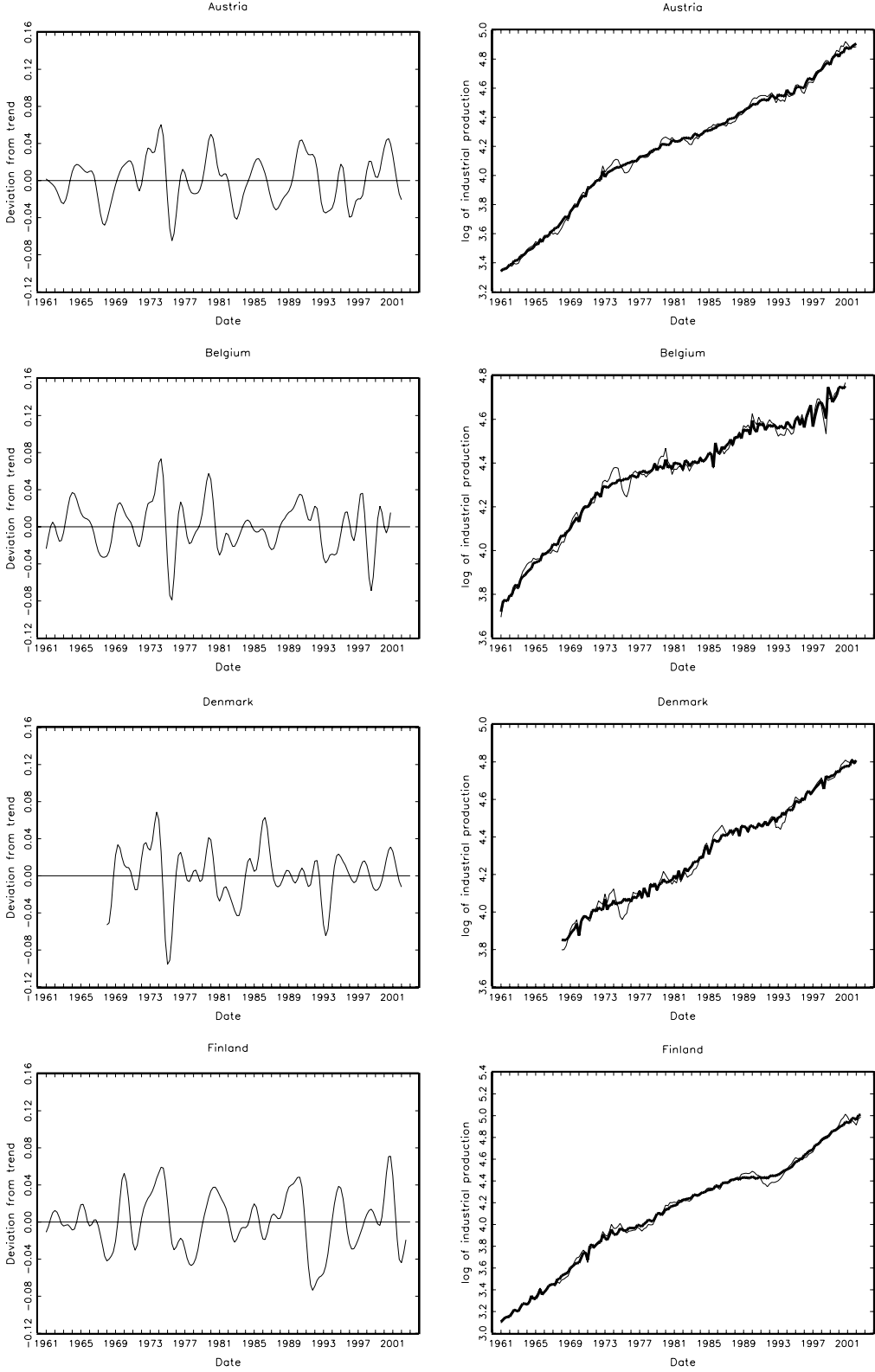
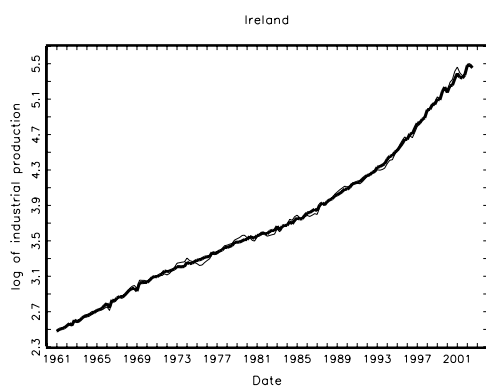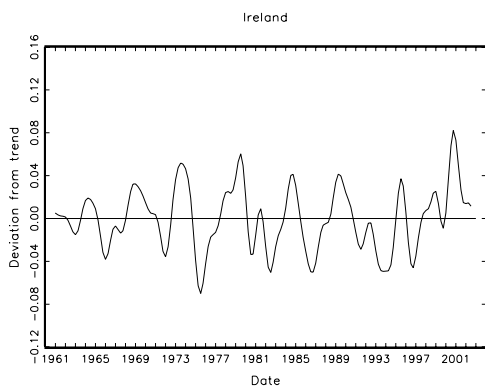1962–99, Sweden 1961–2000, Switzerland 1961–2001, United Kingdom 1961–99, United States 1961–2001.

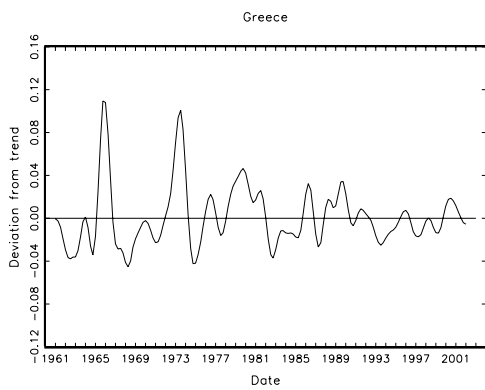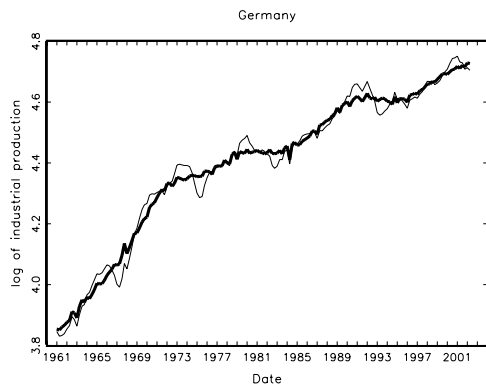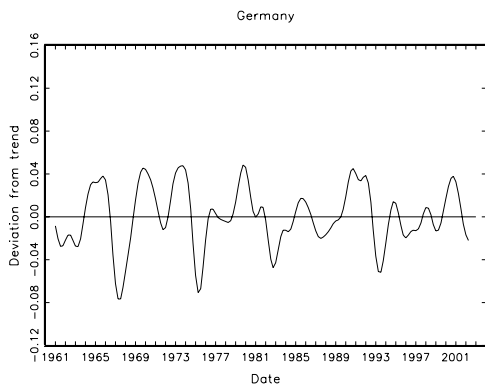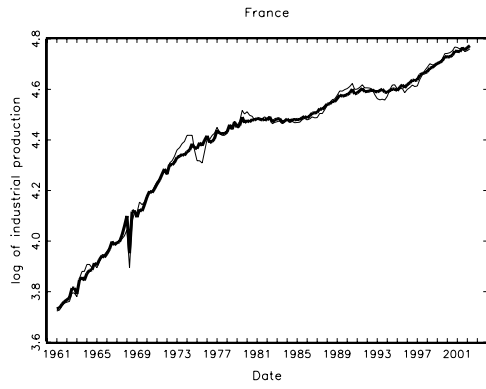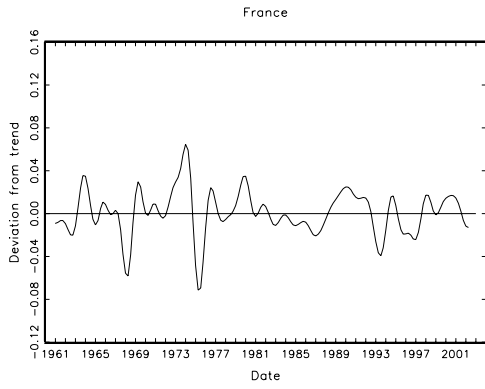**GDP per capita** Real Gross Domestic Product per Capita measured in current US$ taken from Penn World Table 6.1 (CGDP). The sample range is 1960–2000.

Distance Distance between two locations is measured as the great circle between largest cities in each country according to Fitzpatrick and Modlin (1986).

Linguistic distance This measure ranges from 0 (nobody speaks the same primary language in the two countries) to 10000 (everybody speaks the same primary language) taken from Boisso and Ferrantino (1997). Note that we have updated this series such that the primary language in the three Nordic countries Denmark, Norway and Sweden is identical (the language variable is 10000). The reason for this is that the language spoken in the three Nordic countries essentially is the same. In addition we let the language variable between Finland and the three Nordic countries be equal to the measure of identical primary language between Finland and Sweden (600).

APPENDIX B: BANDPASS FILTERED INDUSTRIAL PRODUCTION

Austria

Austria

Belgium

Belgium

Denmark

Denmark

Finland

Finland

France

Germany

Greece

Ireland

Sweden

Sweden

United Kingdom

United Kingdom

United States

United States

Canada

Canada

Japan

Japan

Norway

Norway

Switzerland

Switzerland
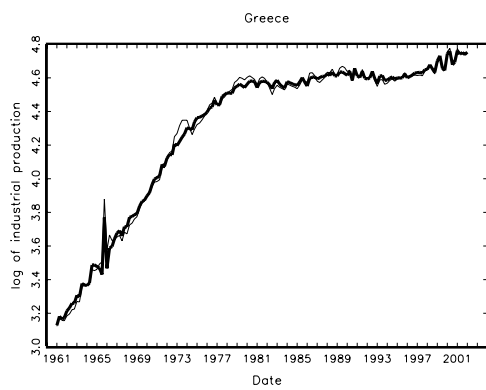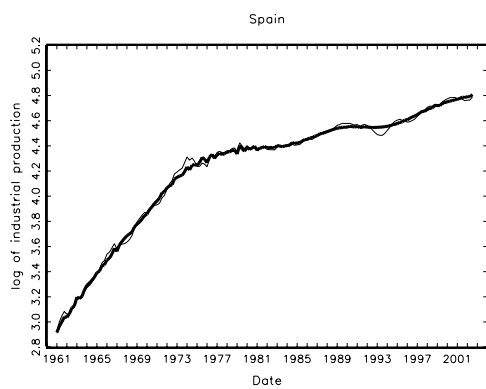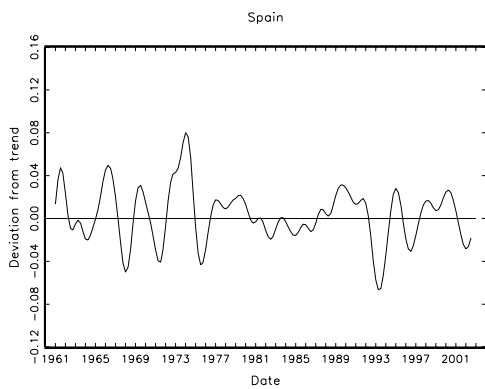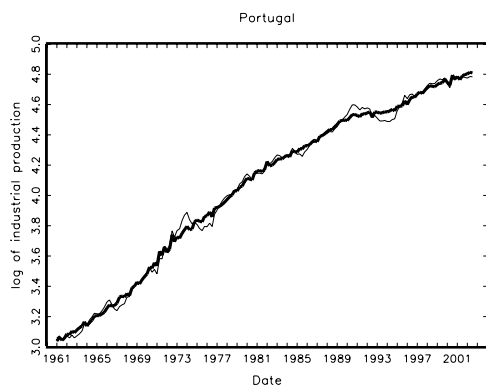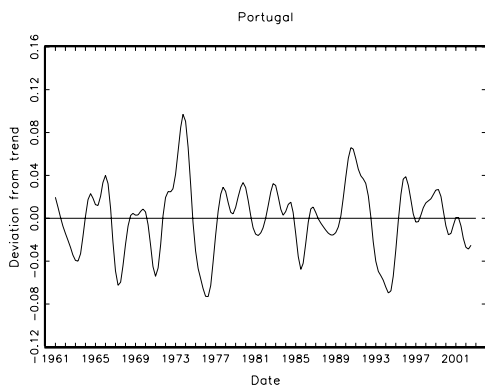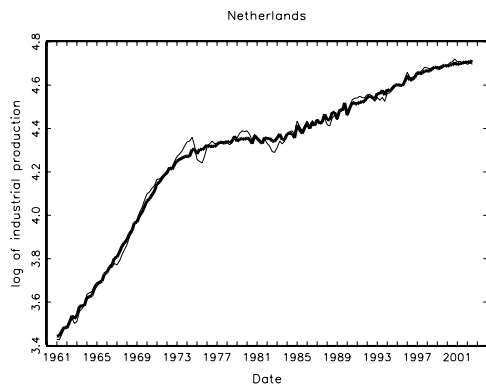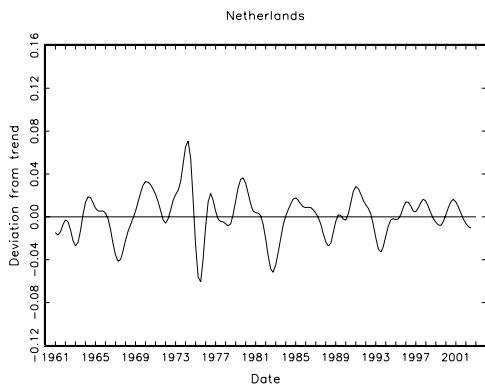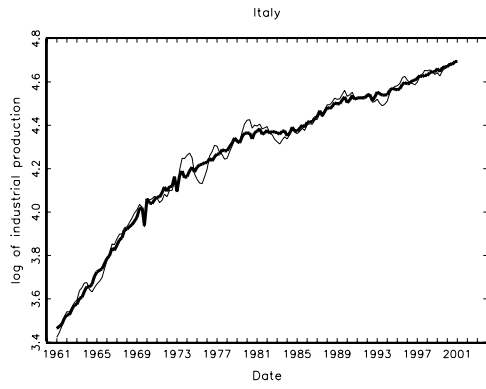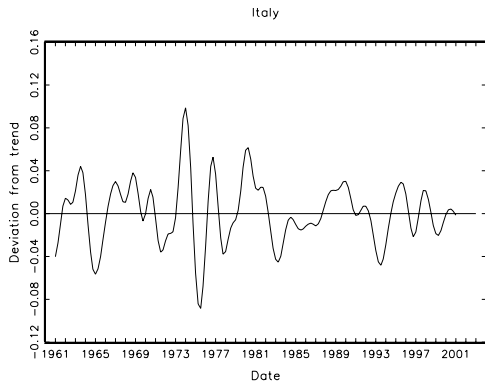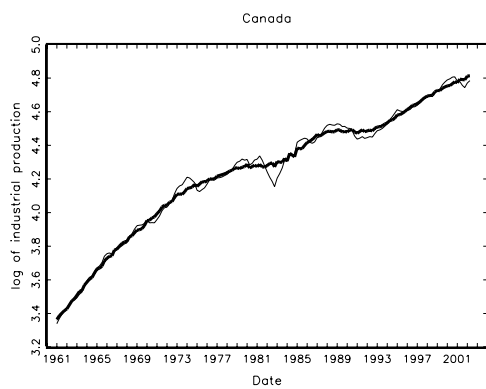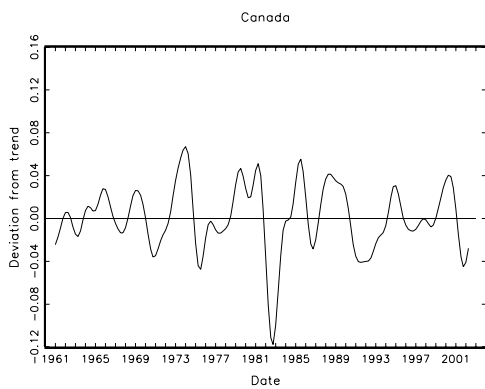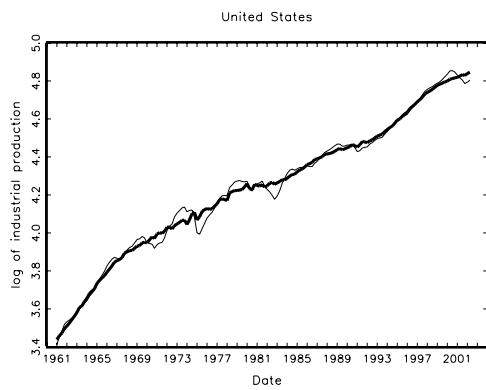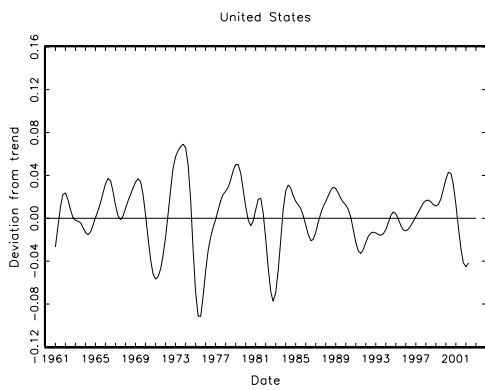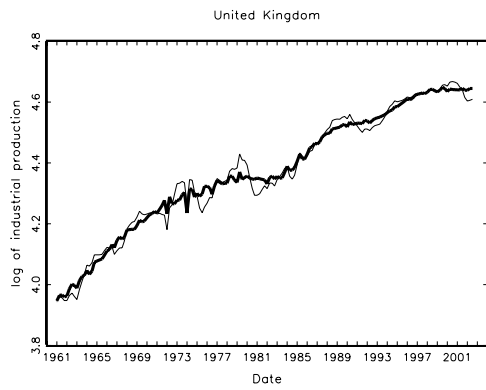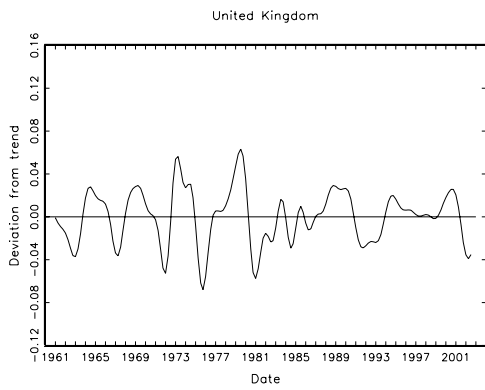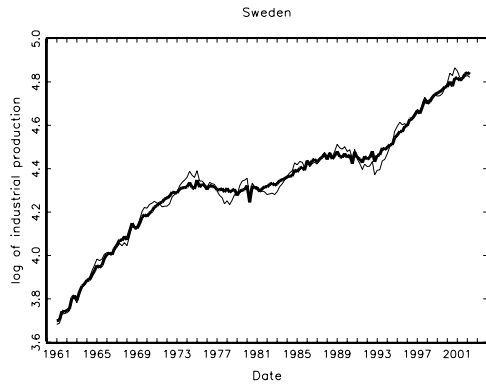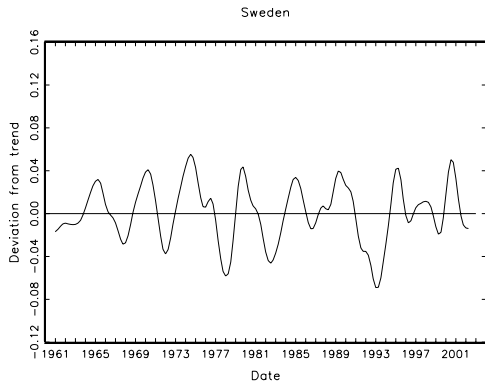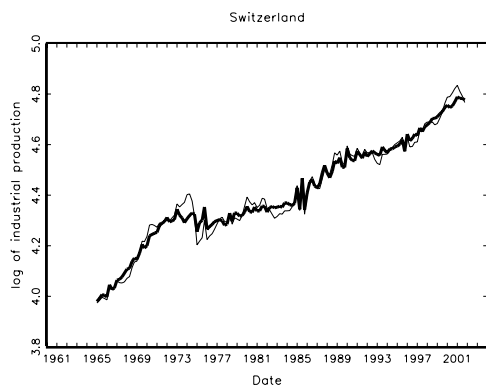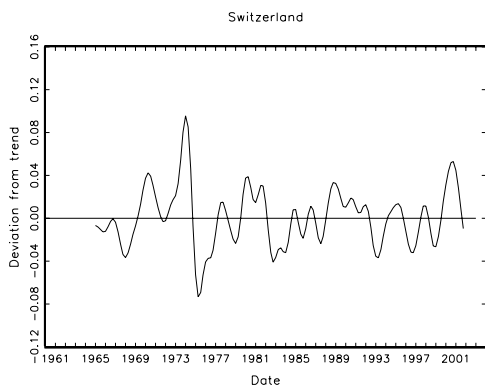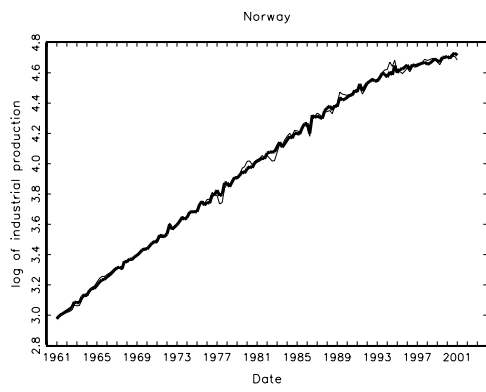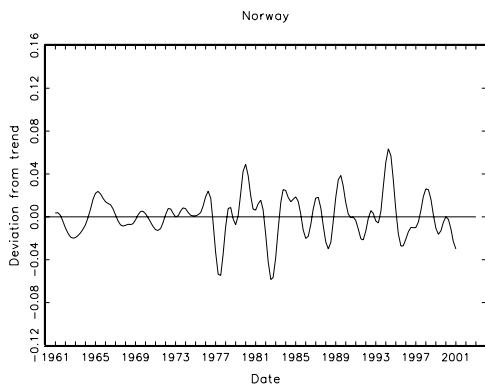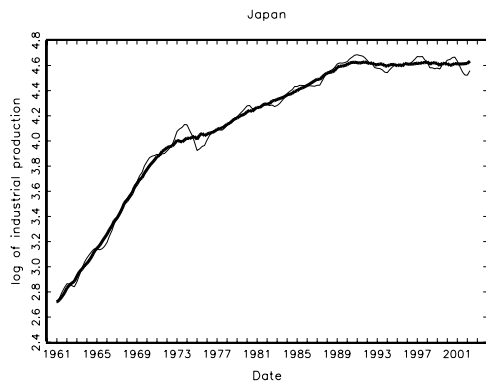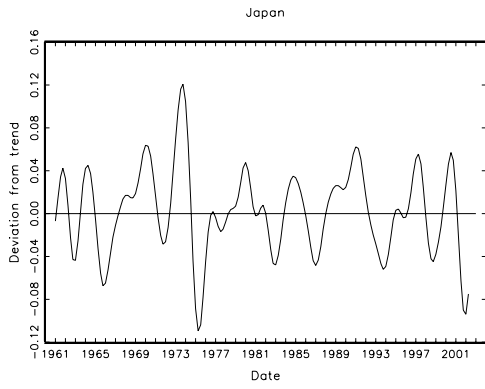
International Business Cycle Synchronization
in Historical Perspective

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April 2005

I. Introduction

The increasing worldwide integration of goods, capital and financial markets—globalization in short—is widely believed to have led to more interdependence between national business cycles.[1] This notion has only been reinforced by the broadly concurrent recent downturns in the industrial countries. Paradoxically, however, the empirical evidence for the past three decades is so mixed that it remains difficult to make a strong case for the notion of increased or increasing business cycle linkages among industrial countries. Depending on the sample period, output correlations have even decreased in recent decades, largely on account of a remarkable cycle de-synchronization among the major industrial countries in the late 1980s and early 1990s (Helbling and Bayoumi, 2003).[2]

The troubling recent evidence on patterns in business cycle synchronization may partly reflect the short sample period. In the short term, much of the business cycle dynamics depends on the shock dynamics, which tends to overshadow the effects of integration. Changes in the latter, as a recent essay in the IMF's *World Economic Outlook* (2001) has pointed out, are often minor over short periods of time. Against this, we review and attempt to explain changes in international business cycle synchronization over 120 years, using annual data for 16 countries that cover four distinct eras with different international monetary

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[1] For example, in the recent encyclopedia *Business Cycles and Depressions*, Dore (1997) considers the synchronization of international cycles a stylized fact and argues that "[i]nstitutional changes such as free capital mobility, floating exchange rates, and the increase in international arbitrage and speculative activities have increased interdependence among the major capitalist nations, which is likely to lead to further synchronization of cycles."

[2] See also Doyle and Faust (2002) and Kose, Otrok, and Whiteman (2003).

regimes.[3][4] The four eras covered are 1880-1913 when much of the world adhered to the classical Gold Standard, the interwar period (1920-1938), the Bretton Woods regime of fixed but adjustable exchange rates (1948-1972), and the modern period of managed floating among the major currency areas (1973 to 2001). Across the four eras that we examine, the variation in cross-border integration in the markets for goods, capital and financial assets has been considerably larger than over the last 20 years while the influence of particular shock realizations appears arguably to have been somewhat less important. The annual data for 16 industrial countries that we use in this paper come from Mitchell (1998a, 1998b, and 1998c) and other sources. They were used by Bergman, Bordo, and Jonung (1998) and Bordo and Jonung (2001).[5]

For the explanation of the changes, we proceed in two steps. First, we examine them from an impulse-propagation perspective. In particular, we investigate whether the increased synchronization reflects changes in the nature of the impulses (the "shocks") driving the economies, particularly those of global shocks, changes in the transmission channels, or both. We then proceed to examine the extent to which changes in business cycle synchronization

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[3] These references also provide more details on the data. The countries included in our data set are Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. In some of the tables, we list the countries by their geographical proximity rather than in alphabetical order.

[4] This approach follows Bergman, Bordo and Jonung (1998) and Backus and Kehoe (1992). Unlike these papers, we focus on international synchronization and devote less attention to the comparison of national business cycle properties such as output volatility or output-consumption comovements.

[5] The IMF's *International Financial Statistics* was used to update the dataset to 2001.

over the four eras can be related to changes in structure, such as changes in policies or trade integration.

From a historical perspective, the evidence in favor of increased business cycle synchronization is much more clear-cut than that based on the past several decades only. Based on.16 countries' real GDP over the past century and a quarter, demarcated into four exchange rate regimes, we found a secular trend towards increased synchronization that occurs across exchange rate regimes (Bordo and Helbling, 2004). This evidence is rather puzzling, however, considering the usual explanation for increased synchronization. While there appears to be an almost linear increase in business cycle synchronization over time, the level of globalization, that is, the degree of cross-border integration in markets for goods, capital, and labor, has followed a U-shaped pattern during the same period (Obstfeld and Taylor, 2003, and Bordo, Eichengreen and Irwin, 1999). Starting from a relatively high degree of globalization during the period of the classical gold standard, international integration decreased sharply during the interwar period before it began to rise again, first slowly during the Bretton Woods period and then more rapidly in the current floating rate period. Recent studies have documented that the degree of globalization prevailing in the 1880s was only reached again 100 years later (ibid.).

The difference in the paths of business cycle linkages and changes in globalization may not necessarily be surprising from a theoretical perspective since the correlation between business cycle synchronization and integration is not necessarily positive. For example, Krugman (1993) noted that stronger trade integration may lead to greater regional

specialization, which can lead to less output synchronization with industry-specific shocks. Relatedly, Heathcote and Perri (2002) showed how increased financial integration may be an endogenous reaction to the regionalization of real sector linkages, as the latter allow for gains from the global diversification of asset portfolios. That said, the apparent lack of cycle synchronization during the classical gold standard nevertheless remains somewhat of a surprise even considering the theoretical ambiguities regarding the correlation between business cycle synchronization and integration.

The paper is at this stage largely exploratory given the data that we have been able to collect for the entire sample period. Structural data in particular were difficult to find, which is problematic given that a fully satisfying structural econometric investigation requires rather detailed data on trade and sector structures. In addition, analyzing business cycle features with annual data implies that higher frequency features are not captured adequately. Nevertheless, we believe that using a much longer data sample provides a much-needed broader and complementary perspective on business cycle synchronization despite these problems.

The paper is organized as follows. Section II discusses conceptual issues regarding international business cycle synchronization and provides the basic stylized facts. The subsequent section looks at the role that changes in this structure of shocks may have played in the observed changes in the synchronization of cycles. Section IV analyzes how changes in trade integration, capital mobility, and policies have contributed to the observed increased international synchronization of business cycles. Section V summarizes changes in

globalization over the last 120 years. The following section then examines how the results can contribute to resolving the puzzle between the U-shaped pattern in globalization and the secular increase in business cycle synchronization.

II.   CROSS-COUNTRY BUSINESS CYCLE YNCHRONIZATION OVER TIME

The notion of business cycles becoming increasingly synchronized across countries captures the observation that the timing and magnitudes of major changes in economic activity appear increasingly similar. For example, in the most recent slowdown, output growth started to weaken at about the same time in the major advanced economies (e.g., Helbling and Bayoumi, 2003). Despite frequent use, however, definitions of synchronization vary widely in the literature. As noted by Harding and Pagan (2004), most current definitions are not capturing business cycle synchronization in the tradition of the National Bureau of Economic Research (NBER), which are based on turning points in reference cycles. In their paper, they develop a statistical apparatus to test cycle synchronization in the NBER tradition. Specifically, they consider national business cycles to be synchronized if turning points in the corresponding reference cycles occur roughly at the same points in time. On this basis, they have derived a statistical measure, the concordance correlation, that allows one to test whether national cycles are significantly synchronized or not. This approach to measuring synchronization boils down to national business cycles being in the same phase—expansions and recessions—at about the same time.

In this paper, we will not follow Harding and Pagan. Analyzing cycles using turning points would add an unwarranted layer of complexity to the analysis. Ultimately, as Harding and Pagan (op. cit.) have shown, their measure of cycle synchronization depends on the moments of output growth. For an analytical understanding of the changes in the synchronization, it is, therefore, sufficient to focus on the changes in these moments.[6] Hence, to establish the stylized facts, we can use correlations among output growth rates as a measure of the strength of cross-country linkages in macroeconomic fluctuations. This is also the most widely used measure in the recent academic literature on the international business cycle.

We will, however, follow Harding and Pagan (2003, 2004), Stock and Watson (1999), and others by using real gross domestic product—or output in short—as the measure of aggregate economic activity or the business cycle rather than synthetic reference cycle series based on a number of series (the NBER approach).

 Figure 1 shows the correlation coefficients for log output growth by percentile for the four eras. The distribution of the correlation coefficients differs substantially from era to era. In particular, there has been a tendency toward higher, positive output correlations. During the Gold Standard, about one half of all country pairs were characterized by negative output correlations and the average output correlation coefficient is about 0 (Table 1). A first important step toward synchronization occurred during the interwar period, when the share of

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[6] In Bordo and Helbling (2004), measurement issues are discussed in greater depth, and patterns of cycle synchronization are established using three different measures.

negative correlations fell below 30 percent while the average correlation increased to about 0.15. A subsequent reversal during the Bretton Woods era was small, and correlations remained, on average, above those found for the Gold Standard era. A second important increase then occurred during 1973-2001, when less than 10 percent of all country pairs were characterized by negative output correlations and the average correlation was 0.33.

Are these changes over time statistically different? This question is relevant since the confidence intervals for the bilateral correlation coefficients are relatively wide given the few observations per era.[7] We used both nonparametric and parametric tests to address the issue. (Nonparametric) Wilcoxon Rank sum tests suggest that the upward shifts in the distribution of the correlation coefficients are significant at the 5 percent level for the interwar period (compared to the Gold Standard era) and for the modern floating era (compared to both the interwar and the Bretton Woods eras). The downward shift in the distribution of correlation coefficients from the interwar to the Bretton Woods eras is only significant at the 10 percent level.

The Wilcoxon rank sum test does not require any assumption about the underlying distribution of the correlation coefficients. In practice, however, it is typically assumed that the correlation coefficients of a vector series of log first differences of outputs reflect an

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[7] The sampling standard deviation of estimated correlation coefficients depends on the size of the estimated coefficient and the number of observations. Given the former, small samples tend to amplify the sampling uncertainty greatly. For example, for a correlation coefficient of 0.15—the average for the interwar period—the standard deviation for a sample of 20 observations is 0.23. With 50 and 100 sample observations, the standard deviations decline to 0.14 and 0.10, respectively.

underlying multivariate normal distribution, at least asymptotically. For this reason, we also formally tested for the equality of the covariance and correlation matrices over subsequent periods using the tests proposed by Jennrich (1970). In a first step, we tested for the significance of the changes in the average correlation coefficients. The changes between the Gold Standard and the interwar eras and between the Bretton Woods and the modern floating eras, respectively, are statistically significant while the decline between the interwar and the Bretton Woods eras is insignificant (Table 2). Given the small number of observations per era, these are strong results.

Beyond average correlations, however, the statistical significance of the changes in output co-movements in general is more ambiguous. Regarding the six possible pairs of covariance matrices for the four eras, all but two are statistically significantly different from each other at the 5 percent level (Table 3), which bears on the factor model-based approach to measuring synchronization discussed in the next subsection. The pairs that are insignificantly different are 1880-1913 vs. 1926-1938 and 1880-1913 vs. 1951-1972, respectively. Regarding correlation matrices, only two are statistically different at the 5 percent level (1926-1938 vs. 1973-2001 and 1951-1972 vs. 1973-2001, respectively). To some extent, insignificance reflects "substitution" among country pairs, as some correlations increased while others decreased.

For smaller groups, especially the (old and new) core countries and European countries, the changes in the correlation matrices from era to era are generally statistically significantly different, except for the pair 1880-1913 vs. 1926-1938. We attribute the fact that the changes

between those two eras are often insignificant to the few number of observations for the interwar era, which tends to reduce the sampling precision (as noted in footnote 7). Overall, the results of all the tests support the notion of a secular increase in business cycle synchronization.

So far, we have looked at business cycle synchronization through a global lens, noting the increased synchronization without consideration for other factors. However, one would expect that synchronization patterns differ considerably across groups of countries, depending on factors such as "gravity" or country size. The evidence clearly illustrates that the extent to which gravity has shaped the synchronization trends depends on the region (Table 2). For core European countries (the old "EEC") and Continental European countries, the increase in business cycle synchronization was clearly much sharper than the general increase. At the other end of gravitas, business cycle synchronization between Japan and the other countries in the panel has increased by less. In particular, there is no evidence for an increase between the Bretton Woods era and the modern floating rate period.

The fact that the increase for all Continental European countries was smaller than that for the Core European countries suggests that the forces of gravity are affected by common policies, preferential trading agreements, and specific currency arrangements. The increase in correlations among the Anglo-Saxon countries is also remarkable even though it seems more

difficult to attribute this to forces of gravity.[8] While we do not believe that common

institutions and heritage among the Anglo-Saxon countries account directly for the increased

synchronization, as Otto et al. (2001) have argued, they likely have fostered similar patterns

in the transmission of shocks through what appear to be similar, market-based financial

systems.[9]

While the regional perspective reinforces the notion of a trend increase, it should be noted

that stark regional differences have only really emerged during the modern floating rate

period. Forces of gravity do not appear to have been a factor behind business cycle

synchronization during the classical Gold Standard, as differences in correlations among

regions were minor, with the high correlation between Canada and the United States and, to a

much lesser extent, among the Scandinavian countries, being the main exceptions. During the

Bretton Woods period, increased regional synchronization began to emerge in the core

European countries. Interestingly, the increased synchronization during the interwar period

was primarily on account of an increased synchronization between the cycles in the United

States and other countries, which in turn seems to reflect the equity boom bust cycle and its

effects from the mid-1920s to the mid-1930s.

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[8] The emergence of strong business cycle linkages among core European countries and among the Anglo-Saxon countries was noted, among others, by Helbling and Bayoumi (2003) and Stock and Watson (2003).

[9] See Bayoumi and Edison (2003) on the distinction between market- and bank-based financial systems.

So far, all the cycle correlations we have studied were based on log first differences of output. Does the detrending method matter for our findings? Naturally, high frequency noise is not a great concern, given our panels of annual data, but it is possible that the increases in cycle correlations from the 19th to the end of the 20th century really reflect changes in trend co-movements. In Bordo and Helbling (2004), we also examined correlation patterns in bandpass-filtered log output data. The results show that the detrending method makes little difference and that the same principal changes in the patterns of cycle synchronization are found with bandpass-filtered output data.

III. EXPLAINING INCREASED SYNCHRONIZATION: THE ROLE OF SHOCKS

Using a standard measure of synchronization, we found evidence of increased cross-country business cycle synchronization over time among industrial countries. From an impulse-propagation perspective, the increased synchronization could reflect changes in the nature of the impulses (the "shocks") driving the economies, changes in the transmission channels and mechanisms, resulting inter alia from increased integration, or, most likely, both.

Disentangling the relative contributions of the changes in the correlation of shocks and changes in the transmission channels to the changes in output correlations is difficult, however, as this would require a comprehensive structural model of the economy that can be estimated empirically. Such a model, which would need to allow for factors such as changes in trade and financial integration and a multitude of shocks, seems beyond our reach, given

the current state of the art in multi-country modelling. Financial integration, for example, is

not yet satisfactorily accounted for in any of the leading multi-country models.

Against this background, we will proceed with a more modest research agenda. In this

section, we will focus on deriving measures of the impulses driving each economy and study

the changes in their properties over time. On this basis, we will then attempt to assess the

extent to which changes in the properties of shocks may help to explain the observed changes

in the synchronization of cycles. In the next section, we will focus on how changes in

integration and the policy environment may have shaped changes in business cycle

synchronization.

Is there evidence that global shocks have been driving the increased business cycle

synchronization? This is a natural hypothesis, given the evidence of increased globalization,

that is, economic interdependence through trade in goods, services, and assets. To structure

our discussion, the following canonical, simple model of joint output dynamics in a two-

country set up is a helpful illustrative device:[10]

$$\begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \end{pmatrix} + \begin{pmatrix} v_{1t} \\ v_{2t} \end{pmatrix} \tag{3.1}$$

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[10] Canova and Dellas (1993) show how a very stylized two-country real business cycle model implies such a bi-variate vector autoregressive representation. Doyle and Faust (2002) use a simple error-components structure to illustrate similar issues.

where y_{it} denotes the log output growth rate in country i. Following Stock and Watson (2003), the error vector v is assumed to be determined by the following factor structure:[11]

$$\begin{pmatrix} v_{1t} \\ v_{2t} \end{pmatrix} = G\zeta_t + \begin{pmatrix} \eta_{1t} \\ \eta_{2t} \end{pmatrix} \tag{3.2}$$

In this factor VAR (FAVAR) model, ζ is a global shock and η_i is a country-specific idiosyncratic shock. G is a vector of factor loadings. According to this model, increased output synchronization—as measured by output correlation—between countries 1 and 2 can, ceteris paribus, arise for three reasons:

- Increases in the variance of the global shock relative to the country specific idiosyncratic shocks.

- Increases in the covariance of the idiosyncratic shocks η_1 and η_2.[12]

- Increases in the "transmission" coefficients a_{12} and a_{21}, which determine the spillover effects that shocks in country 1 have on country 2 and vice versa.[13] In addition,

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[11] In contrast to the FAVAR model, the coefficient matrix A is usually assumed to be zero in standard dynamic factor model where the dynamics arises from those of the factors, which are modelled as autoregressive processes.

[12] We mention this for completeness from a general perspective. Typically, idiosyncratic shocks have to be uncorrelated in order for the global shock to be identified in the two variable model. With many variables, however, limited correlation among idiosyncratic shocks may be allowed, depending on the specification and estimator.

increases in the autoregressive parameters also increase correlations, as greater

persistence in a country's output fluctuation increases the scope for spillovers.

Extending the simple bivariate model (3.1) and (3.2) to a general model that includes all the

16 countries in our sample proved to be difficult. First, given few observations for each era,

very few degrees of freedom would be left if the model were estimated even with one lag.

For the interwar era, the number of common observations for all 16 countries is even less

than the number of parameters, so that comparability of the model across eras could not be

ensured. Second, in our set of annual data, the degree of autocorrelation in output growth is

generally low in all eras. While there are some intrinsic dynamics in the cross-country output

dynamics, they are generally insignificant, as the null hypothesis of $a_{11}=a_{12}=a_{21}=a_{22}=0$ could

usually not be rejected in bi-variate VARs. In the circumstances, we used two simplified

versions of the general factor VAR model for the analysis:

- *The center country model*. In this version, the equation for each country's real GDP

  growth includes lagged own GDP growth and lagged GDP growth in the center

  country (the United Kingdom in the Gold Standard era and the United States in the

  other eras). The rationale behind this model is that idiosyncratic shocks in the center

  country can be transmitted through the traditional channels while idiosyncratic shocks

  elsewhere have only limited effects on other countries.

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[13] In the simple model of Canova and Dellas (op. cit.), these coefficients follow from the production structure, as foreign intermediate goods are needed to produce the final consumption goods.

- *The trade linkages model*. In this version, the equation for each country's real GDP growth includes lagged GDP growth and lagged GDP growth in important trading partner countries (the ones reported in Mitchell (1998a, 1998b, and 1998c, as explained below). The rationale behind this model is, of course, straightforward.

We estimated the models with a two-step, semi-parametric procedure. In the first step, we used SURE estimators to obtain the coefficients a_{ij} and the residual series v_{it}. In a second step, we used the static approximate factor model of Ng and Bai (2002) to obtain the global shock ζ and the idiosyncratic shocks η_i from the residual series v_{it}. This model allows for serial correlation, heteroskedasticity, and some limited cross-correlation in the idiosyncratic components. Following standard practice in the literature, we use the first common factor as a measure of the common shock driving cross-country business cycle fluctuations.[14] Both models turned out to be roughly similar in terms of information criteria for all eras, although the restrictions implied by the center model compared to the trade model were rejected by standard likelihood ratio tests.

A first set of results concerns the issue of whether the moderation in the volatility of national output growth rates over time in the postwar period reflects primarily reductions in the

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[14] Bai and Ng (2002) proposed to use information criteria to determine the appropriate number of factors. However, their Monte Carlo simulations show that for panel datasets where the cross-sectional and time dimensions are as low as in ours, the tests are not very reliable and tend to imply too high a number of factors.

volatility of global shocks.[15] Table 4 shows the average standard deviations of the national

output series (log growth rates) and compares them with the estimated variances of the global

shock and the average idiosyncratic shock. As was to be expected, the direction of change in

the standard deviations of both global and idiosyncratic shocks generally follows that of the

average standard deviation of output growth. However, what matters for the changes in

output correlations is the relative change in the standard deviations of the two types of

shocks. While idiosyncratic shocks were clearly more volatile than global shocks during the

Gold Standard, the magnitudes of their average standard deviations became more similar

during the other eras in both models. However, from the interwar era, decreases over time in

the average standard deviation of idiosyncratic shocks relative to the standard deviation of

the global shocks were minor. This implies that, on average, the contribution of global

shocks to the increase in the average output correlation has been minor, taking the a_{ij}

coefficients as given.

A second set of results concerns the issue of whether global shocks or spillovers drive the

observed increases in output synchronization. Table 5 presents averages of 1 to 4-step ahead

forecast error variance decompositions for the output growth rates during the four eras,

distinguishing between the shares of total output variance explained by the global shock, the

idiosyncratic shocks, and transmission. To have a variance decomposition based on

orthogonal shocks, we used the diagonal of the variance-covariance matrix of the η_i series

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[15] The general moderation in the amplitude of output fluctuations has been analyzed by Blanchard and Simon (2001).

rather than the full matrix, thereby ignoring the limited cross-correlation among idiosyncratic shocks allowed for by our nonparametric factor model. Given that the cross-correlation among idiosyncratic shocks is minor, the assumption of orthogonal idiosyncratic shocks appears to be an acceptable simplification. This set-up implies that the transmission of shocks—which can be both due to global shocks and idiosyncratic shocks—occurs with a one-year lag.[16] Output synchronization due to a global shock is thus immediate, while that due to transmission occurs gradually. To be precise, we note that the columns labeled with transmission in Table 9 capture the combined effects of the lagged effects of idiosyncratic shocks elsewhere.

The variance decomposition shows the following. First, idiosyncratic shocks have become less important in shaping each country's output dynamics. Second, both global shocks and transmission have become more important. Third, the relative importance of the last two factors in accounting for the lesser role of idiosyncratic shocks depends on the model. The center model suggests that the increases in the variance share of the global shock account for most of the reduction in the variance share of the idiosyncratic shocks. The increase accounted for by the transmission of idiosyncratic shocks is minor. On the other hand, the trade model suggests that both increases in the variance shares of the global factor and the transmission account for the reduction in the variance share of idiosyncratic shocks. However, it is noteworthy that shock transmission appears more important for peripheral

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[16] The shares of the global shocks and the idiosyncratic shocks reported in Table 9 are the shares explained by each country's own autoregressive structure in response to each of the two shocks. We do not, therefore, distinguish between the transmission of global shocks and idiosyncratic shocks.

countries than for core countries in the trade model. For the core countries, the increase in the variance share related to global shocks accounts for most of the decrease in the share explained by idiosyncratic shocks.

Our two FAVAR models thus suggest that the increased business cycle linkages among core countries, as measured by output correlations, largely reflect the dynamics of common global shocks. Remarkably, the increased importance of transmission for peripheral countries only arises in the trade model. This suggests that it is not transmission from the center country, a channel that operates in both models, that accounts for the increased variance share of transmission. It is rather the intra-European transmission that matters in the modern floating era, a fact that seems consistent with the above average output synchronization among European countries reported in Table 1.

For a further understanding of the role of global shocks, Figure 3 is instructive. Each panel shows the global shocks from the trade model (solid lines) for an era, supplemented by dotted lines depicting the global shocks from a simple static approximate factor model for output growth rates (taken from Bordo and Helbling, 2004) and bars showing time dummies—the equivalent of global shocks—from an error components model that are significant at the 5 percent level.[17] [18] We estimated the latter to obtain a measure for large and important shocks.

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[17] Naturally, only the product ΛF_t is identified in this factor model. We normalized the square of the factor loadings, i.e., $\Lambda'\Lambda/16=1$, to identify F_t. We believe this to be the natural normalization, as it allows for comparable variances between outputs and factors. The alternative would be to normalize the factor variance to 1 (Bai and Ng, 2002).

[18] We estimated the following traditional error component model with our panel dataset:

The global shocks implied by the two factor-based approaches—the trade model and the simple factor model—are surprisingly similar except for the interwar period, although the shocks from the trade model are generally smaller in magnitude. The latter finding is not that surprising since the possibility of transmission implies lower shock variances with equal output variances. The general picture emerging from Figure 2 is that global shocks appear noticeably important at times of world-wide downturns, suggesting an asymmetry between downturns and upturns.[19]

Overall, our results are broadly consistent with globalization. With increased economic and financial interdependence through trade and financial linkages, the scope for global shocks or the rapid transmission of shocks in the center countries has clearly increased. In addition, with global shocks, floating exchange rates do not provide much scope for insulation, since shocks affect all countries in similar ways. At the same time, business cycle amplitudes have clearly moderated during the post-World War II period, reflecting, among other factors, changes in sectoral structure, automatic stabilizers, the use of lender of last resort operations, and the use of discretionary counter-cyclical policies.[20] In this context, it is interesting to note that the volatility of idiosyncratic shocks has decreased more than that of global shocks.

$$y_{i,t} = \lambda_t + \eta_{i,t}$$

where λ_t denotes a time dummy taking on the value 1 in time t and $\eta_{i,t}$ a shock specific to country *i*.

[19] This corroborates Helbling and Bayoumi (2003), who found a similar result for the G-7 countries during 1973-2001 using quarterly data and a dynamic factor model to isolate common cycles.

[20] See McConnell and Perez-Quiros (2000), Ahmed, Levin and Wilson (2002), Blanchard and Simon (2001), IMF (2002), Dalsgaard, Elmeskov, and Park (2002), and Stock and Watson (2002) for recent studies examining the volatility of output fluctuations in industrial countries, especially the United States, and the reasons thereof.

Among other factors, this finding is consistent with the notion that the changes in the sectoral structure and the use of automatic stabilizers as well as other counter-cyclical policies have been fairly similar across the industrial countries.

Nevertheless, some aspects of our results remain puzzling. The much larger standard deviations of idiosyncratic shocks during the gold standard may be explained by structural factors and the conduct of macroeconomic policies. Clearly, agriculture was much more important, rendering economies more susceptible to idiosyncratic shocks as weather conditions. Similarly, the general absence of lender of last resort policies (except in the United Kingdom?) and macroeconomic stabilization policies could also have contributed to relatively larger idiosyncratic shocks. The fact that the transmission of idiosyncratic shocks played such little role during the classical gold standard, however, remains puzzling.

IV. EXPLAINING INCREASED SYNCHRONIZATION II: INTEGRATION AND POLICIES

Changes in the nature of shocks are only one reason for the observed increased in business cycle synchronization. In parallel with the factor model-based literature on the sources of international business cycle linkages, the role of structural factors such as trade integration and exchange rate regimes in determining shock correlations as well as the transmission coefficients a_{ij} has also been studied. For example, as noted by Canova and Dellas (1993), the extent to which two or more countries are linked through trade is an important determinant of the a_{ij} coefficients and thus of the strength of business cycle linkages. In this

section, we will focus on how changes in integration and the policy environment may have
shaped changes in business cycle synchronization.

A. Trade Integration

Starting with Canova and Dellas (1993), the role of trade interdependence in explaining
international business cycle linkages has received considerable attention in the literature.[21]
Frankel and Rose (1998) found that in the period from 1959-1993, OECD countries with
closer trade links tended to have more tightly correlated business cycles. In this subsection,
we follow Frankel and Rose's methodology and examine the linkages between business cycle
synchronization and trade links for the four eras that are the subject of our paper. In
particular, we will try to address the questions of whether and to what extent the observed
changes in trade linkages can explain the changes in business cycle synchronization.

Using data from Mitchell (1998a,1998b, and 1998c) for the Gold Standard and the interwar
period and from the *IMF's* Direction of Trade Statistics for the Bretton Woods era and
modern floating era, we constructed a measure of the trade intensity between countries *i* and *j*
proposed by Frankel and Rose (1998):[22]

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[21] See, for example, Frankel and Rose (1998), Otto, Voss, and Willard (2001), and Imbs (2003).

[22] We also constructed the other measure proposed by Frankel and Rose (1998), where bilateral trade is
normalized by total trade:

$$w_{ijt}^T = \frac{X_{ijt} + M_{ijt}}{X_{it} + M_{it} + X_{jt} + M_{jt}}$$

(continued)

$$w_{ijt}^Y = \frac{X_{ijt} + M_{ijt}}{Y_{it} + Y_{jt}} \tag{4.2}$$

where X and M denote exports and imports, respectively, and where a double subscript ij

stands for bilateral trade values. Y denotes nominal GDP. Unfortunately, based on the limited

information provided in Mitchell (1998a, 1998b, and 1998c), we could not construct the two

measures for all the 120 correlation observations that we have for each era. We will thus

show results for a sample of 59 observations for each of the four eras and for a sample of all

the 120 country pair combinations for the post-World War II eras.

With these measures, we estimated cross-sectional regressions of the form for each era, τ, of

the form:

$$f(corr_{ij,\tau}) = \alpha + \beta \ln(\bar{w}_{ij,\tau}^k) + \varepsilon_{ij,\tau} \tag{4.3}$$

where the bar over the trade intensity measure w^k (k=T, Y) indicates that it is an era average

and where the function f(·) maps the output correlation coefficient $corr_{ij}$ from the interval [-

1,1] to [-∞,∞] so that standard assumptions in the linear regression model are met.[23] As do

Frankel and Rose, we treat trade intensity as an endogenous variable and use gravity

variables as instrumental variables. Specifically, the following three instruments are used: the

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where simple subscripts i or j indicates aggregate trade values. We found that this measure lacked a clear time trend, which suggests that the direction of trade has been quite stable over time.

[23] We use the function $f(x) = \ln\left(\frac{1+x}{1-x}\right)$ following Otto, Voss, and Willard (2001). Frankel and Rose (1998) used raw correlations.

natural logarithm of the distance between the main business centre in each country, a dummy variable for common borders, and a dummy variable for common language.

Table 6 shows the results for both trade intensity measures and for both the smaller and larger sample, as discussed earlier. The estimated β coefficients all have the right sign but they are not always significant. However, the insignificant coefficients are confined to the smaller panel covering all four eras, which may reflect small sample problems, as we are missing bilateral trade relations among the smaller European countries in particular. The simple regressions suggest the following observations.

- There is substantial variation in the slope coefficients (and the constant terms) across eras. In fact, the assumption of identical slope coefficients and constant terms is rejected for both samples.

- As do Frankel and Rose, we find that changes in bilateral trade intensities are estimated to have large effects on output correlations. For example, a one percentage point increase in trade intensity generally raises output correlations by more than 3½ percentage points in the case of bilateral trade normalized by GDP.

- The difference in the estimated β coefficients for the Gold Standard and interwar eras is small. Between the Bretton Woods era and the modern floating rate era, however, the synchronization effects of higher trade intensity appear to have increased, which may suggest that the synchronization effects of trade intensity depend on other factors as well. We will take up this issue below, but note in the meantime that this finding is

consistent with the argument that stronger trade linkages in recent years have reflected common policies, including, for example, those related to European monetary integration.[24] It is also consistent with our earlier finding of increased structural shock correlations, since bilateral output correlations are determined by the product of the transmission coefficients, which in turn can be considered to be functions of trade intensities, and shock correlations.[25]

- Finally, similar to Otto, Voss, and Willard (2001), we find that while they are significant determinants, trade intensities alone explain relatively little of the overall variation in bilateral output correlations, especially for the interwar and the Bretton Woods eras. For the Gold Standard era, bilateral trade intensities appear to explain about the same share of output correlations as during the modern floating era with the first measure. Interestingly, the explanatory power of the gravity variables in the first stage regressions appears to increase over time.

So far, the results suggest that bilateral trade intensities explain only a small share of the differences found in bilateral output correlations for each era. Can changes in trade intensities from era to era explain the increased international business cycle synchronization? In Table 7, we show the estimated impact of the actual changes in trade intensities between eras on bilateral output correlations (the second set of columns in the table corresponds to the larger

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[24] This argument was advanced by Bayoumi and Eichengreen (1993).

[25] In the general autoregressive model (3.1), the positive interaction between transmission coefficients and shock correlations holds for a wide range of the admissible parameter values.

sample for the postwar eras). Since the restriction of identical slope coefficients between eras can generally be rejected, we use both the estimated values for the current and the previous era to generate predicted changes.[26]

The actual changes in the average bilateral output correlation are generally much larger than the changes predicted by changes in trade intensities. The model is successful in explaining the increase in output correlations from the interwar to the Bretton Woods eras, where the rise in trade intensity explains roughly half of the increase or more, depending on the β coefficient used in the calculations. This finding is consistent with the notion that trade liberalization after World War II, when the earlier increase in the restrictiveness of trade regimes was reversed under the umbrella of the General Agreement on Tariffs and Trade (Irwin, 1995), has played an important role in shaping business cycle synchronization. The model is less successful in explaining the strong increase in output correlations from the Bretton Woods era to the modern floating rate period. We interpret this as possible evidence that the momentum of trade liberalization has slowed down in recent decades, as efforts in the most recent GATT/WTO rounds have shifted from tariff reductions on industrial goods towards nontariff barriers and trade in agriculture and services (Irwin, op. cit.). It also may be that increased financial integration played a bigger role in shaping output synchronization than trade integration during recent decades.

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[26] We do not use changes in the constant between eras in the calculation of the predicted changes.

B. Asset Market Integration

Increasing asset market integration is another channel through which globalization can affect international business cycle synchronization. Baxter and Crucini (1995), for example, show how asset market integration affects the spillover effects of country-specific shocks and, thus, output correlations. Unfortunately, asset market integration remains difficult to measure. Bilateral data in (net) asset trade is all but unavailable, especially for a period covering our four eras. Measuring asset market integration through the correlation of asset returns may suffer from problems of reverse causality. We decided, therefore, to use a very crude indicator to measure asset market integration. Based on the annual capital control dummy variables for each country prepared by Bordo et al (2001), we derived an indicator, which we will refer to as CC, that measures the number of years (as a fraction of the total number of years covered by each era) during which capital flows were subject to restrictions.

With this indicator, we first estimated the simple regression equation:

$$f(corr_{ij,\tau}) = \alpha + \delta \overline{CC}_{ij,\tau} + \varepsilon_{ij,\tau}$$

(4.4)

where the function $f(\cdot)$ is the same as above for each era but the Gold Standard era. The latter is because our dummy variables suggest that none of the countries in our sample imposed capital controls. Ordinary least squares was used to estimate the coefficients. Subsequently, we also estimated the following equation that combines trade and asset market integration:

$$f(corr_{ij,\tau}) = \alpha + \beta \ln(\overline{w}_{ij,\tau}^{Y}) + \delta\overline{CC}_{ij,\tau} + \varepsilon_{ij,\tau} \qquad (4.5)$$

for both post-World War II eras. By focusing on the postwar period only, we have 120

observations for the trade intensity measures, which is preferable, given that we suspect

small sample problems for the data set covering all four eras. As above, we treat the trade

intensity measure w^{Y} as an endogenous variable using the gravity variables discussed above

as instruments (and our capital control indicator CC).

The results are shown in Table 8. The δ coefficients have the right signs for the interwar and

modern floating rate eras but are insignificant. The conclusion is that adding the capital

control indicator to the trade equation does not add to the explanatory power of the equation.

We interpret these results mainly as a reflection of possible shortcomings of our dummy

variable rather than as a rejection of the hypothesis that financial market integration has been

a major factor behind international business cycle synchronization.

C. Policies

Exchange Rate Policy

One of the main arguments, if not the main argument, in favor of flexible exchange rates has

been that they allow a country to insulate itself from external shocks through an independent

monetary policy. With fixed exchange rates, the scope for pro-cyclical spillovers can be

expected to be larger, unless capital controls or other restrictions allow for some monetary independence.

To some extent, we have accounted for differences in the exchange rate and external policy environment by distinguishing between four eras with different international monetary regimes. Nevertheless, there are interesting cross-sectional variations in the exchange rate regime in each era. For example, Italy went off the Gold Standard in 1894 and did not return to a gold parity until 1928. To the extent that the cross-sectional variation in exchange rate regimes has changed over time, this may be a factor that could explain changes in the average business cycle synchronization from era to era. To estimate the effects of exchange rate regimes, we have constructed a dummy variable, which, again, is based on the annual exchange rate regime indicators for each country prepared by Bordo et al (2001). The indicator, which we will refer to as Z, measures the number of years (as a fraction of the total number of years covered by each era) during which the exchange rate between two countries was pegged (disregarding re-alignments in the case of fixed but adjustable rates).

With this indicator, we estimated the simple equation:

$$f(corr_{ij,\tau}) = \alpha + \gamma \overline{Z}_{ij,\tau} + \delta \overline{CC}_{ij,\tau} + \varepsilon_{ij,\tau} \qquad (4.6)$$

for each era.[27] We would expect the γ coefficient to be positive for the reasons noted above. Despite earlier problems, we kept the capital control indicator CC in the equation, since it is important to control for these effects. Subsequently, we also added the exchange regime indicator to the trade equation but only for the two post-World War II eras for the reason explained above.

The results are shown in Table 9. The γ coefficients generally have the right sign and are significant at the 10 or 5 percent levels, except for the Gold Standard era. The latter may be explained by the fact that only four out of the 16 countries had not pegged their currencies to gold (at least during some time) in this era. For the interwar period, the γ coefficient has the wrong sign, which may reflect the fact that the countries hanging on to the Gold Standard after the United States and other countries went off resorted to exchange controls and increased trade restrictions to maintain their peg. The δ coefficients are generally of the right sign, except for the Bretton Woods period.

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[27] As explained above, the capital control indicator CC is redundant for the Gold Standard era.

The exchange rate regime effect is not robust to small variations in the specification.[28] For example, adding the trade intensity variable reduces the size of the exchange rate regime effect considerably. Similarly, the significance also changes once that additional variable is included. Finally, we would like to note one interesting aspect for the modern floating rate period. If a European country dummy is included, the exchange rate regime indicator becomes insignificant, which can be interpreted as evidence that the exchange rate pegging within Europe (all bilateral fixed exchange rate regimes in the modern floating rate period are confined to that continent for our panel of countries) has been really important or that the exchange rate indicator picks up the effects of European integration more generally.

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[28] Frankel and Rose (1998), who in one specification added a dummy variable for country pairs with fixed exchange rates, argued that the exchange rate regime choice is also endogenous and used the same gravity variables as instruments to correct for this endogeneity. We remain somewhat skeptical about the relevance of these instruments and note the technical problems in using a 1-0 variable as an endogenous variable in a linear regression. We have, however, used instrumental variable estimators with the same instruments to check the robustness of our results. For the simple equation (0.6), the results are robust. In fact, the size of the exchange rate effect increases somewhat, and the standard errors of the γ coefficients decrease. For the interwar period, the sign of the γ coefficient changes. If the trade intensity variable is included, the results do not remain robust. In particular, as Frankel and Rose, we find that the γ coefficients are negative and insignificant.

V. PATTERNS OF GLOBALIZATION IN RECENT HISTORY

Among economic historians, the consensus points to two phases of rapidly rising globalization in recent economic history (e.g., Bordo, Eichengreen, and Irwin, 1999, or the papers in Bordo, Taylor, and Williamson, 2003). The first phase occurred between 1860 and 1914. The second one, which is still on-going, started in the early 1970s. Between these two phases, the earlier increases in economic and financial integration were reversed, partly reflecting the wars and the ensuing economic difficulties and partly reflecting a backlash against integration in commodity and labor markets by groups adversely affected by these forces initiating tariff protection and restrictions on migration (O'Rourke and Williamson 1998), and partly reflecting the Great Depression. At the end of World War II, the level of integration was generally lower than in 1860. There is a broad agreement that the level of integration reached at the on-set of World War I was only reached again in the 1980s.

For illustrative purposes, Obstfeld and Taylor (2003) characterized the time path of global capital market integration, when described by a single composite measure, as having broadly followed a U-shaped pattern (Figure 2). More specific measures also point to the same broad pattern. For example, foreign assets and liabilities as a percent of GDP or net capital flows, as measured by external current account balances, followed a U-shaped pattern. Other measures providing a similar picture of integration patterns over time include real interest differentials, covered interest parity measures, and equity and bond return differentials.

The U-shaped pattern is more general and also extends to integration in merchandise trade (Findlay and O'Rourke, 2003, or Esteordeval, Frantz, and Taylor, 2002) and labor markets (Bordo, Eichengreen, and Irwin, 1999). In commodity markets, Findlay and O'Rourke (op. cit.) showed that international trade increased distinctly faster than either population or real output during the two phases of globalization. Accordingly, trade shares, that is, trade as a percent of GDP, increased substantially. Conversely, during the interwar period, trade and output rose and fell at roughly similar rates. At the same time, there was also a strong commodity price convergence during the first globalization phase, as price differences in major commodities across countries decreased substantially. Interestingly, Findlay and O'Rourke argue that in the second globalization phase, pressures for price convergence have been more moderate.

VI. EXPLAINING DIFFERENCES IN THE TIME PATH OF GLOBALIZATION AND BUSINESS CYCLE SYNCHRONIZATION

As noted earlier, there is a puzzling disconnect between the time path of globalization and the time path of business cycle synchronization. The latter has followed a secular increase over time, almost linear if there were not the interwar period hump. In contrast, the level of globalization, that is, the degree of cross-border integration in markets for goods, capital, and labor, has followed a U-shaped pattern during the same period. What do our results tell us about this disconnect? Specifically, we will use the results to explore three hypotheses explaining aspects of the disconnect.

First, we explore what we call *the global shock hypothesis*. According to this hypothesis, the above-trend degree of business cycle synchronization during the interwar period—when integration was lower than during the classical gold standard— is the result of an exceptionally large adverse global shock. Given that the interwar period was short, with the data only covering the period 1925-38 for all countries, the great depression affect the sample statistics more than it would have if the era had lasted longer. We found some evidence in favor of this hypothesis. According to both the center country and the trade linkages models of international business cycle dynamics, the variance of the global shock increased relative to the idiosyncratic shocks during the interwar period. Everything else being equal, this explains increased cross-border output co-movements. However, the variance decomposition of the same models suggests that increased transmission accounted for most of the increased role of external factors in the determination of output variances. This suggests that despite the on-going disintegration during the interwar period, the forces of transmission can still be large. Clearly, the transmission of large shocks in the largest country, the U.S., was, unsurprisingly, a key factor in the worldwide Great Depression.

A second hypothesis is what we call the idiosyncratic shock hypothesis, which postulates that changes in economic structure—especially the declining share of the agricultural sector in total output and the systematic use of stabilization policies—resulted in a decline in the size of idiosyncratic shocks relative to global shocks. Everything else being equal, this can contribute to explaining increased cross-border output co-movements. We found evidence in favor of this hypothesis for the transition from the classical gold standard to the other eras

during which relative shock variances decreased. For other transitions, the changes in relative variances were, on average, very minor.

A third hypothesis postulates that while seemingly similar, the depth and breadth of cross-border integration before World War I was different from that in the current era. Bordo, Eichengreen, and Irwin (1999) argued that global capital market integration today is broader and deeper, including a larger set of financial instruments, a larger number of more diverse financial intermediaries operating on a global scale, and a wider range of sectors using international markets for financial purposes. In addition, there has been a shift from debt to equity finance at the global level. Similarly, in international trade, the depth or cross-border integration has increased (e.g., Krugman, 1995). The share of trade in tradables production has increased with intra-industry trade and the shift toward trade in manufacturing products, and producers have been able to break production geographically at a much larger scale. While we intend to investigate this hypothesis more systematically, we have been constrained by a lack of data. In particular, we believe that with deeper and broader increased economic and financial interdependence through trade and financial linkages, the scope for global shocks has clearly increased. In addition, with highly integrated capital markets, it may be in practice quite difficult to distinguish between true global shocks and what appear to be global shocks but are really rapidly transmitted shocks in the center countries.

VII. CONCLUSION

In this paper, we have documented that there <u>is</u> a secular trend towards increased synchronization for much of the twentieth century and that it occurs across diverse exchange rate regimes. This finding is of interest because it is in marked contrast to much of the recent literature, which has focused primarily on the evidence for the past 20 or 30 years and which has produced mixed results.

We then considered a number of possible explanations for the observed pattern of increased synchronization. We first ascertained the role of shocks demarcated into country-specific (idiosyncratic) and global (common). Our key finding here is that global (common) shocks are the dominant influence across all regimes, although we note, however, that with reduced form models of the kind used in this paper, it remains difficult to distinguish between "true" global shocks and major shocks in the center country(ies).

 This finding, coupled with earlier evidence produced by ourselves and others, that business cycles since World War II have become less volatile, less frequent and asymmetric with a tendency towards recoveries exceeding downturns in duration, has some interesting implications. We suggest that what may be occurring is that the weakening in national business cycles since World War II coupled with the diminution of idiosyncratic shocks reflect the forces discussed by Zarnowitz (1992) and others, such as changes in the composition of output, the advent of automatic stabilizers, improvements in discretionary

monetary and fiscal policy, the implementation of effective lenders of last resort and a

financial safety net, and the proliferation of private risk sharing instruments.[29]

At the same time, the increasing importance of global shocks and, to some extent,

transmission we posit reflects the forces of globalization, especially the integration of goods

and services through international trade (Findlay and O'Rourke 2003) and the integration of

financial markets (Obstfeld and Taylor 2003). We present evidence showing a modest role

for increasing bilateral trade in explaining synchronization, with stronger evidence for

regional integration in Europe and North America. Evidence for the role of financial

integration proxied by the removal of capital controls is inconclusive. Given that these

proxies contain limited information about the actual extent of cross-border financial

integration, we plan to use other measures in future research.

Finally, we began considering explicitly the role of the policy regime in explaining the

pattern of synchronization. We find little evidence for the prediction that adhering to fixed

exchange rates fosters synchronization except in the period since 1973, and these results

appear driven largely by the process of European Monetary Union.

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[29] We would like to emphasize that the decrease in idiosyncratic shock volatility does not necessarily imply that it is the volatility of the underlying "deep structural" shocks (e.g., a widespread drought) that we are measuring. Given that we derive the shocks on the basis of GDP series alone, it means that the effects of these deep shocks on output have diminished. There is, however, some evidence that shocks that are widely perceived as being exogenous may have an endogenous component. Barsky and Kilian (2001), for example, argue that the sharp increase in real oil prices in the 1970s was in part a reaction to the earlier massive expansion of the world money supply.

Have we succeeded in explaining the disconnect between the time path of globalization and the time path of business cycle synchronization? While recognizing the limitations of attaching structural explanations based on evidence from a reduced form model, we think that shifts in the relative importance of idiosyncratic and global shocks together with the notion of the Great Depression being an outlier are important parts of the explanation. We have so far been less successful in shedding light on the apparent lack of transmission during the classical Gold Standard period despite rapidly increasing globalization, we believe that explanations based on differences in the depth and breadth of globalization between the two phases of globalization identified in section III are likely to be promising. We intend to pursue further research along this line. .

What are the policy lessons to be gleaned from these findings? One lesson from the dampening of national cycles and the diminution in idiosyncratic shocks is that to the extent that they reflect sound domestic macro policy and the creation of an environment conducive to the development of both private and public risk sharing institutions and instruments that these policies should continue to be fostered.

A second lesson is that globalization seems to be associated with the creation of a global business cycle. Whether policies should be developed at the global level to counter it is another matter. Regarding monetary policy, experience suggest that the key to success has been that policy makers get their policy objectives right. In addition, for monetary policy to be effective, it is also critical that policy makers get the shocks right. In this sense, policy coordination is likely to be very important. As Obstfeld and Rogoff (2002) have argued, there

is probably little gain from policy coordination beyond this, provided that central banks have the right policy objectives. The generally negative experience with policy coordination in the 1970s and 1980s supports this view (Frankel, 1990).

A third lesson, to paraphrase Forrest Gump, is that shocks happen! We live in a stochastic world and shocks generate business cycles via diffuse propagation mechanisms. Moreover productivity shocks occur in a non linear fashion, asset markets overshoot and people are at times over optimistic and other times over pessimistic. In this reality the best strategy is to encourage the development of private market mechanisms to insure against cyclical risks, in the case of incomplete markets related to market failures to provide public insurance, and to maintain stable and predictable macro policies.

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Figure 1. Bilateral Output Correlation Coefficients By Percentile
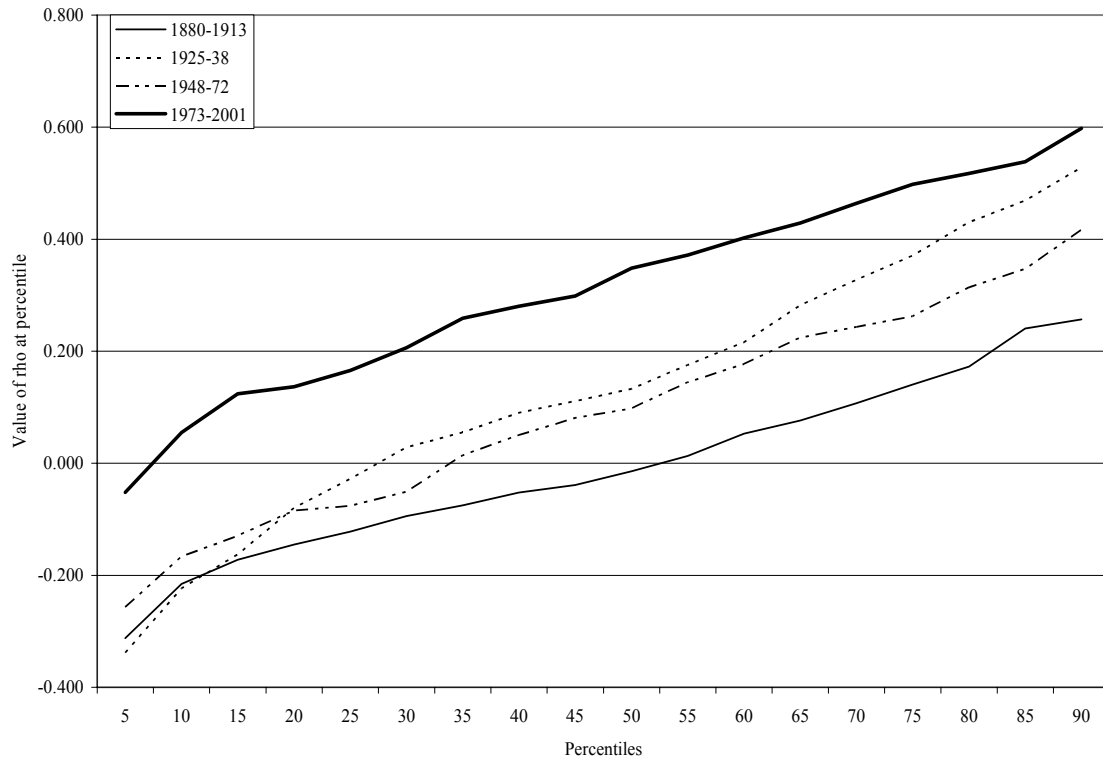
Figure 2. A Stylized View of Global Capital Market Integration
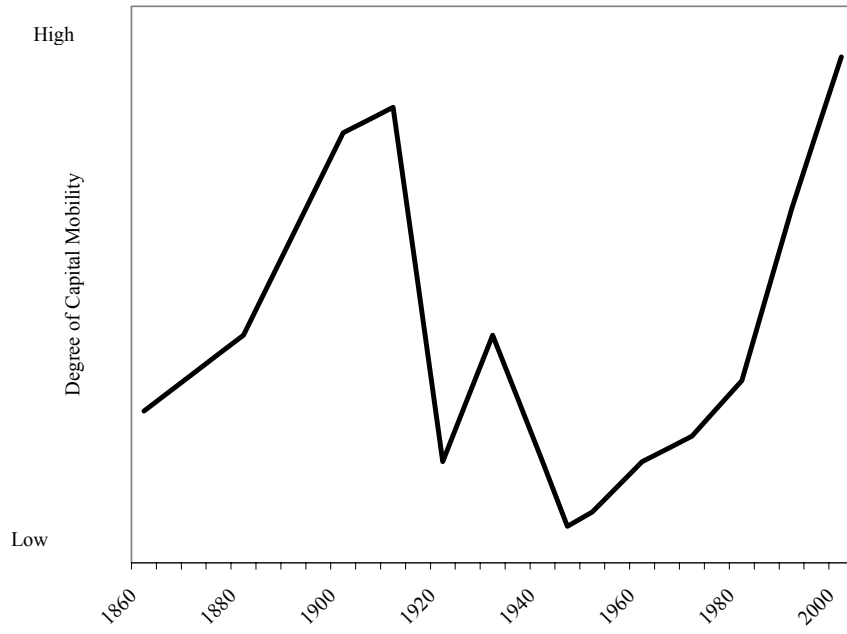
Source: Adapted from Obstfeld and Taylor (2003)

Figure 3. Global Shocks, 1887-2001

(Solid Lines: trade model; dotted lines: simple factor model; and bars: significant time dummies)

Gold Standard

Interwar Period

Bretton Woods

Modern Managed Floating Period
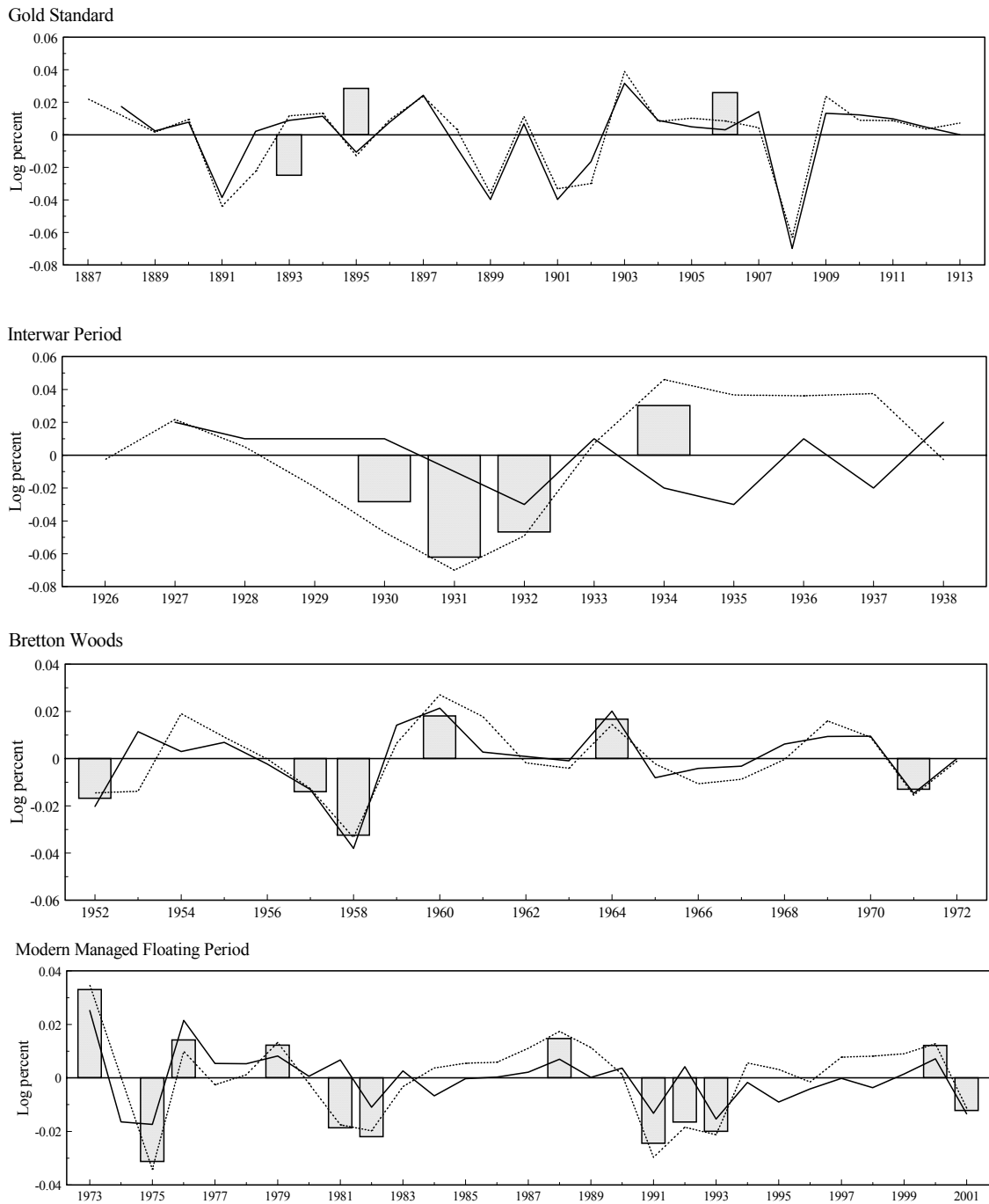
Source: Authors' calculcations (see text for details).

Table 1. Average Output Correlations By Region and Era
(Based on first differences of log output)

Region (Number of obs.)	1880-1913	1920-38	1948-72	1973-2001
All countries (120)	0.01	0.15	0.12	0.33
Core countries (15)[a]	0.02	0.13	0.15	0.45
Peripheral countries (45)[a]	0.02	0.21	0.11	0.27
One country core, one periphery (60)	0.01	0.12	0.11	0.33
Continental European countries only (55)	0.01	0.08	0.10	0.49
One country Continental European (55)	0.01	0.17	0.13	0.26
Core European countries only (6)[b]	0.07	0.10	0.25	0.59
One country Core European (48)[b]	-0.02	0.09	0.14	0.36
One Country North America 28)	0.00	0.28	0.04	0.38
One country Japan (15)	-0.08	0.05	0.16	0.17
Anglo-Saxon Countries (6)[c]	0.12	0.29	0.17	0.63
Memorandum items:				
USA-Canada	0.55	0.86	0.61	0.77
Scandinavian countries only (6)	0.11	0.48	0.17	0.31
One country Scandinavian (48)	0.00	0.17	0.11	0.25

[a] Core countries comprise France, Germany, the United Kingdom, the United States, the Netherlands, and Switzerland during 1880-1913 and 1920-39 and the G-7 countries afterwards.

[b] Core European countries comprise France, Germany, the Netherlands, and Switzerland during 1880-1913 and 1920-39 and the EEC countries in the panel (France, Germany, Italy, the Netherlands) afterwards.

[c] Comprises Australia, Canada, the United Kingdom, and the United States.

Table 2. Jennrich Test for Equality of Average Correlation Coefficients
(Marginal significance levels)

Region (Number of obs.)	1880-1913 vs. 1926-38	1926-38 1952-72	1952-72 1973-2001	1880-1913 1952-72	1880-1913 1973-2001	1926-38 1973-2001
All countries (120)	0.01	0.85	0.06	0.02	0.00	0.03
Core countries (15)						
old	0.30	0.40	0.25	0.02	0.00	0.08
new	0.04	0.85	0.02	0.05	0.00	0.09
Continental European countries (28)	0.26	0.19	0.01	0.01	0.00	0.00
Core European countries (6)						
old	0.92	0.12	0.50	0.06	0.00	0.05
new	0.98	0.15	0.01	0.07	0.00	0.00
Anglo-Saxon Countries (6)	0.49	0.76	0.01	0.68	0.00	0.04
Memorandum items:						
USA-Canada	0.18	0.48	0.66	0.34	0.14	0.70
Scandinavian countries only (6)	0.11	0.25	0.57	0.60	0.25	0.51

Note: See Table 1 for definition of regions and country groups and Jennrich (1970) on the computation of the variance-covariance matrix of the correlation coefficients.

Table 3. Jennrich Test for Covariance and Correlation Matrix Equality
(Marginal significance levels)

Region (Number of obs.)	1880-1913 vs. 1926-38	1926-38 1952-72	1952-72 1973-2001	1880-1913 1952-72	1880-1913 1973-2001	1926-38 1973-2001
		Covariance matrices				
All countries (120)	0.86	0.01	0.01	0.28	0.00	0.00
Core countries (15)						
old	0.04	0.00	0.01	0.00	0.00	0.00
new	0.07	0.00	0.01	0.00	0.00	0.00
Continental European countries (28)	0.06	0.01	0.00	0.00	0.00	0.00
Core European countries (6)						
old	0.00	0.00	0.02	0.00	0.00	0.00
new	0.01	0.00	0.02	0.00	0.00	0.00
Anglo-Saxon Countries (6)	0.44	0.00	0.00	0.00	0.00	0.00
Memorandum items:						
USA-Canada	0.36	0.00	0.96	0.00	0.00	0.00
Scandinavian countries only (6)	0.08	0.01	0.53	0.05	0.00	0.02
		Correlation matrices				
All countries (120)	0.86	0.01	0.01	0.28	0.00	0.00
Core countries (15)						
old	0.04	0.00	0.01	0.00	0.00	0.00
new	0.07	0.00	0.01	0.00	0.00	0.00
Continental European countries (28)	0.06	0.01	0.00	0.00	0.00	0.00
Core European countries (6)						
old	0.00	0.00	0.02	0.00	0.00	0.00
new	0.01	0.00	0.02	0.00	0.00	0.00
Anglo-Saxon Countries (6)	0.44	0.00	0.00	0.00	0.00	0.00
Memorandum items:						
USA-Canada	0.36	0.00	0.96	0.00	0.00	0.00
Scandinavian countries only (6)	0.08	0.01	0.53	0.05	0.00	0.02

Note: See Table 1 for definition of regions and country groups and Jennrich (1970) on the computation of the variance-covariance matrix of the correlation coefficients.

Table 4. Output and Shock Standard Deviations By Era
(Based on first differences of log output)

Aggregates[1]	1880-1913	1920-38	1948-72	1973-2001
Average output growth	0.047	0.057	0.027	0.023
Center Model				
Global factor	0.023	0.028	0.014	0.012
Idiosyncratic shocks	0.037	0.040	0.020	0.016
Trade Model				
Global factor	0.022	0.017	0.013	0.010
Idiosyncratic shocks	0.034	0.024	0.018	0.014

[1] Unweighted averages across countries.

Table 5. Variance Decomposition of Output Growth
(Fractions of forecast error variance; based on first differences of log output; simple averages over countries)

Countries (Number of obs.)	1887-1913			1926-38			1952-72			1973-2001		
	Global Factor	Trans-mission	Idio-syncratic Shocks	Global Factor	Trans-mission	Idio-syncratic Shocks	Global Factor	Trans-mission	Idio-syncratic Shocks	Global Factor	Trans-mission	Idio-syncratic Shocks
Center model												
All countries (16)												
1-step ahead	0.22	0.0	0.78	0.24	0.0	0.76	0.28	0.0	0.72	0.36	0.0	0.64
2-step ahead	0.22	0.03	0.75	0.21	0.12	0.67	0.27	0.04	0.69	0.33	0.10	0.57
3-step ahead	0.21	0.05	0.74	0.21	0.14	0.65	0.27	0.04	0.69	0.33	0.10	0.57
4-step ahead	0.21	0.05	0.74	0.21	0.15	0.64	0.27	0.04	0.69	0.33	0.10	0.57
New core countries (7)												
1-step ahead	0.19	0.0	0.81	0.31	0.0	0.69	0.24	0.0	0.76	0.45	0.0	0.55
2-step ahead	0.19	0.02	0.79	0.29	0.07	0.64	0.23	0.02	0.75	0.42	0.08	0.51
3-step ahead	0.19	0.03	0.78	0.29	0.09	0.62	0.23	0.02	0.75	0.42	0.08	0.51
4-step ahead	0.19	0.03	0.78	0.28	0.10	0.62	0.23	0.02	0.75	0.42	0.08	0.51
Trade model												
All countries (16)												
1-step ahead	0.23	0.0	0.77	0.24	0.0	0.76	0.32	0.0	0.68	0.31	0.0	0.69
2-step ahead	0.20	0.13	0.67	0.17	0.40	0.43	0.28	0.16	0.56	0.25	0.24	0.51
3-step ahead	0.19	0.17	0.64	0.16	0.47	0.37	0.27	0.19	0.54	0.24	0.29	0.47
4-step ahead	0.19	0.18	0.63	0.15	0.52	0.33	0.27	0.20	0.53	0.23	0.32	0.45
New core countries (7)												
1-step ahead	0.27	0.0	0.73	0.22	0.0	0.78	0.27	0.0	0.73	0.46	0.0	0.54
2-step ahead	0.25	0.12	0.63	0.18	0.26	0.56	0.24	0.11	0.65	0.38	0.17	0.45
3-step ahead	0.24	0.16	0.60	0.17	0.33	0.50	0.24	0.12	0.64	0.37	0.19	0.44
4-step ahead	0.24	0.16	0.60	0.15	0.40	0.45	0.24	0.13	0.63	0.37	0.19	0.44

Note: See Table 1 for regions and country groupings.

Table 6. Bilateral Trade-Output Regressions[a]

(Standard errors in parenthesis; coefficients significant at the 5% level are bolded)

	Limited Sample (59 Observations)					Full Sample (120 Observations)		
	1880-1913	1920-38	1950-72	1973-2001	Panel	1950-72	1973-2001	Panel
β[b]	0.120	0.134	0.087	**0.210**	**0.138**	**0.123**	**0.205**	**0.168**
	(0.071)	(0.154)	(0.099)	(0.088)	(0.057)	(0.056)	(0.053)	(0.042)
R-square [c]	-0.013	-0.017	0.022	0.071	0.028	0.066	0.16	0.123
R-square first-stage regressions	0.179	0.187	0.398	0.460	0.271	0.431	0.551	0.484
F-test[d]					0.000			0.000
Number of observations	59	59	59	59	236	120	120	240

[a] Constant is not reported. Standard errors are heteroskedasticity-consistent.

[b] Instrumental variable estimate.

[c] From an OLS regression of trade equation 4.3.

[d] Marginal significance level from an F-test of the restriction that the panel coefficients are not significantly different from those obtained for each period.

Table 7. Actual and Predicted Change in Output Correlations[a]

(All variables in percent or percentage points)

	Limited Sample (59 Observations)				Full Sample	
	1880-1913	1920-38	1950-72	1973-2001	1950-72	1973-2001
Average trade intensity	0.757	0.491	0.698	0.956	0.460	0.612
Change in average trade intensity		-0.266	0.207	0.258		0.152
Average actual change in output correlations		13.409	2.332	22.815		21.615
Predicted change						
Based on β of previous era		-1.962	1.695	0.992		1.271
Based on β of current era		-2.198	1.110	2.348		2.093
Based on β of panel		-2.265	1.744	1.560		1.724

[a] All data including correlation coefficients are reported in percent (percentage points). The β coefficients are those shown in Table 15.

Table 8. Asset Market Integration, Bilateral Trade and Output Correlations[a]

(Bolded signifies significance at the 5% level and bolded-italicized significance at the 10 percent level)

	1920-38	1950-72	1973-2001	1950-72	1973-2001
δ	-0.083	0.066	-0.089	0.034	-0.039
	(0.165)	(0.108)	(0.110)	(0.100)	(0.104)
β[b]				*0.119*	**0.191**
				(0.059)	(0.047)
R-square [c]	0.002	0.003	0.007	0.059	0.155
R-square first-stage regressions				0.324	0.447
Number of observations	120	120	120	120	120

[a] Constant is not reported. Standard errors in parenthesis are heteroskedasticity-consistent.

[b] Instrumental variable estimate.

[c] From an OLS regression of equations 4.4 and 4.5.

Table 9. Exchange Rate Regime, Asset Market Integration, Bilateral Trade and Output Correlations[a]

(Bolded signifies significance at the 5% level and bolded-italicized significance at the 10 percent level)

	1880-1913	1920-38	1950-72	1973-2001	1950-72	1973-2001
γ	0.122	***-0.417***	**0.603**	**0.624**	***0.42***	0.332
	(0.085)	(0.233)	(0.187)	(0.176)	(0.231)	(0.205)
δ		-0.132	0.001	***-0.183***	-0.009	-0.1
		(0.167)	(0.114)	(0.103)	(0.105)	(0.114)
β[b]					***0.109***	**0.15**
					(0.063)	(0.059)
R-square [c]	0.006	0.012	0.064	0.092	0.09	0.172
R-square first-stage regressions					0.363	0.364
Number of observations		120	120	120	120	120

[a] Constant is not reported. Standard errors in parenthesis are heteroskedasticity-consistent.

[b] Instrumental variable estimate.

[c] From an OLS regression of equation 4.6.

Business Cycle Affiliations and their determinants:

where do we stand?[*]

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Abstract: The paper derives deviation cycles for OECD countries and examines their synchronization through cross-correlations and the application of clustering techniques. Dividing the whole period (1970-2003) into three sub-samples allows an assessment of changes in business cycle affiliation over time. The UK, for example, appears to move from a US association to a European one. The paper also reports the results of applying a non-parametric procedure to test for business cycle association. This test suggests that the European grouping is not a very distinctive one. A discussion of what factors might make for a business cycle association is followed by an example using panel data estimation techniques.

Keywords: Cycles; clustering; panel data estimation

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Business Cycle Affiliations and their determinants: where do we stand?[*]

Introduction

This paper is about cyclical affiliations. This term is meant to refer to the alleged tendency for some countries' business cycles to cluster together with others. One affiliation of arresting interest is that of the European business cycle". There are several papers which discern the existence of such a cycle (e.g., Artis et al. 2004; Kaufmann 2003) and there is an obvious reason to be interested in such a notion in the context of European Monetary Union. The European Business Cycle forms the subject for analysis of the CEPR's Business Cycle Dating Committee and its coherence is a positive indicator for monetary union.

Some years ago, with my colleague Wenda Zhang, I wrote a paper (Artis and Zhang, 1997) in which we employed the OECD's trade cycle data base and a presentational device first presented by Baxter and Stockman (1986) to indicate the possible arrival of an European cycle, associated with the Exchange Rate Mechanism (ERM) of the European Monetary System.

In our paper we took industrial production deviation cycles estimated by the OECD on the basis of a modified NBER algorithm and showed the cross plots of the cross correlations of those cyclical deviates vis-a-vis the US and vis-a-vis Germany for a sequence of two periods. The first of these was typified as a "pre-ERM period" (1961:1 to 1979:3), the second as the ERM period (1979:4 to 1993:12). The interest in the picture was that where the observations for the first period suggested a broad "world cycle", in the second a number of countries could be seen as having moved strongly towards a stronger affiliation with Germany, with Germany and the US themselves much less closely related to each other. The UK was a prominent exception, with the European countries that had moved towards a stronger identification with Germany being those that were associated with the ERM either as full or as "apprentice" (shadowing) members. It might have been thought that this movement would be strengthened in subsequent years. Figures 1-3 show that this has not been so. These figures plot the cross correlations of the cyclical deviates of industrial production, again as identified by the (now revised) OECD trade cycle data base, now for three periods. The first of these is labelled the pre-ERM period (Figure 1), and the world cycle phenomenon seems again a loosely reasonable characterization. In the second period (Figure 2), as in the original paper, a number of European countries have moved above the line – leaving the UK and the Northern "periphery" below the line. In the third period however (Figure 3) matters look very different. The US and Germany are now themselves highly correlated and it makes no sense to speak of a distinctive German affiliation.

It seems that we have to revisit the notion of a European business cycle, or at least refine what we mean by it. Though important, this is incidental to the main theme of the paper to which there are two parts which can be seen as a development of Artis (2003 and 2004). The first part is devoted to looking for evidence of business cycle affiliations employing a multi-country quarterly GDP data set and focussing on the notion of the deviation cycle. To begin with, clustering techniques – both hierarchical and fuzzy clustering methods - are used in an attempt to "let the data speak" as to whether there are, or not, well-defined business cycle affiliations. Then a non-parametric technique recently employed by Bovi (2003) is used to assist in the same endeavour. The second part of the paper is then devoted to an attempt to motivate a panel data explanation of business cycle affiliation; for an empirical example the results established in Artis (2003, 2004) are reassembled.

The measurement of cycles

In order to comment on business cycle affiliation it is necessary in the first instance to have a good idea of how to measure the cycle. Economists have made considerable progress in this respect in recent decades.

Business "cycles", as such, are not entirely well-termed, since the term "cycle" suggests a degree of regularity which is not found in practice. Nevertheless the idea is that it is possible to observe broad-based movements in the economy which have an oscillatory character, even if those oscillations do not occur with a strictly uniform periodicity and vary in the total length of time taken to work themselves out. Useful ground-clearing was undertaken by Pagan and others (see Harding and Pagan, 2001) in resurrecting and clarifying the notions of the classical and the growth (or deviation) business cycles. The non-parametric algorithms which have resulted have permitted further refinements: for example, Artis, Marcellino and Proietti (2002) base their algorithms on a Markov-Chain approach which provides a flexible, yet rigorous framework for the identification of cycles. In these excursions, a dating algorithm identifies (strictly alternating), peaks and troughs and imposes minimum phase (expansion and recession) lengths and a minimum length for the cycle as a whole. They provide the opportunity to add amplitude restrictions in addition.

A cycle-dating algorithm may be applied to an original or to a transformed series describing the economy. The most common transformation (in addition to seasonal adjustment) is that of de-trending; here too, economists have made significant progress in recent decades. The suggestion by

Baxter and King (1995) to make use of frequency domain analysis has proved highly important in this regard. Their argument is that since we "know" what the typical periodicity of a business cycle is, we should use this information to clean the data of periodicities which are greater or lower than those that span the cycle. These other periodicities should be thought of as mere blips and bumps (or seasonal cycles) in the case of the higher frequency oscillations or, or in the case of the lower frequencies, as longer run movements perhaps of the type associated with the adoption of a new technology or process. At any rate, this approach has given the profession new confidence in detrending and without completely laying all doubts to rest (see for example, Harvey and Trimbur (2003)) has substantially qualified the reservations that an earlier generation had entertained in reaction to a series of critical papers (e.g., Harvey and Jaeger (1993)) which had shown that existing methods could lead to the spurious identification of cycles which were not present and to other damaging mistakes. For purposes of the current paper, the point is that recent work seems to have allowed the efficient identification of cycles, from which one may proceed at least to *measure* affiliations between countries with some confidence.

Affiliation

Commonly, measures of affiliation between business cycles are in fact measures of synchronization and a standard means of assessing this is to measure the cross-correlation between the detrended series. A standard product would therefore be a cross-correlogram showing the cross-corrrelations of the countries analysed in the sample under consideration The cross-correlogram shows all the pair-wise cross-correlation coefficients that can be estimated and lends itself to an application of clustering. However there are still other characteristics of business cycles that could be taken into account, although as soon as more than one characteristic is involved a weighting problem arises. Clustering methods can be applied to multi-dimensional problems of this type (see Artis (2003) for an example) although they cannot avoid the need for weighting (albeit this might be of a studiedly "neutral" type). Another drawback of the traditional cross-correlogram approach is that it is confined to pair-wise comparisons, when often enough a comparison of *groups* is what is required. Shortly below we take advantage of recent papers by Bovi (2003, 2004) to show how this weakness may be redressed. Table 1 indicates the data set we are using, the countries involved and the time periods for which the (quarterly) GDP series are available.

Cyclical histories

Using these data we proceed to derive deviation cycles using the H-P band-pass method described in Artis, Marcellino and Proietti (2003). That is, the data are filtered twice through low-pass Hodrick-

Prescott band pass filters to isolate those frequencies with periodicities that correspond to the business cycle (i.e. 1.25 to 8 years in this case). The cross-correlogram that results from computing the pair-wise cross-correlations between all the countries in the sample is shown as Table 2. Then, the dating algorithm described in Artis, Marcellino and Proietti (2002) is applied to identify cycles in the detrended output series. This yields up to ten complete deviation cycles, depending on the country and the data available. Table 3 then contains a summary of business cycle "stylized facts"[1] whilst Figure 4a-d gives a graphic summary of the series showing, the detrended cycles and the peaks and troughs located by the dating algorithm.. The number of cycles identified varies across countries partly because data availability varies across countries, as reported in Table 1. The dating algorithm of the deviation cycle, roughly described above, also insists that a peak (trough) can never be identified at a point which is below (above) trend, even if it should be associated with an inflexion in the rate of change of output relative to trend (this distinguishes the deviation from the growth rate cycle – see Artis *et al* (2003), Appendix B). By construction the deviation cycle should be a stationary series, so that it is not surprising that average expansion and recession probabilities (which are the fractions of time that the economy is in one or other phase) should be roughly equal at around 0.5. The average duration, in quarters, of the two phases is also roughly equal at 7 –10 quarters, but with a number of outliers – Denmark for example has recession durations that average over 11 quarters and Portugal of 17 quarters whilst extra-long expansion durations are registered for Switzerland and the Netherlands. Average amplitudes, measured as the proportionate increase from trough to peak for expansions and from peak to trough for recessions are not at all symmetrical. Expansion amplitudes are generally much higher than recession amplitudes, though the latter are not often negative. "Steepness" is measured as the quotient of amplitude and duration: the relative symmetry of durations and the asymmetry of amplitudes thus reflects in very unequal measures of steepness in expansion as opposed to recessions – the former being very much higher than the latter in all countries.

. The cross-correlogram already yields evidence of business cycle affiliations in that it is obvious that there are relatively high cross-correlations between particular pairs of countries but clearer pictures emerge from the application of cluster analysis to these data. To begin with, hierarchical ("hard") clustering methods are applied, first to the cross-correlation data for the whole period, then to a two-dimensional measure in which cross-correlation data are combined with pair-wise "distance" measures. The latter are measured as the RMS of the distances between any two countries' detrended

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[1] See Harding and Pagan (2001) for a discussion of the stylized facts of the business cycle.

data. A clustering algorithm starts with a distance matrix showing some measure of dissimilarity between the countries located along the axes; this will be a square matrix with a diagonal of zeroes and symmetric above and below the diagonal. The algorithm then first forms a cluster from the two observations which are closest together; replacing these by another value, the algorithm then proceeds to find the next smallest difference between any two observations (counting the just completed first cluster as one of these) and so on. The initial values entering the distance matrix are in the form of dissimilarities between (in our case) countries in respect of some characteristic (possibly several characteristics) – so the algorithm will cluster together countries which are similar in respect of that characteristic (or set of characteristics). In the case illustrated in Figure 5, the characteristic, x_{ki}, is a measure of the cyclical synchronicity of the country in question *with all the other countries.* Clustering algorithms are long on alternative measures of distance (the measurement of the difference between observations) and on alternative ways to compute the "replacement" value of a cluster after one has been identified. They are short on measures of significance or adequacy (though some appear in the context of "fuzzy" clustering). In the construction of Figure 5, we selected the distance measure

as the Euclidian distance (i.e. as $\sqrt{\sum_{k=1}^{22}(x_{ki}-x_{kj})^2}$) and the cluster replacement measure as that of

average linkage. Experimentation with alternative distance measures did not in general reveal any significant difference.   The clustering algorithm reveals, it seems, a cycle cluster based on the US, Canada, Great Britain and Australia and a "European cycle" itself based on two clusters, one involving Germany, Austria, Switzerland and the Netherlands, and the other involving France, Spain, Belgium, Italy, Portugal and Ireland; but at the level at which these two are joined, there is also Japan. And then a number of other European countries – especially, the UK (denoted GBR), Sweden, Norway and Denmark are not so close. This is, if nothing else, a warning not to invest the notion of a "European" cycle as such with too much that is idiosyncratically European.

Contemporaneous cross correlation is not the only dimension in which we might want to measure similarity of business cycle experience. Some investigators (e.g., Massman and Mitchell (2002), Barrell and Weale (2003)) have suggested as an alternative the distance between cycles, as might be measured for example by the RMS of the squared differences over a period of time.   The suggestion responds to the idea that whilst (for example) synchronization may not change over time, the amplitude of cycles may do so and thus the difference between cycles, for a given degree of synchronization, may increase or diminish. Figure 6 repeats the clustering exercise of Figure 5 for a combination of the cross correlation and distance measures, defined as $\sqrt{(1-r_{ij})^2 + dist_{ij}^2}$, where r_{ij} is

the cross correlation and *dist*$_{ij}$ is the RMS distance between the cycles of countries *i* and *j*. . As in the case of the simple cross-correlation this measure is computed over all *j* for each *i*. The picture provided by the clustering over this composite measure is however very little different from the picture provided when using the cross correlation measure alone. Figures 7, 8 and 9, however, use the composite measure, but in three sub-samples: 1970-79, 1980-92 and 1992-2003. These should give a picture of how cyclical affiliations may have varied over time. Figure 7 shows that in the first period there is no very well-defined European cluster though most European countries cluster away from the US and Canada; the UK (GBR) is shown as closer to some European countries than to the US in this period. In the second period a clearer European grouping emerges, albeit with some prominent exceptions and with the inclusion of Japan in the Euro group. In the third, most recent period, two European groupings can be seen to emerge – with Sweden, Finland and Norway being exceptional and Canada moving to the Euro-group. The groupings seem less clear and less constant through time than might have been expected.

We may now turn to the fuzzy clustering analysis. In fuzzy clustering less information is wasted than in hard clustering: countries may be typified as having "membership coefficients", belonging (say) as x % to one group or cluster and as to (1-x)% the other (in the case that only two clusters are distinguished). More generally the analysis furnishes the possibility of discerning whether there is a "distinct" set of groupings or not. To approach this question we use one of the "goodness of fit" measures associated with fuzzy clustering, which is the measure of average silhouette width. Maximising the average value of the cluster silhouette width is a way to determine the "optimal" number of clusters.

The average silhouette measure is bounded by +/-1, with positive values indicating that the clusters are relatively well defined. In Table 4, which covers the whole period this criterion produces two clusters, of which one (cluster 1) is a good deal larger than the other. It involves most of the advanced industrial countries including both (most of) Europe and North America. Two clusters also are detected in the first subperiod (Table 5), more or less even in numbers of members. The UK is clustered with Canada and the USA; most other European countries are clustered separately. The second subperiod (Table 6) finds a larger number (5) of clusters to be optimal, suggesting a higher degree of idiosyncrasy in the period. Table 7, finally, finds 3 clusters to be optimal for the most recent decade, one of these being a fairly prominent "European" grouping, including the UK.

The McNemar test

In this section of the paper we deploy a non-parametric technique to ask questions about the coherence of particular groupings. The procedure involves the "McNemar test" and has been given prominence recently by Bovi (2003, 2004). Many of the papers in the stream of literature associated with the identification of the European business cycle look outwards, over a period of time, from inside a European group to identify a closer union (or otherwise). The important point made by Bovi is that this should be complemented by an analysis of whether any such development has proceeded faster or slower than similar processes elsewhere. Bovi himself uses long run data on classical cycles to look at this question, focussing in particular on the position of the UK. Our data sample in this section of the paper is much shorter and we shall not ask exactly the same questions of the data.

How does Bovi's procedure work? Bovi himself recognizes a contribution by McNemar, made as long ago as 1947 (McNemar 1947). The key here is a contingency table approach, as in Table 8. This can be motivated by reference to the Venn diagrams in Figure 10. These diagrams show how we can divide our observations into four cells (as in Table 8). When all the countries in Group 1 are in the same phase ("in synch."), based on applying the dating algorithm discussed above to the deviation cycle series there will be some periods in which the countries making up Group 2 are also "in synch" – the intersection of these two sets gives the cell labelled N_{11}, the number of observations in which both groups are "in synch". Similarly, whilst the members of Group 1 are "out of synch" with each other, there will be some periods when the members of Group 2 are also out of synch: the intersection of these two sets corresponds to the cell labelled N_{22} in Table 8.

The cells labelled N_{12} and N_{21} correspond to the remaining intersections identified in Figure 10.

The information in the contingency table can be used to test whether Group 1 is more (or less) coherent than Group 2, in the sense that it is (or not) more often "in synch" than Group 2. McNemar offers the difference $(N_{12}-N_{21})^2/(N_{12}+N_{21})$ as a suitable test statistic for which a Chi^2 distribution is suggested (provided that numbers are large enough). Bovi points out that a continuity correction (due to Sheskin (2002)) may also be applied (the statistic becomes $(|N_{12} - N_{21}|-1)^2/(N_{12} + N_{21})$). In principle, the test can also be applied, *mutatis mutandis* to the information in the leading diagonal cells, which we have done here as a check on the main results. Whilst the attraction of the approach is that it can be applied to groups of countries, it can also be applied to individual countries or to groups that are represented by a single aggregate number – it is just that in this latter case the country in question (or the aggregate) can only ever be typified as being "in synch" with itself. If a single country or aggregate takes the place of group 1 (2) in the formula, then the cells N_{22} (N_{12}) and N_{21} (N_{22}) are null.

In the current application we recognize at first pass nine groups, two individual countries and one aggregate. The groups are: Core EMU (Germany, France and Italy); EMU (all current members of EMU except Greece, and Luxembourg for which data are not available); non-EMU (Denmark, UK, Sweden), EU 15 (all except Greece and Luxembourg); the G-7; the rest of the world (ROW) – all countries listed in Table 1 (i.e OECD) minus the groups already mentioned; the OECD (all countries in Table 1 minus the EU countries; "Anglo" – the USA, UK and Canada, EMUUK – the EMU plus the UK and NAMU, the US and UK. Two individual countries are shown – the US and Germany and one aggregate - that for the EU 15, denoted EU15*.

Table 9 gives a first set of results. For their interpretation, bear in mind that in terms of the formulae quoted above, the countries reported in the rows are group 1 whilst those reported in the column heads are group 2. This means that a positive and significant value of the test statistic reported would indicate that the group defined in the row is more coherent than that reported in the column, whilst a significant negative figure would have the opposite implication. Bearing in mind the critical values listed at the foot of the table, it is clear that rather little is significant that does not involve one of the individual countries or the EU15 aggregate. The main exception is that some of the figures in the OECD column border acceptable levels of significance. But significance here means that there is a difference in the coherence of the groups compared. On this basis there is little to support the view that there is a distinctive coherent European grouping – only the EU15-OECD pairing might suggest otherwise (the same can be said at a lower level of significance for Core EMU and non-EMU pairings with OECD here. Clearly, though, the pairings that involve an individual country or the EU15 in aggregate tell a different story – which seems to suggest that individual countries are more idiosyncratically different than any grouping: but recall that key entries for these entities are null.

An attraction of the Bovi –McNemar methodology is that it allows one to examine the movement of the measure of relative coherence over time. Unfortunately, our sample is rather too short to allow this, but for what it is worth we tried splitting the sample. In table 10 we concentrate exclusively upon the groups (dropping the individual countries and the EU15 aggregate), split the sample into two equal-sized sub-samples and introduce a continuity correction. Not too surprisingly, as the results show, the sub-samples are too small to support much reliable inference, and there is little that can even be tested, and of that little that is significant except for some of the comparisons involving the OECD. But these comparisons do not involve EMU or core-EMU.

The results we have obtained seem to show that whilst some business cycle groupings can be detected for periods of time, only a few of these are reasonably persistent through time. The presence of a persistent – or growing – "European" grouping seems particularly hard to detect, especially given the implicit acceptance of the contrary view. Among the possible explanations for this must be counted the following: changes in the relative frequency of global versus regional or national-idiosyncratic shocks; changes in the interrelationships between economies (to put it loosely, the growth of "globalization"), and the habit of examining the European cycle by starting with Europe and looking at its development, so to speak from the inside out. There is a clear risk here of failing to distinguish globalization from Europeanization. Something must be added also to account for differences in the results that may be obtained, on the one hand by working with industrial production data or by working with GDP data.[2]

How to explain affiliation?

The main purpose of this section is to set up a framework for thinking about the determinants of business cycle affiliation and to provide an empirical illustration.

We start from the following heuristic formula which pertains to two countries represented in a VAR framework:

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{1_{t-1}} \\ y_{2_{t-1}} \end{bmatrix} + \begin{bmatrix} g_1 \\ g_2 \end{bmatrix} \begin{bmatrix} G_0 t \end{bmatrix} + \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} H_1 t \\ H_2 t \end{bmatrix}$$

Here, outputs of the two countries 1 and 2 are shown as depending ultimately upon idiosyncratic and common shocks, the vectors H and G respectively. Initial inter-country spillovers are contained in the h_{ij} ($i \neq j$) parameters, whilst subsequent inter-country interaction is represented, along with the purely domestic elements of the propagation mechanism, in the matrix of a_{ij} adjustment parameters. Our task is to think about the factors that determine the parameters distinguished here.

Before we begin to discuss this, though, there is one important point of clarification to be made (this is a point which is very well discussed by Mathias Hoffman (2004) in his discussion of the paper by Bordo and Helbling (2004)). In discussing changes through time in the relative business cycle synchronization of countries, the relative frequency (and size) of the shocks H and G may be of key importance. For given values of the a_{ij}, h_{ij} and g_i parameters an increase in the relative frequency

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[2] A paper that is close to this one, both in its problem set and in its methodology is that by Camacho et al (2004), which works entirely with industrial production data.

(and/or size) of G-shocks as opposed to H-shocks will lead to an increase in synchronization. That is, nothing need be happening to the structural parameters for "globalization" to appear to be on the increase. The framework also supports some other interesting propositions. One that represents an interesting special case for our purposes is the idea that if all shocks are common shocks (and H is null), business cycle synchronization may still differ according to differences between the propagation mechanisms, represented in this case by the a_{ij} parameters. The g_i may be regarded as simply "calibration parameters" that mediate the impact of the common shock on the economy according to relevant structural characteristics.[3] (An example of a "g" parameter would be a "share of oil" value of some kind). This idea is present in the paper by Adão et al (1999), which discusses the (ir)relevance of differing monetary transmission mechanisms to the optimality of a single monetary policy when the Central Bank can only respond to common shocks.

Differences between propagation mechanisms. Centring ourselves for the moment on the propagation mechanisms, we can make a first pass at identifying factors which might be relevant by considering that what are normally thought of as the relevant features are the structural characteristics of the labour and product markets and those of the financial sector. A good deal of work has gone into identifying relevant features of the labour market in the context of the literature on unemployment (e.g.see Nickell (1997) and Nickell et al (2005)). Rather less work has been done on product markets and in practice it may be that those papers which have employed measures of the economic structure (as in "share manufacturing" etc – see Traistaru (2004) for example) are capturing the important points. On financial structure, the important book by Allen and Gale (2000) has shown how financial structures may be described with a particular emphasis on whether the system is dominated by intermediation through banks or through more broad-ranging market institutions. It is easy to suppose that this distinction would correspond to a distinction between the speed of transmission of a shock through the system; thus, the more "bank-based" systems of (say) Germany and Japan might conduce to a slower pass-through and more persistence of a shock than the floating-rate market-based systems of (say) the UK and US. Measuring these features is not so straightforward, as they are multi-dimensional and data points are often missing.

Spillover effects

Spillover effects from one country to another are comprehended by the structural parameters of the model. Traditional inter-country modelling gave pride of place to linkages through trade, as for

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[3] It has been remarked that "all shocks are idiosyncratic shocks" in the light of the fact that in general $g_1 \neq g_2$, but we prefer to take care of this issue by making explicit the *g* coefficients and allowing for their possible inequality. Our focus, just the

example in the IMF's Multi-Mod. Many more recent papers have followed the early lead of Frankel and Rose (1997, 1998) in demonstrating a link between business cycle synchronization and some measure of trade intensity: Gruben et al (2002) provide a recent study. Yet there is some confusion about the most appropriate measure to use. Keynesian-style analysis would view the trade linkage as a channel for the operation of the "trade multiplier"; yet other observers have chosen to emphasize that the *type* of trade – whether inter- or intra-trade is important in exposing the country in question to shocks of the same type that hit the partner (inter-trade) or not (intra-trade). This goes back to the debate initiated by Krugman (1993) when he pointed out that monetary union might promote more specialization in trade (more inter-trade, less intra-trade) and hence lead to less vulnerability to common shocks, and more to idiosyncratic ones. Both views on the relevance of trade are correct in themselves. A country that does a lot of trade with a particular partner exposes itself to the operation of the trade multiplier given a disturbance in the other country (see Kenen (2003)). At the same time, if that trade takes the form of the exchange of very different types of goods, the country is exposed to a different range of (technological and demand) shocks than its partner. A high level of intra-trade, on the other hand, conduces to a common vulnerability to shocks[4]. These distinctions can be taken further, for intra-trade itself can be divided into horizontal and vertical intra-trade – an intra trade in components or in qualities[5]. The latter type may open a country to asymmetric demand shocks where the former does not. The recent experience of the 2001 downturn and in particular its widespread nature has given rise to speculation about what other channels, in addition to trade, could be responsible. But this is a quest which is due to the idea that the shock was initiated in the US, a hypothesis which is explored in some detail in Artis, Galvao and Marcellino (2003). The results of their examination suggest that the shock must have had a greater common dimension than initially appreciated, perhaps due to a wealth effect associated with high European holdings of US Dotcom shares (see, e.g., Castren et al, 2003 for an instructive working out of such an idea).

Otherwise, some way of quantifying the financial channels for shock-spillover would be indicated since what stands out to most people as a factor that has been leading the integration of recent years is the increased mobility of capital: Imbs (2003) has achieved some success in this direction. Again, some financial variables that assist the transfer of a shock are identified in Artis, Galvao and Marcellino (2003) and others are explored in Andreou et al. (2000). However, Hoffmann (2003) has pointed out an important qualification to the expectation that more integrated world capital markets

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same is on the a_{ij} coefficients.

[4] Fidrmuc (2004) using the same database as we have used here and in Artis (2003) has successfully found a role for intra-trade as opposed to total trade

[5] See Fontagné and Freudenberg (1999)

will lead to faster spillovers and therewith a higher degree of business cycle integration round the world. This is the possibility that those same financial channels, by providing an avenue for insurance and risk-sharing, will lead to more specialisation in production and an increased vulnerability to idiosyncratic shocks – this is the possibility first raised by Kalemli-Ozcan et al (2001). Thus the net effect, and its timing, of increased financial integration on business cycle synchronization is ambiguous – and an empirical matter.

The example

We can return to the data we described above to illustrate an exercise in attempting to explain business cycle affiliation. In the exercise we describe the aim is to explain the cross-correlations shown in Table 2 by reference to the type of variables we have discussed.[6] The framework is a quasi-panel estimation framework – "quasi" because the cross-correlations to be explained are only those estimated vis-à-vis the US and Germany. The time dimension of the study is relatively weak: averages for just three sub-periods (1970-79; 1980-1992 and 1993-2001) are used. The results shown in Table 11 are broadly representative of those that can be obtained where various transformations of the variables are experimented with. The explanatory variables used here include trade, labour market structure, goods market structure, financial market structure and "share of oil", together with a currency union status dummy. Trade is represented by trade intensity, instrumented by a gravity equation in the manner made standard by the example of Frankel and Rose (1997, 1998). It can be seen that this variable is always highly significant, except in the cases where Canada and Austria are omitted from the sample (either jointly or individually). This might suggest that the trade variable is distorted by outlier values when those two countries are included and is a caution on the interpretation normally placed on the significant and positive effect of trade on synchronization that is normally imputed to this variable. The labour market variables, disappointingly, did not produce any significance; measurement problems might be blamed, since as discussed above the relevant measurement is not obvious. In this case, available data lend themselves to the use of the NAWRU but the estimates of this variable lean heavily on current unemployment, so that some endogeneity might be suspected (which would be an issue if the results were significant..).[7] Relative financial structure is estimated as the *difference* of the value for the given country from that of the US, Germany of the ratio of bank credit to stock market valuation. (In one of the trials reported the country value of the variable was used, but the rationale for the variable points to the relative value as the correct expression: the

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[6] In this paper, due to reasons beyond our control, it was not possible to use the latest data set in the estimation and instead we have fallen back on the data set used in Artis (2003, 2004).

[7] Meanwhile, Fidrmuc has achieved some success in using the index of employment protection legislation as the labour market indicator.

more different, the lower the cross-correlation, as indicated by the negative signs). Industrial structure (or its "relative" version) – measured by the ratio of manufacturing to GDP – did not yield any significant effects. Traistaru (2004), employing a richer set of variables measuring economic structure, came up with more promising effects.

Thus one of the most important "new" findings here is that differences between the structure of the financial sector in the different countries appear to play an important role. The sensitivity of trade to the inclusion of Canada or Austria in the sample is also noteworthy. The failure of labour market indicators to yield a significant effect is, on the other hand, quite disappointing. These results are interesting enough to prompt further research with an extended sample and some further experimentation with appropriate indicators.

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Figure 1: Business Cycle Cross Correlation (OECD trade cycle database), pre-ERM period 1961:1-1979:3
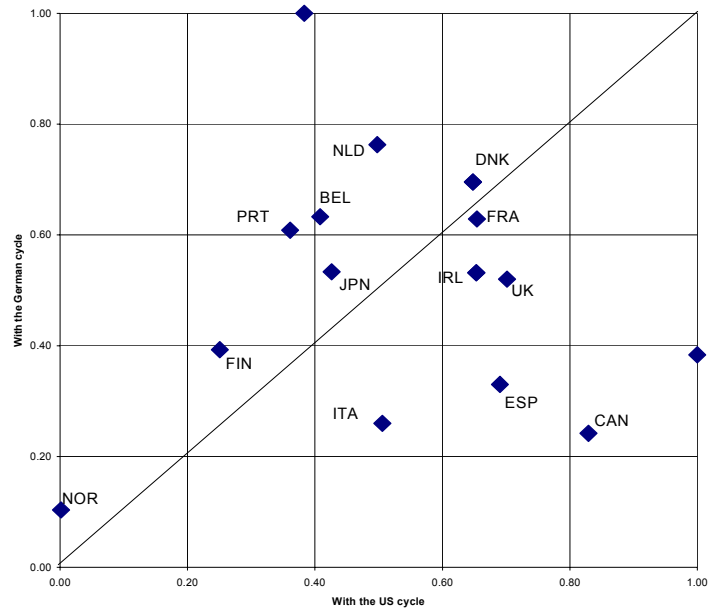
Figure 2: Business Cycle Cross Correlation (OECD trade cycle database), ERM period 1979:4-93:12
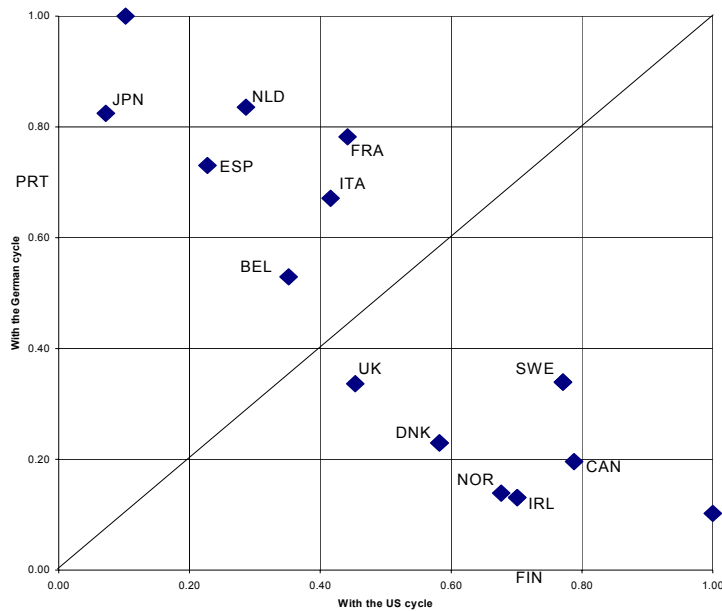
Figure 3: Business Cycle Cross Correlation (OECD trade cycle database), post-ERM period 1994:1-
2000:12
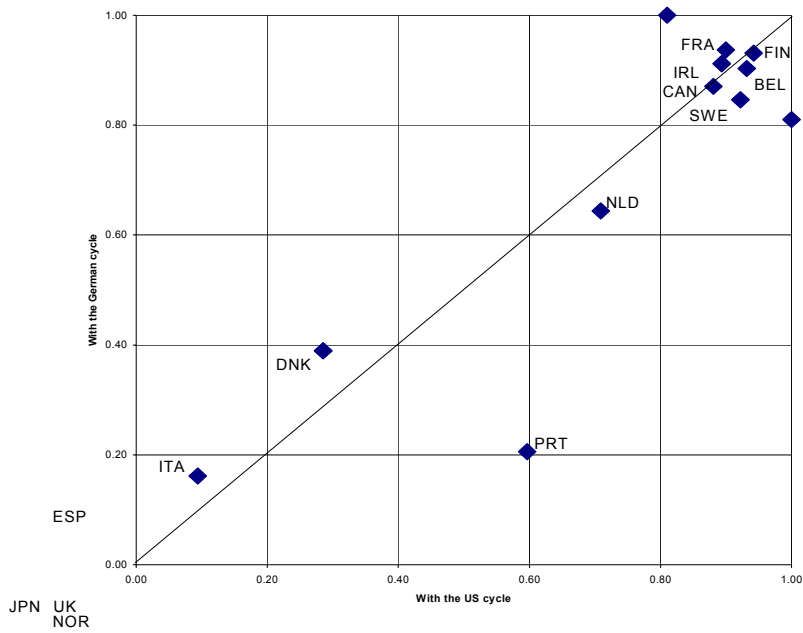
Figure 4a. Business cycles – deviation cycles, peaks and troughs
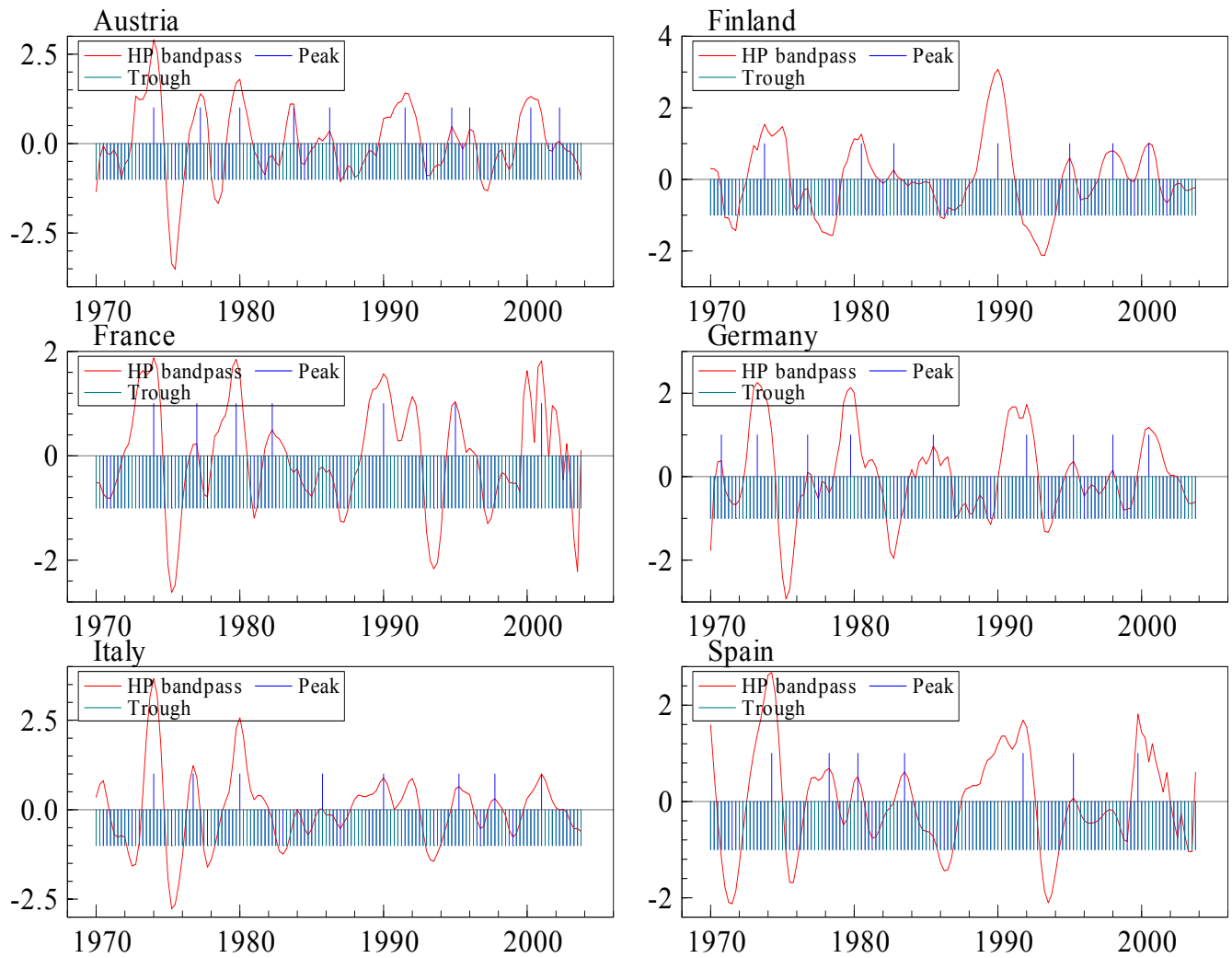
Figure 4b. Business cycles – deviation cycles, peaks and troughs
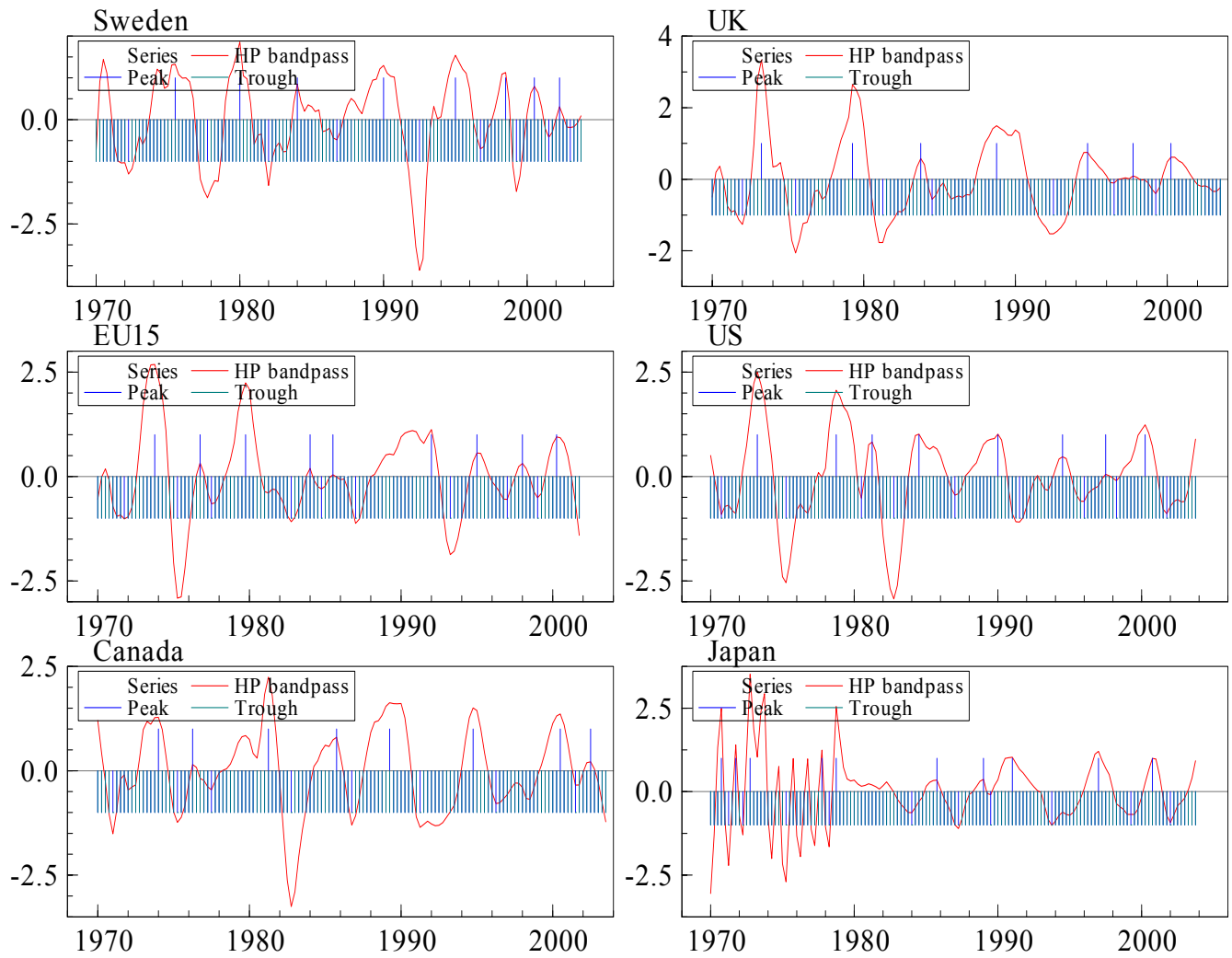
Figure 4c. Business cycles – deviation cycles, peaks and troughs
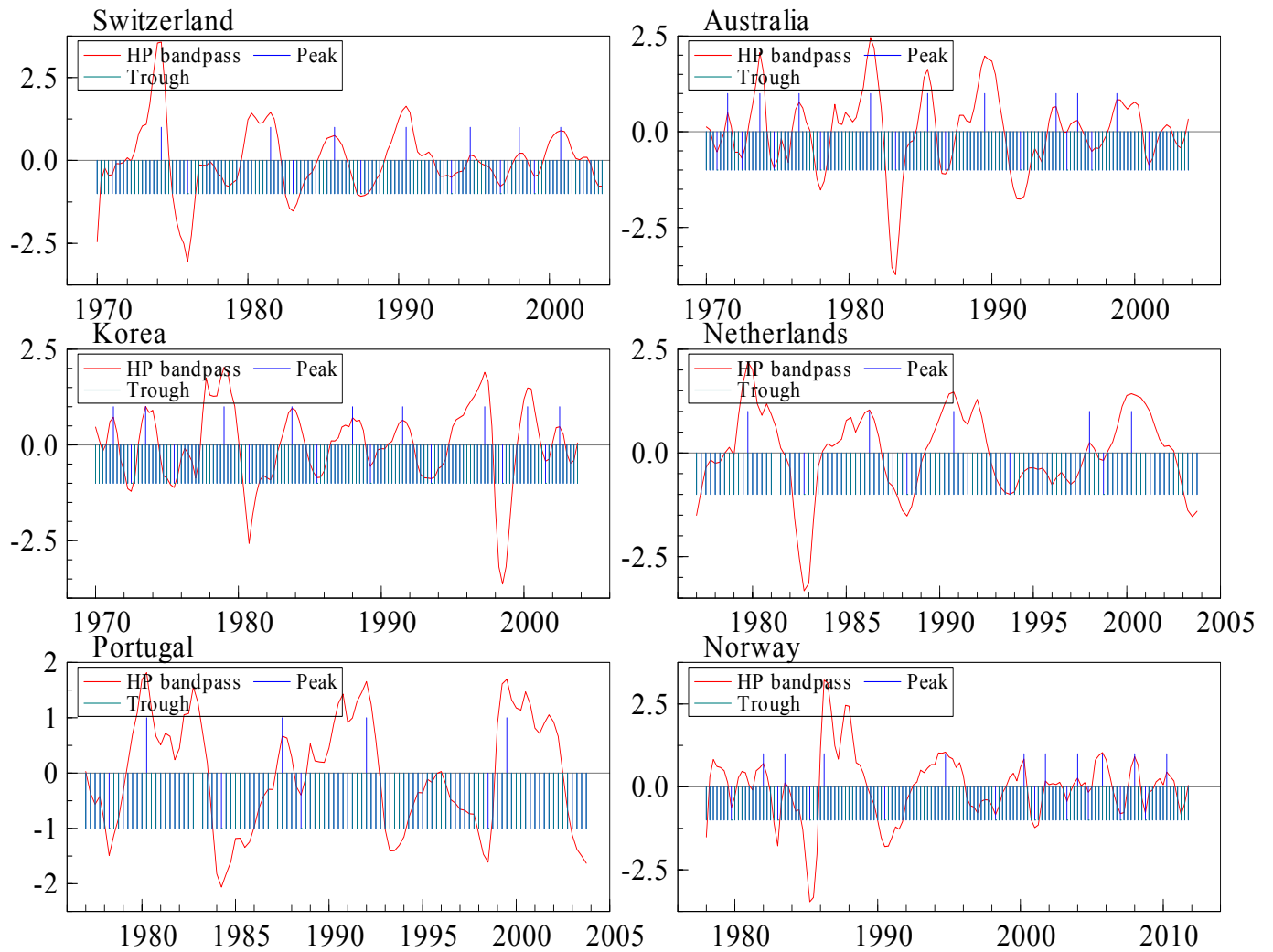
Figure 4d. Business cycles – deviation cycles, peaks and troughs
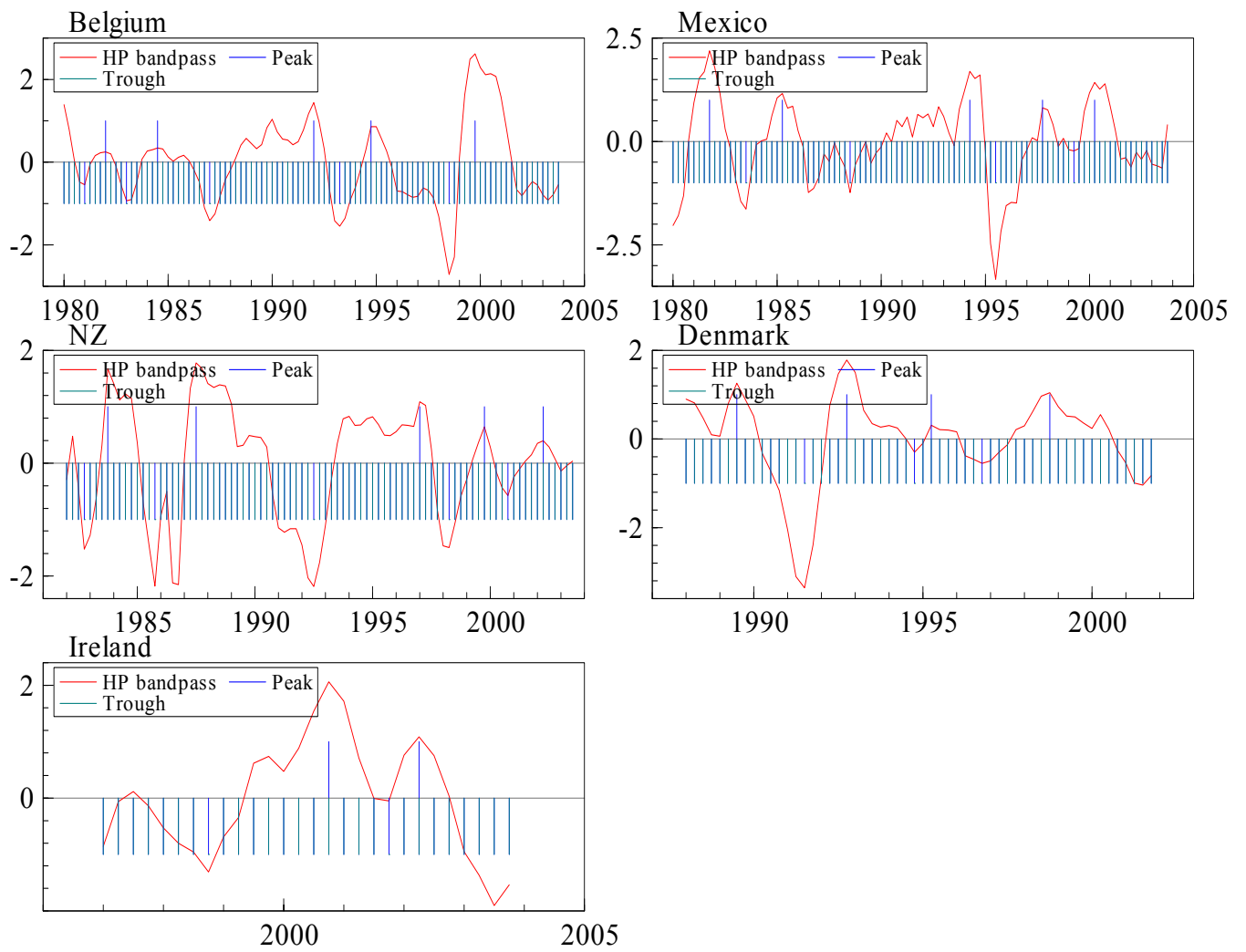
Figure 5: Hierarchical average-linkage cluster tree (dendrogram) using Euclidean dissimilarity measure based on cross-correlations of cyclical deviates, full sample 1970-2003
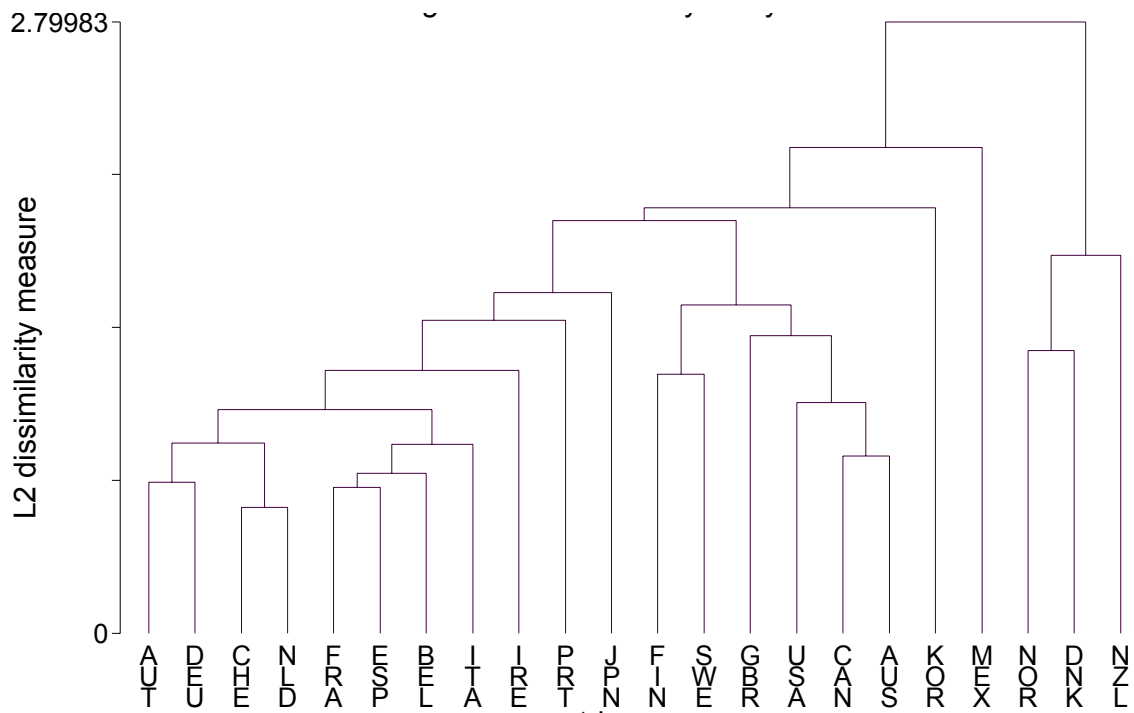
Figure 6: Hierarchical average-linkage cluster tree (dendrogram) using Euclidean dissimilarity measure based on the combined cross-correlation and distance measures, full sample 1970-2003
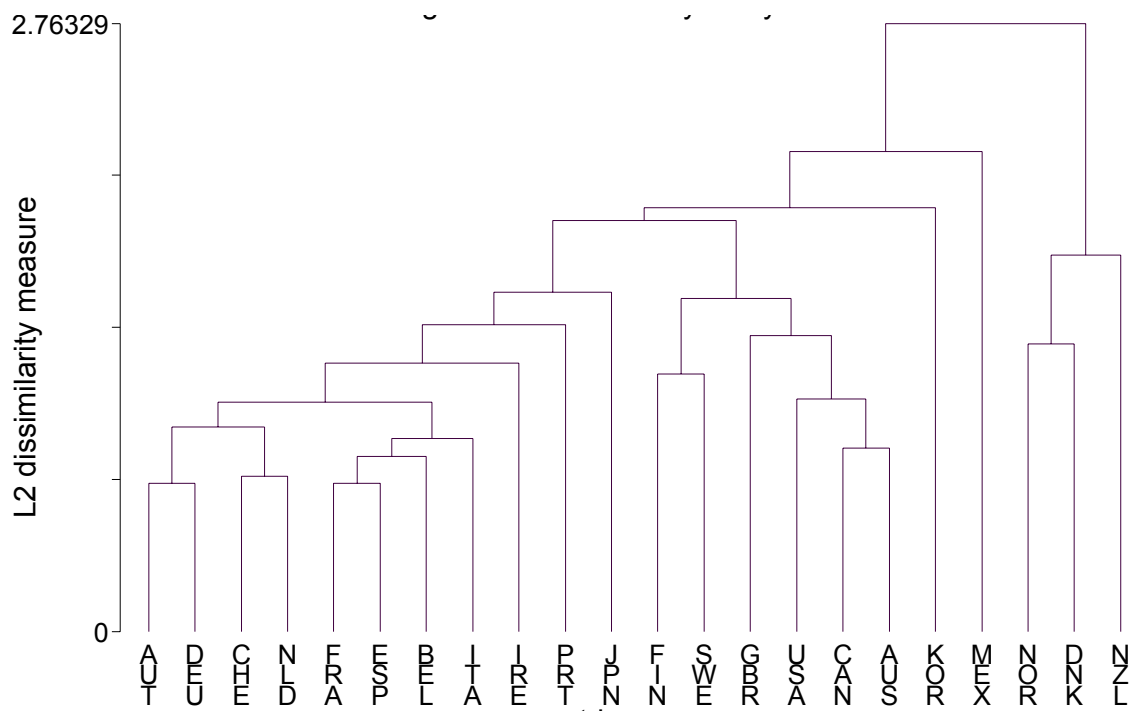
Figure 7: Hierarchical average-linkage cluster tree (dendrogram) using Euclidean dissimilarity measure based on the combined cross-correlation and distance measures, 1970-1979
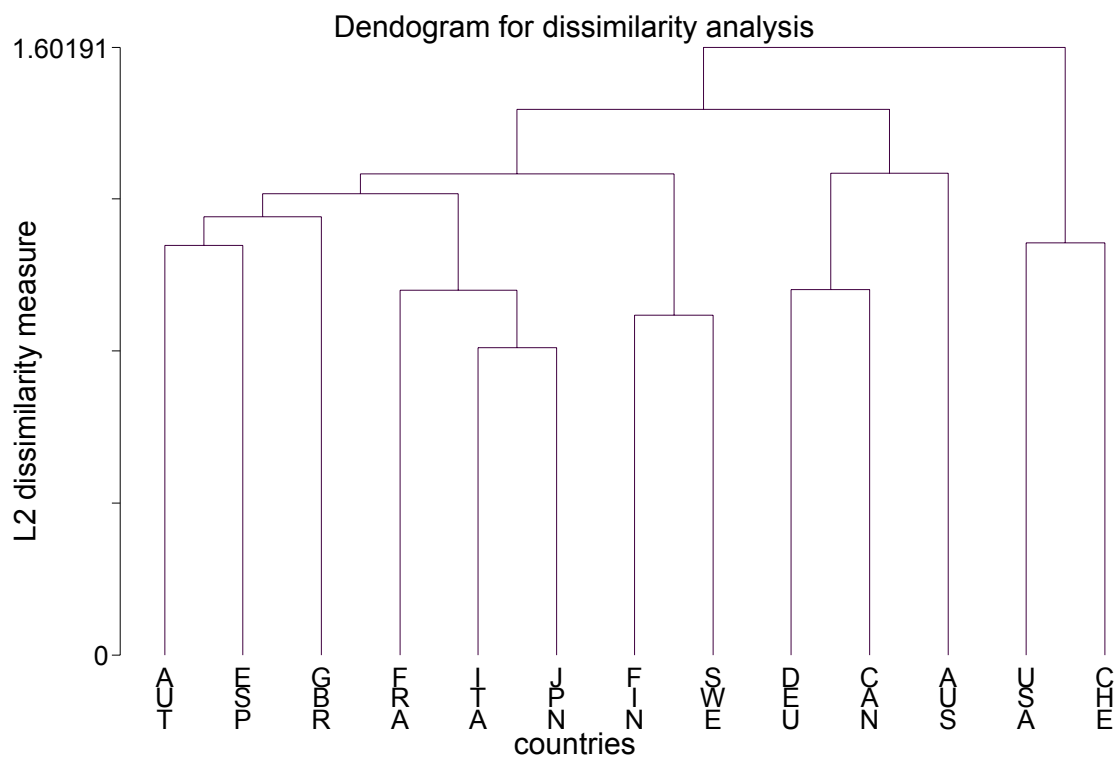
Figure 8: Hierarchical average-linkage cluster tree (dendrogram) using Euclidean dissimilarity measure based on the combined cross-correlation and distance measures, 1980-1992
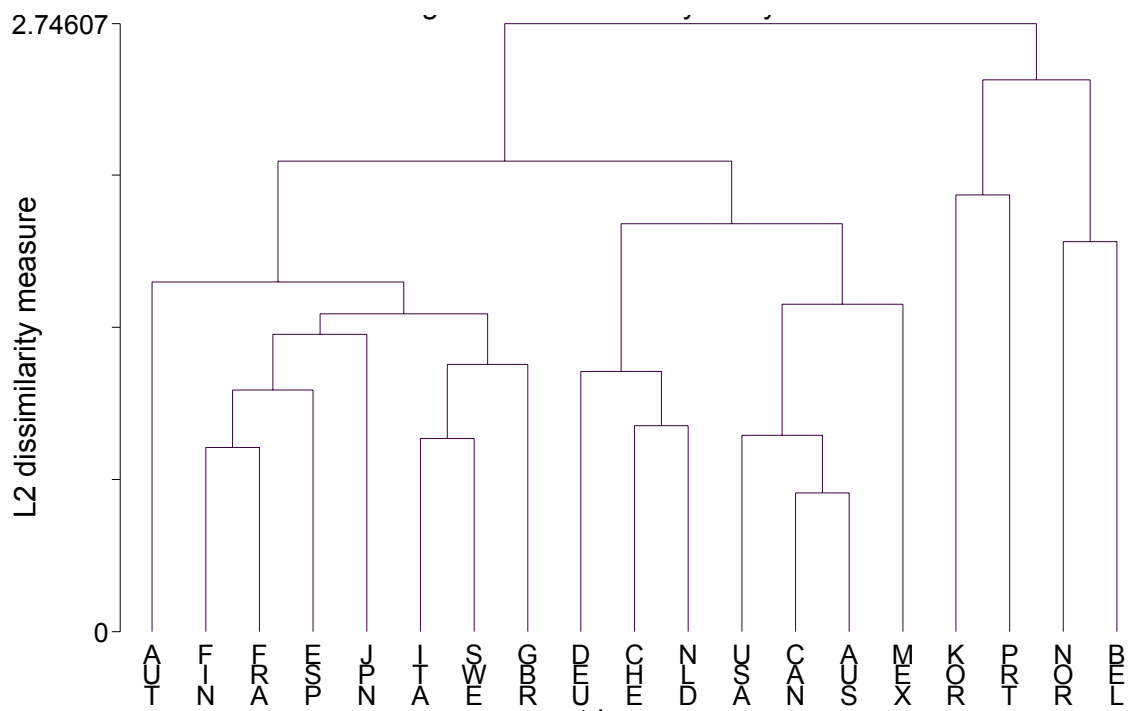
Figure 9: Hierarchical average-linkage cluster tree (dendrogram) using Euclidean dissimilarity measure based on the combined cross-correlation and distance measures, 1993-2003
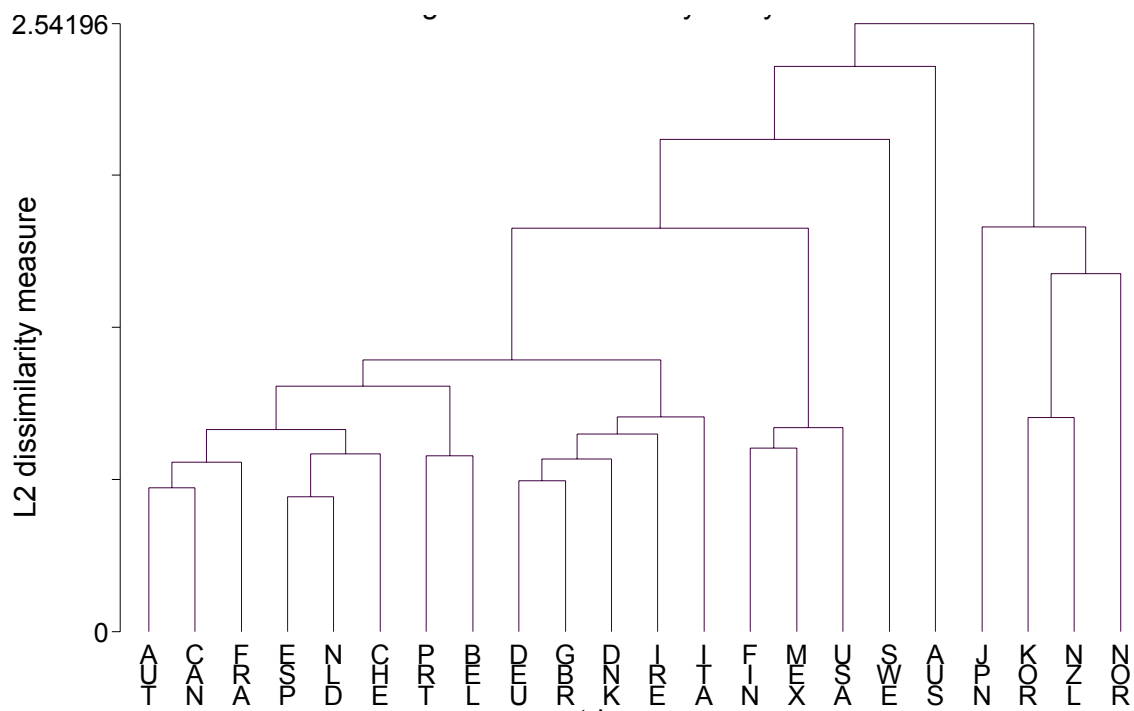
Figure 10
The McNemar Contingencies
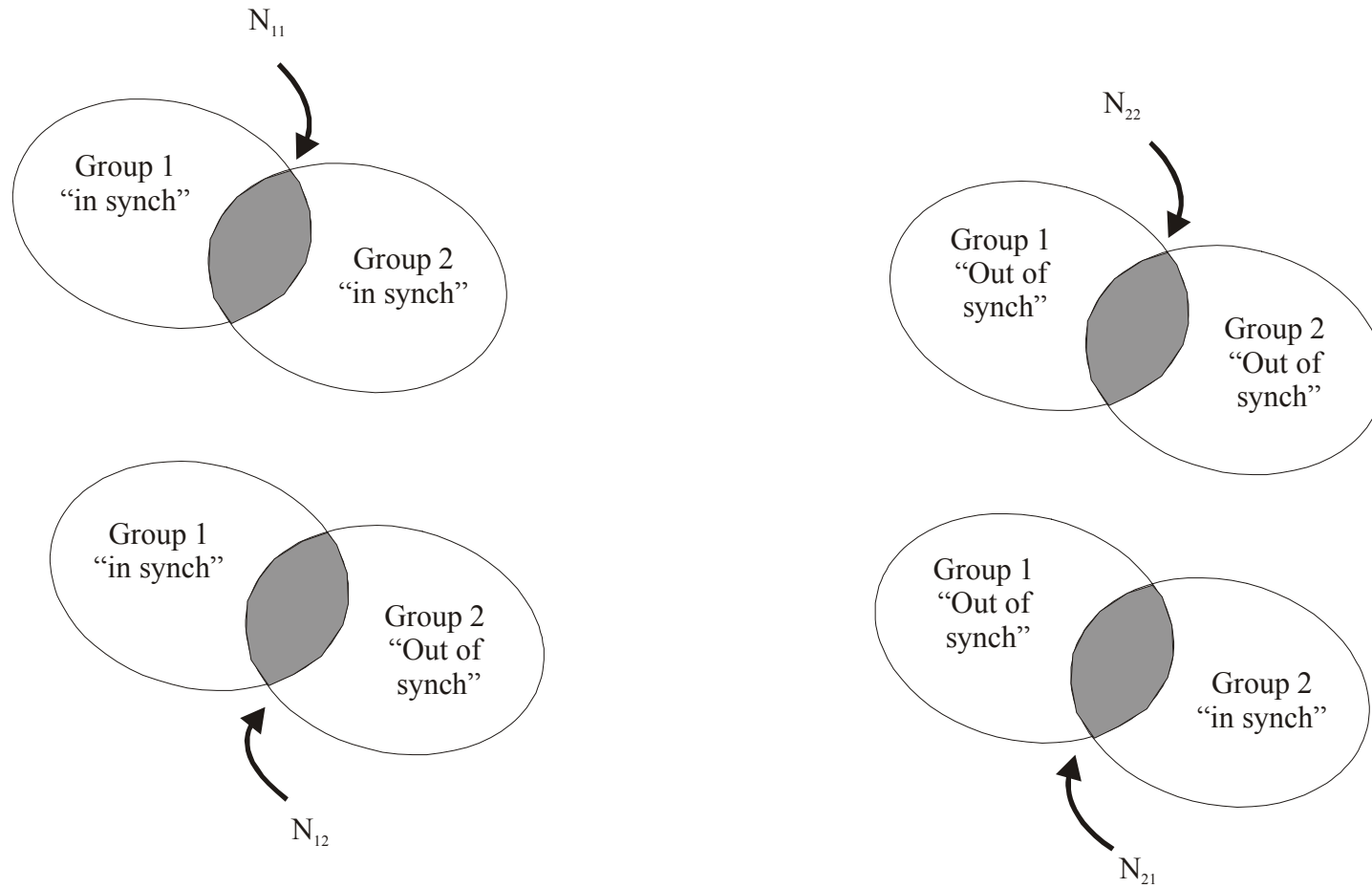
Table 1: Country sample in business cycle analysis

	Country	ISO-Code	Sample size
1	Austria	AUT	1970-2003
2	Finland	FIN	1970-2003
3	France	FRA	1970-2003
4	Germany	DEU	1970-2003
5	Italy	ITA	1970-2003
6	Spain	ESP	1970-2003
7	Sweden	SWE	1970-2003
8	United Kingdom	GBR	1970-2003
9	EU15		1970-2003
10	US	USA	1970-2003
11	Canada	CAN	1970-2003
12	Japan	JPN	1970-2003
13	Switzerland	CHE	1970-2003
14	Australia	AUS	1970-2003
15	Korea	KOR	1970-2003
16	Netherlands	NLD	1977-2003
17	Portugal	PRT	1977-2003
18	Norway	NOR	1978-2003
19	Belgium	BEL	1980-2003
20	Mexico	MEX	1980-2003
21	New Zealand	NZL	1982-2003
22	Denmark	DNK	1988-2003
23	Ireland	IRL	1997-2003

Table 2: Cross-correlations, full sample 1970-2003

	AUT	FIN	FRA	DEU	ITA	ESP	SWE	UK	EU15	USA	CAN	JPN	CHE	AUS	KOR	NLD	PRT	NOR	BEL	MEX	NZL	DNK	IRE
AUT	**AUT**																						
FIN	0.27	**FIN**																					
FRA	0.69	0.43	**FRA**																				
DEU	0.76	0.16	0.65	**DEU**																			
ITA	0.68	0.44	0.65	0.64	**ITA**																		
ESP	0.61	0.50	0.68	0.45	0.57	**ESP**																	
SWE	0.05	0.59	0.09	0.01	0.31	0.02	**SWE**																
UK	0.38	0.48	0.59	0.43	0.43	0.44	0.37	**UK**															
EU15	0.79	0.49	0.82	0.84	0.81	0.68	0.21	0.68	**EU15**														
USA	0.33	0.22	0.41	0.56	0.36	0.27	0.06	0.65	0.62	**USA**													
CAN	0.25	0.49	0.41	0.35	0.48	0.29	0.37	0.50	0.50	0.72	**CAN**												
JPN	0.28	0.18	0.33	0.50	0.21	0.20	-0.05	0.34	0.45	0.32	0.10	**JPN**											
CHE	0.69	0.45	0.56	0.67	0.67	0.48	0.11	0.28	0.68	0.44	0.49	0.32	**CHE**										
AUS	0.09	0.45	0.21	0.16	0.38	0.03	0.34	0.24	0.31	0.49	0.75	0.10	0.43	**AUS**									
KOR	0.21	-0.07	0.29	0.28	0.21	0.31	-0.02	0.43	0.32	0.24	0.08	0.19	-0.05	-0.21	**KOR**								
NLD	0.56	0.28	0.43	0.82	0.58	0.31	0.19	0.16	0.66	0.52	0.46	0.27	0.75	0.30	0.78	**NLD**							
PRT	0.54	0.32	0.56	0.33	0.49	0.59	-0.05	0.01	0.39	-0.27	0.02	0.17	0.31	-0.01	0.56	0.30	**PRT**						
NOR	-0.22	-0.25	-0.15	-0.25	-0.03	-0.27	-0.02	0.09	-0.19	0.06	0.10	-0.34	-0.28	0.01	-0.24	-0.19	-0.01	**NOR**					
BEL	0.66	0.32	0.64	0.52	0.52	0.66	0.02	0.25	0.65	0.35	0.44	0.26	0.44	0.19	0.71	0.52	0.55	-0.11	**BEL**				
MEX	-0.02	-0.03	-0.01	0.16	-0.14	-0.01	-0.23	-0.31	-0.04	0.24	0.21	0.17	0.32	0.30	0.10	0.20	-0.03	-0.20	0.21	**MEX**			
NZL	-0.26	0.23	-0.08	-0.34	0.03	0.02	0.46	0.59	-0.06	0.27	0.45	-0.23	-0.23	0.31	-0.19	-0.23	-0.15	0.25	0.08	-0.21	**NZL**		
DNK	-0.47	0.03	-0.21	-0.61	-0.30	-0.39	-0.07	0.15	-0.33	0.55	0.29	-0.47	-0.28	0.42	-0.43	-0.37	-0.38	0.53	-0.21	-0.06	0.11	**DNK**	
IRE	0.73	0.31	0.71	0.81	0.76	0.65	0.12	0.64	0.61	0.19	0.84	0.09	0.81	-0.15	0.90	0.82	0.75	-0.03	0.67	0.51	0.16	-0.37	**IRE**

Note: start dates of the samples may vary (see Table 1).

Table 3: Business cycles: stylized facts, 1970-2003*

	AUT	FIN	FRA	DEU	ITA	ESP	SWE	GBR	EU15	USA	CAN	JPN
Number of cycles P-P	10	7	7	9	8	8	8	7	9	8	8	10
Number of cycles T-T	9	8	7	8	8	8	9	7	9	9	8	10
Average Expansion Probability	0.64	0.40	0.49	0.50	0.49	0.49	0.52	0.50	0.55	0.59	0.66	0.43
Average Recession Probability	0.36	0.60	0.51	0.50	0.51	0.51	0.48	0.50	0.45	0.41	0.34	0.57
Average Duration of Expansions	8.70	7.86	9.43	7.56	8.25	9.57	8.88	9.71	7.78	10.00	11.13	5.90
Average Duration of Recessions	5.44	10.13	10.00	8.50	8.75	9.85	7.22	9.57	6.44	6.22	5.75	7.70
Average Amplitude of Expansions	0.0912	0.1096	0.0967	0.0724	0.0881	0.0970	0.0909	0.0990	0.0695	0.1156	0.1263	0.1558
Average Amplitude of Recessions	0.0038	0.0199	0.0238	0.0081	0.0084	0.0467	-0.0177	0.0120	0.0171	0.0124	0.0030	-0.0450
Steepness of expansions	0.0104	0.0139	0.0103	0.0096	0.0107	0.0101	0.0102	0.0102	0.0089	0.0116	0.0114	0.0264
Steepness of recessions	0.0007	0.0020	0.0024	0.0009	0.0010	0.0047	-0.0002	0.0012	0.0027	0.0021	0.0005	-0.0058

	CHE	AUS	KOR	NLD	PRT	NOR	BEL	MEX	NZL	DNK	IRL
Number of cycles P-P	7	9	9	5	4	10	5	5	5	4	2
Number of cycles T-T	6	10	8	4	4	10	5	4	5	3	2
Average Expansion Probability	0.61	0.59	0.60	0.56	0.37	0.46	0.44	0.55	0.49	0.39	0.46
Average Recession Probability	0.39	0.41	0.40	0.44	0.63	0.54	0.56	0.45	0.51	0.61	0.54
Average Duration of Expansions	11.71	8.89	9.00	12.20	10.00	6.30	8.40	10.60	8.60	5.50	6.50
Average Duration of Recessions	8.83	5.60	6.88	11.75	17.00	7.30	10.80	10.75	8.80	11.33	7.50
Average Amplitude of Expansions	0.0934	0.1053	0.2172	0.1028	0.1282	0.1195	0.0806	0.1687	0.1471	0.0471	0.1884
Average Amplitude of Recessions	-0.0293	0.0121	0.0433	0.0175	0.0541	0.0129	0.0203	-0.0605	-0.0157	0.0264	0.0670
Steepness of expansions	0.0080	0.0119	0.0241	0.0084	0.0128	0.0190	0.0096	0.0159	0.0171	0.0086	0.0290
Steepness of recessions	-0.0033	0.0140	0.0063	0.0015	0.0032	0.0018	0.0019	-0.0056	-0.0153	0.0109	0.0089

Note: start dates of the samples may vary (see Table 1).

Table 4: Fuzzy clustering, correlation of business cycles, full sample: 1970-2003.

	coefficients		silhouette width	belongs to cluster
Austria	0.64	0.36	0.79	1
Finland	0.52	0.48	0.49	1
France	0.70	0.30	0.81	1
Germany	0.67	0.33	0.78	1
Italy	0.72	0.28	0.79	1
Spain	0.69	0.31	0.76	1
Sweden	0.38	0.62	0.25	2
United Kingdom	0.55	0.45	0.50	1
EU15	0.74	0.26	0.81	1
United States	0.51	0.49	0.41	1
Canada	0.51	0.49	0.46	1
Japan	0.51	0.49	0.45	1
Switzerland	0.71	0.29	0.77	1
Australia	0.38	0.62	0.06	2
Korea	0.45	0.55	-0.11	2
Netherlands	0.72	0.28	0.75	1
Portugal	0.55	0.45	0.51	1
Norway	0.35	0.65	0.61	2
Belgium	0.76	0.24	0.76	1
Mexico	0.39	0.61	0.19	2
New-Zealand	0.32	0.68	0.54	2
Denmark	0.34	0.66	0.62	2
Ireland	0.70	0.30	0.72	1
Silhouette width	0.66	0.31		

Number of clusters	2
Average silhouette width	0.55
Dunn's coefficient	0.55
Normalised Dunn's coefficient	0.10

Table 5: Fuzzy clustering, correlation of business cycles, sample: 1970-1980.

	coefficients		silhouette width	belongs to cluster
Austria	0.55	0.45	0.55	1
Finland	0.44	0.56	0.17	2
France	0.50	0.50	0.40	1
Germany	0.58	0.42	0.56	1
Italy	0.53	0.47	0.51	1
Spain	0.53	0.47	0.49	1
Sweden	0.45	0.55	0.09	2
United Kingdom	0.49	0.51	0.00	2
EU15	0.53	0.47	0.51	1
United States	0.47	0.53	0.24	2
Canada	0.45	0.55	0.23	2
Japan	0.58	0.42	0.50	1
Switzerland	0.55	0.45	0.50	1
Australia	0.41	0.59	0.50	2
Korea	0.54	0.46	0.29	1
Netherlands	0.60	0.40	0.56	1
Portugal	0.53	0.47	0.37	1
Norway	0.49	0.51	0.21	2
Belgium	0.57	0.43	0.53	1
Mexico	0.51	0.49	-0.03	1
New-Zealand	0.45	0.55	0.35	2
Denmark	0.41	0.59	0.43	2
Ireland	0.59	0.41	0.57	1
Silhouette width	0.45	0.27		

Number of clusters	2
Average silhouette width	0.37
Dunn's coefficient	0.51
Normalised Dunn's coefficient	0.01

Table 6: Fuzzy clustering, correlation of business cycles, sample: 1980-1992.

	coefficients					silhouette width	belongs to cluster
Austria	0.09	0.13	0.16	0.33	0.29	0.25	4
Finland	0.23	0.06	0.15	0.46	0.10	0.47	4
France	0.11	0.06	0.10	0.61	0.12	0.66	4
Germany	0.12	0.14	0.42	0.17	0.15	0.80	3
Italy	0.13	0.05	0.24	0.49	0.10	0.34	4
Spain	0.07	0.05	0.08	0.64	0.16	0.62	4
Sweden	0.10	0.05	0.18	0.55	0.13	0.48	4
United Kingdom	0.17	0.07	0.13	0.41	0.21	0.51	4
EU15	0.09	0.04	0.18	0.59	0.10	0.43	4
United States	0.40	0.07	0.35	0.10	0.08	0.60	1
Canada	0.58	0.05	0.24	0.08	0.05	0.76	1
Japan	0.14	0.08	0.25	0.42	0.12	0.26	4
Switzerland	0.12	0.03	0.73	0.08	0.04	0.68	3
Australia	0.69	0.04	0.16	0.06	0.04	0.76	1
Korea	0.03	0.07	0.04	0.06	0.80	0.63	5
Netherlands	0.10	0.05	0.73	0.08	0.05	0.84	3
Portugal	0.13	0.24	0.11	0.19	0.33	0.67	5
Norway	0.13	0.47	0.15	0.09	0.16	0.73	2
Belgium	0.04	0.79	0.05	0.04	0.08	0.71	2
Mexico	0.62	0.06	0.13	0.12	0.07	0.68	1
Silhouette width	0.70	0.72	0.78	0.45	0.65		

Number of clusters	5
Average silhouette width	0.55
Dunn's coefficient	0.39
Normalised Dunn's coefficient	0.24

Table 7: Fuzzy clustering, correlation of business cycles, sample: 1992-2003.

	coefficients			silhouette width	belongs to cluster
Austria	0.33	0.11	0.56	0.79	3
Finland	0.57	0.18	0.26	0.43	1
France	0.23	0.11	0.66	0.82	3
Germany	0.22	0.13	0.65	0.82	3
Italy	0.22	0.20	0.58	0.74	3
Spain	0.34	0.11	0.54	0.71	3
Sweden	0.32	0.42	0.26	0.12	2
United Kingdom	0.26	0.11	0.63	0.74	3
EU15	0.32	0.10	0.58	0.68	3
United States	0.63	0.17	0.20	0.61	1
Canada	0.25	0.09	0.67	0.78	3
Japan	0.26	0.56	0.18	0.54	2
Switzerland	0.24	0.08	0.68	0.76	3
Australia	0.42	0.37	0.21	0.52	1
Korea	0.15	0.71	0.14	0.58	2
Netherlands	0.37	0.08	0.54	0.65	3
Portugal	0.38	0.19	0.43	0.50	3
Norway	0.24	0.61	0.16	0.47	2
Belgium	0.35	0.10	0.54	0.67	3
Mexico	0.65	0.16	0.19	0.61	1
New-Zealand	0.13	0.76	0.10	0.67	2
Denmark	0.23	0.10	0.67	0.73	3
Ireland	0.19	0.07	0.74	0.81	3
Silhouette width	0.55	0.48	0.73		

Number of clusters	3.00
Average silhouette width	0.51
Dunn's coefficient	0.44
Normalised Dunn's coefficient	0.20

Table 8

Group 1		Group 2	
		In-synch	Out-of-synch
	In-synch	N_{11}	N_{12}
	Out-of-synch	N_{21}	N_{22}

Table 9: Bovi-McNemar test statistics, full sample 1970-2003

		Core EMU	Non EMU	EU15	EU15*	G7	ROW	OECD	USA	ANGLO	DEU	EMUUK	NAMU
								GROUP 2					
GROUP 1	EMU	0.33	0.20	-	92.25	1.29	-1.64	-3.86	100.15	0.17	92.25	-	-1.09
	Core EMU		0.00	0.09	90.27	0.57	-2.46	-5.26	98.15	0.00	85.72	0.09	-1.96
	Non EMU			0.06	95.34	0.53	-2.91	-5.76	96.33	0.00	95.34	0.06	-2.88
	EU15				89.29	0.31	-3.52	-6.55	95.34	-0.05	87.72	-	-2.91
	EU15*					-95.04	-107.04	110.04	0.07	-99.04	-	-89.29	-108.00
	G7						-9.00	-13.24	84.25	-1.33	91.35	-0.31	-6.37
	ROW							-	102.54	4.57	109.00	3.52	0.09
	OECD								105.53	9.31	112.00	6.55	1.60
	USA									-88.17	0.07	-95.34	-98.19
	ANGLO										97.15	0.05	-
	DEU											-87.72	-108.00
	EMUUK												-2.91
	NAMU												

Note: critical values Chi^2(1)　at 1% = 2.71 / at 5% = 3.84 / at 10% = 6,63

Note: *Clusters of countries*:
EMU : all EMU countries; coreEMU : FRA,DEU,ITA; nonEMU : GBR,SWE,DNK; EU15 : all EU countries; G7 : USA,CAN,JPN; ROW : all non EU countries; OECD : all OECD, not EU; ANGLO : only USA,CAN,GBR; EMUUK : EMU with UK included; NAMU : USA and UK,
Single countries: USA; EU15*; DEU : Germany

Table 10: Bovi-McNemar test statistics, sample 1970-1985 (upper side) / 1985-2003 (lower side)

		GROUP 2											
		Core EMU	Non EMU	EU15	EU15*	G7	ROW	OECD	USA	ANGLO	DEU	EMUUK	NAMU
GROUP 1	EMU	-	-	-	44.31	1.33	-	-	48.00	0.40	43.31	-	-
	Core EMU	-	-	-	41.33	0.09	-1.33	-2.27	43.09	-0.09	37.23	-	-1.33
	Non EMU	0.33	0.69	-	48.00	1.33	-	-	46.08	-	45.08	-	-
	EU15	-	-	-0.09	42.32	0.33	-	-	44.08	-	39.71	-	-
	EU15*	48.02	49.00	47.61	47.03	-44.00	-49.00	-50.00	-	-46.00	-	-42.32	-49.00
	G7	0.25	0.53		0.06	-51.07	-	-	38.72	-	39.34	-0.33	-
	ROW	-1.92	-1.14	-3.27	-2.57	-58.06	-	-	45.30	-	48.00	-	-
	OECD	-3.77	-3.00	-5.40	-4.57	-60.06	-	-	46.30	-	49.00	-	-
	USA	52.27	55.07	50.28	51.27	-	45.56	57.25	59.24	-40.69	-	-44.08	-45.30
	ANGLO		0.08	-0.33	-0.08	-53.07	-	-	-	-47.52	43.09	-	-
	DEU	49.00	48.49	50.28	48.02	-	52.07	61.00	63.00		54.07	-39.71	-48.00
	EMUUK	-	-	-0.09	-	-47.03	-0.06	2.57	4.57	-51.27	0.08	-48.02	-
	NAMU	-1.14	-0.69	-3.00	-1.92	-59.00	-3.60	-	-	-52.94	-	-60.00	-1.92

Note: critical values Chi^2(1)   at 1% = 2.71 / at 5% = 3.84 / at 10% = 6,63
Note: *Clusters of countries*:
EMU : all EMU countries; coreEMU : FRA,DEU,ITA; nonEMU : GBR,SWE,DNK; EU15 : all EU countries; G7 : USA,CAN,JPN;
ROW : all non EU countries; OECD : all OECD, not EU; ANGLO : only USA,CAN,GBR; EMUUK : EMU with UK included;
NAMU : USA and UK,
Single countries: USA; EU15*; DEU : Germany

Table 11: Business cycle correlation with Germany and the US – pooled panel regressions

	1	2	3	4	5	6	7	8	9	10[1]	11[2]	12[3]
Trade instrumented	0.95*** (3.00)		0.98*** (3.08)	0.89*** (2.82)	0.91*** (3.10)	0.60** (2.03)	0.65** (2.25)			0.26 (0.60)	0.51+ (1.61)	-0.19 (0.35)
Trade share		3.37*** (3.14)										
Labour market flexibility (NAWRU)	0.77 (0.81)								-1.46+ (1.48)			
Relative labour market flexibility		0.42 (0.29)										
Industrial structure			1.36 (1.04)									
Relative industrial structure				0.36 (0.43)								
Financial structure					-0.05*** (2.60)							
Relative financial structure						-0.11*** (3.31)	-0.12*** (3.52)	-0.14*** (4.22)	-0.15*** (4.14)	-0.17*** (3.72)	-0.10*** (2.95)	-0.16*** (3.27)
Relative share of oil imports						-9.10** (2.21)	-8.50** (1.98)			-6.61+ (1.46)	-14.85*** (2.94)	-11.50** (2.05)
ERM membership									0.09 (1.03)			
R² overall	0.34	0.35	0.34	0.33	0.41	0.45	0.50	0.45	0.43	0.51	0.52	0.54
Obs. (countries)	54 (18)	54 (18)	54 (18)	54 (18)	54 (18)	54 (18)	54 (18)	54 (18)	54 (18)	48 (16)	48 (16)	42 (14)

Note: The dependent variable is the correlation between deviation cycles of each country vis-à-vis Germany and the US. Averages over three time periods are considered, 1970-1979, 1980-1992, and 1993-2001. Relative variables are defined as the absolute value of the difference between corresponding variables of each country and Germany (in the 'German' part of the pooled panel data) and the US (in the 'US' part of the panel). For definitions and sources of the variables, see Table 3. Estimation results from random effects regressions are reported. Time fixed effects for period 2 is included showing a significant negative impact (not reported). *t*-values in brackets. *** (**, *, +) = significant at 1 (5, 10, 15)-percent level. [1] The country sample does not include Austria. [2] The country sample does not include Canada. [3] The country sample does not include Austria and Canada.

Comments on Michael Artis, "Business cycle affiliations and their determinants: Where do we stand?"

The paper presents an overview of the recent results in the field of dating business cycles and their coherence among OECD economies. Affiliation is defined as "the alleged tendency for some countries' business cycles to cluster together with others". The topic is (still) very relevant for policy analysis. More specifically, as new EU-members are planning to adopt the euro, we need to know more about the degree of synchronization of business cycles. Some of the most interesting questions are:

- Are the potentially new euro countries more or less "in synch" with the European core countries than some of the already existent peripheral euro countries?

- Why are countries more or less synchronised?

- To what degree do business cycles have to be synchronized in order to have a common currency?

First Artis address the problem of measuring the business cycle. Recent studies of business cycles have analyzed the level of real GDP (classical cycles) or the detrended level of GDP (growth or deviation cycles). There is also a considerable amount of high frequency variation due to e.g. seasonality and noise, which may conceal the underlying cyclical development. For business cycle analysis it is preferable to remove both long-term growth and short-term noise from the observed level of GDP in an efficient way. In the last decades the methods for detrending have improved significantly and by now many economists agree on that the available filtering techniques provide useful results. The preferred detrending filter is the Baxter and King (1999) band-pass filter, which allows the analysts to define the periodicities in the data they want to remove from the original data.

The data consists of quarterly GDP, seasonally adjusted, 1970–2003 in 22 OECD countries and one synthetic "country", the EU-15. Detrending and noise-cleaning is achieved by first removing the trend with an HP-filter and then removing the high-frequency noise from the resulting cycle by another HP-filter, described in Artis, Marcelliano and Proietti (2003). This is an approximation of the Baxter-King band-pass filter technique. Then a modified version of

the cycle-dating algorithm due to Harding and Pagan (2001) is applied to detrended GDP. The algorithm categorises the economy as being either in an expansion, i.e. moving from through to peak, or in a contraction, i.e. moving from peak to through. Some stylised facts about the length of the cycle, amplitude and "steepness" for each county is presented in figure 4 and table 3.

Business cycle affiliation is commonly measured by the cross-correlation between detrended GDP in different countries. The traditional cross-correlogram approach is, however, confined to pairwise comparisions, even though comparisons of groups are often of most interest. A clearer picture emerges when clustering analysis is applied. Clustering analysis is used to describe the coherence between business cycles in the 23 countries described above. Hierarchical and fussy clustering methods are used first on cross correlations and then on a combination of cross-correlations and distance measures. The "distance" between countries i and j is measured by the root mean square difference between the cycles of countries i and j. Business cycle affiliation is defined as the groupings of pair-wise correlations and distances according to the cluster analysis. There seems not to be any strong evidence of a European cluster with especially high degree of coherence. Furthermore, the coherence among European countries does not seem to increase over time. Cluster analysis is a way of "letting the data speak itself" on weather there exists some well-defined country grouping with highly synchronized business cycles. Not surprisingly, when the data speak some curious groupings arise, eg. Japan and central Europe, but this approach is still very useful in order sort out what's going on.

Next, the paper address the crucial question whether some group of countries have converged more over time than other groups of countries. Following Bovi (2003, 2004) the McNemar test is applied to investigate whether one group is more often "in synch" than other groups. A group of countries are defined as being "in synch" when they are all in an expansion or in a contraction. The short time series of data available do not support much reliable inference, but it is hard to detect a European grouping of countries which tend to co-move stronger than other groups. There is, for instance, only weak evidence that the coherence between European countries is stronger than the coherence among all other OECD countries. The conclusion from this exercise confirms earlier results that "whilst some business cycle groupings can be detected for periods of time, only few of these are reasonably persistent through time".

Finally the paper tries to address the question of what determines business cycle affiliation. This section is only preliminary, but gives some hints in which directions future research could evolve. In principle un-synchronized business cycles may arise from either:

    (1) country specific shocks or

    (2) differences between propagation mechanisms to common shocks or

    (3) spillover effects

Differences between the propagation mechanisms may arise from e.g. varying degree of labour market flexibility, differing size of the government sector, monetary regime and fiscal policy response. Spillover effects may arise from both foreign trade and integrated financial markets. In the earlier literature the focus was on trade, but in recent literature the financial channels have been put forward as at least equally important, see e.g. Artis, Galvao and Marcellino (2003).

Artis run a panel regression with cross-correlations vis-à-vis Germany and the US as the dependent variable and different measures of distance, policy and propagation mechanism as the explanatory variables. The (preliminary) results indicate that the financial channel seems to be important. Differences between the structures of the financial sector in different countries appear to play a significant role. On the contrary, labour market variables do not seem to be important. The measures of labour market flexibility is, however rather crude. The importance of relative labour market flexibility in explaining differences in propagation mechanisms may very well increase with a somewhat more detailed specification.

Specific comments:

- A synchronized business cycle is sometimes viewed as a prerequisite for having a common monetary policy. This is often the motivation for studying affiliation. But it would also be interesting to study the degree of policy coordination. If various kinds of policy measures, i.e. short term interest rates and budget deficits, show a high degree of coherence then the cost is low of joining a monetary union even though the degree of coherence of business cycles is low. Policy was already synchronized anyway. Have there been any studies using the methods in the paper on policy measures or on measures of the propagation mechanism?

- I am very sympathetic to the use of detrended GDP-data and focus the analysis on growth cycles instead of classical cycles. It is of course ridiculous to claim that a

country with a fast growing population never has recessions! Is it possible (fruitful) to use GDP per capita or GDP per economically active population instead of just GDP when analyzing business cycles? Maybe the detrending issue is not that import in this case.

- Using a double HP-filter instead of the Baxter-King filter in order to save observations at the end of the sample (and the beginning) is not always safe. The HP-filter also has end-points problems. It is probably best to make forecasts (and backcasts) in order to prolong the sample so that the Baxter-King filter can be applied. One could also use the so called "optimal filters" which already incorporate linear forecast, see e.g. van Norden (2002).

- The section describing cyclical histories is very brief and there are several more aspects of the results which could have been commented on. The length of the sample varies between the countries, which makes comparisons difficult. The samples for Ireland and Denmark for instance are much shorter than for most other countries, which of course affect the number of cycles and the average duration of the cycle.

- It would be interesting to know the proportions of times when the economy stays in the same phase, i.e. N_{22} and N_{11}, in the McNemar test in order to get a feeling of the data.

- Using deviation of actual unemployment from a crude measure of NAWRU as the only labour market variable explaining similarity of the propagation mechanism is not satisfactory. It should be possible to find more relevant measures of the similarity (dissimilarity) of the propagation mechanism.

- It could be worthwhile to control for "policy chocks" in the panel regression by introducing some measure of the synchronization of monetary and fiscal policy. I guess that it would be possible to introduce the correlation between changes in structural fiscal balance as an explanatory variable. Maybe one could also introduce the correlation of the (real) interest rates of the central banks, but this measure is of course endogenous and has to be treated very carefully econometrically.

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EU Enlargement and Endogeneity of some OCA Criteria: Evidence from the CEECs[*]

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Abstract

There are two opposite points of view on the link between economic integration and business cycle synchronization. De Grauwe (1997) classifies these competing views as "The European Commission View" and "The Krugman View". According to the European Commission (1990), closer integration leads to less frequent asymmetric shocks and to more synchronized business cycles between countries. On the other hand, for Krugman (1993) closer integration implies higher specialization and, thus, higher risks of idiosyncratic shocks. Drawing on the evidence from a group of transition countries which have experienced a notable increase in trade openness and economic integration with the European Union during the past decade, this paper tries to determine whose argument is supported by the data.

Nontechnical Summary

There is a large debate in economics on the link between economic integration and business cycle co-movement. According to one viewpoint, closer trade links could lead to business cycle synchronization or, equivalently, increase the symmetry of shocks (European Commission, 1990). This argument is often referred to as the "endogeneity hypothesis" of Frankel and Rose (1998). From the alternative point of view (e.g. Krugman, 1993) the opposite effect should prevail: international trade increases specialization, making shocks more asymmetric. The overall impact of trade integration on shock symmetry could thus be ambiguous, at least theoretically. Modern formal models do not seem to offer a unique answer either.

Focusing on the business cycle criteria of the optimal currency area (OCA), this paper analyzes the effects of trade integration on synchronization of supply and demand shocks between the European Union (EU) and ten candidate Central and Eastern European countries (CEECs) over the past decade. Since the trade of the CEECs with the EU has significantly increased over the transition period, and since several transition countries have pegged their currencies to the Deutschmark, subsequently replaced by the euro, we face a sort of "natural experiment" for testing the impact of trade integration on the correlation of shocks.

Our empirical approach contains two steps. First, using the Kalman-filtering estimation technique in a way advocated by Boone (1997), we obtain the time-varying correlation coefficient of supply and demand shocks between the CEECs and the EU/Germany as alternative benchmarks. Second, we assess whether the estimated shock asymmetry can be explained by trade and exchange rate indicators. The results indicate that higher trade intensity and lower exchange rate volatility contribute to the convergence of demand shocks, thus supporting the European Commission (1990) point of view. Therefore, one policy interpretation is that that joining the European Monetary Union (EMU) would not increase the costs for the candidate countries, in terms of the costs associated with demand shock asymmetry. On the other hand, given the ambiguous results for supply shocks and the limitations of the technique, the overall implications should be mentioned with caution.

*Over the long run everything is
endogenous and we are all dead*

Flandreau and Maurel (2001), p. 19

1. Introduction

According to recent European Union (EU) decisions at the summits in Brussels and Copenhagen[1], EU enlargement is scheduled for 1 May 2004. Ten countries – Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia – have been invited to enter the European Union[2]. The question of sharing a common monetary policy will then emerge. Would it be beneficial for the candidate countries to join the European Monetary Union (EMU) immediately upon entering the EU, or to postpone adoption of the euro for a number of years? A comprehensive assessment of this challenging issue is beyond the scope of our study. In this paper we concentrate on some cost aspects of joining the eurozone, namely on the degree of shock asymmetry between the EU and the candidate countries, with the objective of identifying the effects of economic integration on synchronization of shocks.

The issue of shock asymmetry has received particular attention due to the development of the optimal currency area (OCA) theory, which originates in the work of Mundell (1961), McKinnon (1963) and Kenen (1969). According to the classical OCA criteria, two countries or regions would benefit from forming a monetary union if they are characterized by high similarity of business cycles, have strong trade links, and if they possess an efficient adjustment mechanism[3] that can mitigate the adverse effects of asymmetric shocks[4]. The first criterion is often considered the key one. Indeed, if the business cycles of two countries are highly synchronized, or in other words if countries are exposed to symmetric shocks and exhibit similar responses to these shocks, a common monetary policy response does not introduce imbalances between them. In other words, higher symmetry of shocks between countries, *inter alia*, implies a lower cost of sharing a common monetary policy. Much interest, therefore, has been focused on estimating the degree of shock asymmetry between countries or regions. As far as the EU candidate countries are concerned, empirical studies have only recently begun to appear as longer time series become available. The still scarce evidence suggests that selected Central and Eastern European countries (CEECs) have achieved some synchronization of their business cycles with the EU, at least on the demand side[5]. It is commonly stressed, however, that the period of transition is too short to draw robust conclusions. For this reason, we re-estimate our previous results (2002 and 2004) focusing

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[1] On 18 November and 12–13 December 2002 respectively.

[2] The accession of Bulgaria and Romania has been set for 2007.

[3] E.g. labor mobility, flexibility of factor prices, and a system of fiscal transfers.

[4] There is a tendency in the literature to use the terms "shocks" and "business cycles" as synonyms. However, the term "business cycle" has a broader meaning than "shock": business cycles usually refer to the de-trended components of macroeconomic aggregates such as GDP, industrial production, employment, etc. Hence, the business cycle represents a mixture of shocks (e.g. export, wage, oil, climatic, etc.) and the responses to them.

[5] See Boone and Maurel (1998, 1999a, 1999b), Horvath (2002a), and Babetskii, Boone and Maurel (2002, 2004).

on sensitivity analysis with respect to the choice of countries, time span, and identification approach.

Along with the measurement issue, another question concerns the link between economic integration and shock asymmetry. It is here where the endogeneity issue arises. The endogeneity of the OCA criteria is formulated in the sense of the Lucas critique: currency union affects the underlying OCA criteria in such a way that they are more likely to be satisfied *ex post,* as both monetary and trade integration deepen[6]. Putting it in practical terms, the endogeneity argument means that a policy change (e.g. steps towards forming a monetary union) influences shock asymmetry. There are two opposite views on this subject, classified by De Grauwe (1997) as "The European Commission View" and the "Krugman View". According to the European Commission (1990), closer integration leads to less frequent asymmetric shocks and to more synchronized business cycles between countries. On the other hand, for Krugman (1993) closer integration implies higher specialization and, thus, higher risks of idiosyncratic shocks. Drawing on the evidence from a group of ten transition countries which have experienced an impressive increase in trade openness and economic integration with the European Union during the past decade, this paper tries to find out whose argument is supported by the data. Since the trade of the CEECs with the EU has significantly increased over the transition period, and since several accession countries have pegged their currencies to the Deutschmark, subsequently replaced by the euro, we face a sort of natural experiment for testing the endogeneity argument.

Methodologically, we apply a bi-variate vector autoregressive procedure proposed by Blanchard and Quah (1989), theoretically anchored in the sticky price paradigm for open economies, in order to identify supply and demand shocks for the candidate countries, with Germany and the aggregate EU-15 as alternative benchmarks. Then, using the Kalman filtering technique in a way advocated by Boone (1997), we construct the time-varying correlation of shocks between the candidate countries and the aggregate EU-15 and Germany as alternative benchmarks. The new results are in line with our previous estimates (2002 and 2003) and show more clear-cut patterns. In particular, the results demonstrate that the demand shocks have converged (to levels comparable to present EU member countries such as Ireland, Portugal and Spain), while asymmetries of the supply shocks prevail. Next, we confront the time-varying estimates of supply and demand shock convergence with indicators of trade and exchange rates. We find that (i) an increase in trade intensity leads to higher symmetry of demand shocks; the result for supply shocks is ambiguous; (ii) a decrease in exchange rate volatility has a positive effect on demand shock convergence and no significant impact on supply shocks. The results for demand shocks can be interpreted in favor of "The European Commission View", also referred to as the endogeneity argument by Frankel and Rose (1998) in the OCA criteria discussion, according to which trade links and monetary integration reduce asymmetries between countries. Overall, our results support Kenen's (2001) argument that the impact of trade integration on shock asymmetry depends on the type of shock.

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[6] The term "endogeneity of the OCA criteria" was introduced by Frankel and Rose (1997, 1998). See also Bayoumi and Eichengreen (1997) and Rose (2000) for a discussion.

The paper is structured as follows. After this brief introduction, the second section presents a literature review on the subject of shocks and trade integration and illustrates some stylized facts from the CEECs. The third section describes the data and empirical methodology. The fourth section starts with an illustration of the methodology for the Czech Republic case and then presents a comparative analysis for a group of ten transition countries. The last section concludes and draws policy implications.

2. Shock asymmetry and integration: What do we expect?

2.1 Measuring shock asymmetry

A number of studies focus on measuring the degree of shock asymmetry across countries. In earlier research, the judgment about shocks was based on cross-country correlation of real output, industrial production, or real exchange rate cycles[7]. Such an approach, however, does not allow one to distinguish between the shocks themselves and the reactions to them. Since both components are present in the actual series, similar results in terms of correlation coefficients might be observed in the presence of various combinations of shocks and responses to shocks, for example, in the case of a symmetric reaction to asymmetric shocks or an asymmetric reaction to symmetric shocks.

Blanchard and Quah (1989) propose a bi-variate vector autoregressive (VAR) procedure in order to separate shocks from responses. Moreover, this method makes it possible to identify the origins of shocks, for example, supply and demand. Blanchard and Quah (1989) define shocks as linear combinations of the residuals from a bi-variate VAR representation of real output growth and inflation. By construction, one type of shock (labeled as "demand") has only a transitory impact on the level of output, while another type of shock (labeled as "supply") might have a long-term impact on the level of output.

More precisely, if real output and prices are used as inputs to the VAR model, then "demand" shocks are defined so that they do not have a long-term impact on output, while "supply" shocks might have a long-term effect on output. VAR decomposition has become an especially popular tool in identifying shocks since it was applied by Bayoumi and Eichengreen (1993, 1996) to assess the similarities of economic cycles in the case of European monetary integration. One should, however, be aware of the limitations of the VAR technique. In particular, the methodology does not distinguish whether the corresponding supply and demand disturbances are due to domestic or foreign shocks. VAR decomposition is performed on a country-by-country basis; hence, a country's fluctuations in output and prices may be affected by domestic as well as foreign shocks. Of course, it is not likely that, say, Czech shocks affect fluctuations in macroeconomic fundamentals in Germany or the European Union. However, it seems plausible that German or EU shocks may affect the CEECs. As will be illustrated in Section 2.3, Germany and the EU are important, if not the major, trade partners for the accession countries. The results,

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[7] See, for example, Cohen and Wyplosz (1989), Weber (1991), De Grauwe and Vanhaverbeke (1993), and Artis and Zhang (1995).

therefore, should be interpreted with care. The same level of shock symmetry between two countries may correspond to various combinations of foreign and domestic shocks and responses.

Later, co-movements of shocks across countries and regions were used for the assessment of the OCA criteria. For example, a high correlation between two countries' series of shocks indicates that the economic structures of the countries under consideration are quite similar. This methodology allows Bayoumi and Eichengreen (1996) to identify the "core" European countries, for which the cost of a common monetary policy could thus be low.

Note that the shock-series correlation coefficient is a static measure. Therefore, it is difficult to judge whether shocks become more symmetric or not. However, since the degree of economic integration changes over time, there are few reasons to believe that shock asymmetry remains constant. The dynamics can be partially assessed by splitting up the whole period and calculating the correlation coefficient by sub-periods, provided that the sub-intervals are long enough. There is, however, a more fundamental critique to this approach. Fontagne and Freudenberg (1999) argue that "the central critique to be addressed to studies based on VAR estimates of asymmetric shocks refers to the assumption of structural asymmetries. The only way to relax this assumption is to use the Kalman filter in order to tackle the issue of a dynamic convergence of shocks[8]."

Boone (1997) applies the Kalman filter technique in order to obtain time-varying estimates of shock symmetry. Her results for Western European countries are consistent with those reported by Bayoumi and Eichengreen (1996) and, notably, give rich information about the dynamics of evolving symmetries. The results are generally interpreted in favor of the endogeneity argument: the observable increase in supply and demand shock correlation goes along with deepening European integration.

An increasing number of studies focus on the analysis of symmetries between current European Union members and accession countries. Frenkel, Nickel and Schmidt (1999), Fidrmuc and Korhonen (2001), Horvath (2002a), Frenkel and Nickel (2002), and Babetskii, Boone and Maurel (2002, 2004) follow the structural VAR identification methodology developed by Blanchard and Quah (1989) and Bayoumi and Eichengreen (1996). Supply and demand shocks are extracted from quarterly series of real output and prices. Short time series (less then ten years of quarterly observations) complicate the econometric analysis.

Frenkel, Nickel and Schmidt (1999) and Horvath (2002a) conclude that correlation of neither demand nor supply shocks can be interpreted in favor of convergence. Fidrmuc and Korhonen (2001) find that the cross-country correlation of supply shocks varies substantially from country to country. Correlation of demand shocks between the EU and the CEECs is substantial for Hungary and Estonia, while other accession countries show modest results. Compared to the earlier studies for Western European countries, current results indicate an increase in synchronization between the EU "core" and Italy and Portugal, previously considered "peripheral" countries. Frenkel and Nickel (2002) point out that there is high heterogeneity among

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[8] The authors do not explain the meaning of "structural asymmetries". In the context of their story, this term sounds like a synonym for "parameter stability". It is furthermore unclear why the Kalman filter is the "only" tool available to deal with dynamic convergence. We would prefer to replace "the only" with "a useful" tool.

CEECs and EU countries in terms of correlation of supply and demand shocks, and the adjustment dynamics of output and prices are far from being similar either. However, "the more advanced CEECs are hardly different in the correlation of their shocks vis-à-vis the euro area and the bigger EMU countries than the smaller countries of the EU that have already adopted the euro as their currency". By the same token, some accession countries show evidence of similarity of impulse responses with either Germany, France, Italy, or the EU as a whole.

Babetskii, Boone and Maurel (2002, 2004) extend the analysis of supply and demand shocks by measuring time-varying correlation in a way advocated by Boone (1997). Their results stress an ongoing process of demand shock convergence between the EU and the accession countries. Supply shocks tend to diverge, which is interpreted as a due restructuring process at work and the Balassa–Samuelson effect. Overall, there seems be a problem with the low robustness of the estimated correlation of supply and demand shocks in different studies, despite the fact that they use the same (Blanchard and Quah, 1989) methodology. The diversity of the results might be due to the sensitivity of the correlation coefficient to the VAR specification, data sources, and sample lengths. For example, Frenkel, Nickel and Schmidt (1999) and Babetskii, Boone and Maurel (2002, 2004) use data on the CEECs from the early 1990s and thus include the "transformational recession" in the sample. Fidrmuc and Korhonen (2001) and Frenkel and Nickel (2002) use later data, so the results are believed to be less affected by structural changes. The first objective of the present paper, therefore, is to assess the robustness of the time-varying correlation of shocks.

The debate has been centered so far on the measurement issue, namely, how to identify shocks and how to measure cross-country correlation of disturbances. One serious issue has been omitted. A natural question concerns the determinants and sources of the observable increases or decreases in shock symmetry. To some extent, all the studies mentioned above try to discuss factors that drive the cycles' symmetries or asymmetries. Integration in the various interpretations of this broad concept is often said to be the key factor that affects the understanding of business cycle co-movements. Yet such a potentially important explanatory variable is missing from the analysis. This is the subject to which we now turn.

2.2 Shock asymmetry and integration: Discussing endogeneity

Frenkel and Rose (1998) open a large debate on the endogeneity of OCA criteria fulfillment. In the spirit of the European Commission (1990), Frankel and Rose (1998) put forward an argument that closer trade links could lead to business cycle synchronization or, equivalently, increase the symmetry of shocks. According to the alternative viewpoint, e.g. Krugman (1993), the opposite effect should prevail: international trade increases specialization, making shocks more asymmetric. The overall impact of trade integration on shock symmetry could thus be ambiguous, at least theoretically. Modern formal models of optimum currency areas do not seem to offer a unique answer either[9]. Frankel and Rose (1998) stress the necessity of further analysis of the role of international trade by distinguishing between inter-industry and intra-industry trade. Inter-industry trade (trade which involves exports and imports of different goods, for example, when one country exports cotton and imports wines) reflects specialization, thus potentially causing

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[9] See Ricci (1997b); see also Horvath (2002b), pp. 21–23, for a recent review of OCA models.

asymmetries. On the other hand, intra-industry trade (when a country simultaneously exports and imports products of the same category, e.g. cars) should lead to business cycle co-movements. There is on-going theoretical work in this direction[10].

The concept of integration can be considered in a broader sense, including monetary integration as well. Ricci (1997a) builds a two-country model of optimum currency areas which incorporates monetary and real variables. One of the model's key implications is that "the adoption of fixed exchange rates endogenously (i.e. within the model) increases the desirability of this currency area by reducing the shock asymmetry[11]." Note that in Ricci's model exchange rates affect shock asymmetry indirectly, through trade: flexible exchange rates favor specialization compared with fixed rates. Specialization, in turn, leads to higher asymmetry of shocks. Hence, it follows that exchange rate arrangements may matter for business cycle correlation, at least to the extent that specialization leads to asymmetric responses. Naturally, other determinants beside bilateral trade, its specialization patterns, and exchange rate regimes may influence shock transmission between countries. One might think about tariffs and non-tariff barriers, institutional agreements, border effects, etc.

As for empirical evidence, Frankel and Rose (1998) in their influential work argue that "countries with closer trade links tend to have more tightly correlated business cycles". Econometrically, Frankel and Rose assess the following relationship between trade intensity and correlation of business cycles:

$$\overline{Corr(Q_i, Q_j)}_t = c_1 + c_2 \overline{\log(TI_{ij})}_t + \varepsilon_{ij_t}$$

where the bars denote period-averaged values of trade intensity $\log(TI_{ijt})$ and of the correlation of business cycles $Corr(Q_{it}, Q_{jt})$ [12]. The business cycle Q_{it} in country i at time t is defined as the detrended component of real economic activity (e.g. GDP, index of industrial production, total employment or unemployment). The trade intensity between countries i and j is calculated from exports, imports or total bilateral trade according to the following expressions (natural logarithms of):

$$TI_{ijt}^{EX} = EX_{ijt} / (EX_{it} + EX_{jt})$$

$$TI_{ijt}^{IM} = IM_{ijt} / (IM_{it} + IM_{jt})$$

$$TI_{ijt}^{T} = (EX_{ijt} + IM_{ijt}) / (EX_{it} + EX_{jt} + IM_{it} + IM_{jt})$$

where EX_{ijt} are exports from country i to country j, EX_{it} are total exports from country i, and IM denotes imports. The estimates are performed on a large cross-section of OECD countries over thirty years, and the results seems be very robust as to the choice of indicators of bilateral trade and business cycles. Total trade is further confronted with intra-industry trade. Although not

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[10] See, among others, Kose and Yi (2001).

[11] "Endogenously" means "within the model".

[12] The time dimension is four, since the sample, which covers 1959–1993, is divided into four sub-periods.

directly tested, it is the latter that is said to be particularly relevant for business cycle convergence. Additional inclusion of the exchange rate regime dummy does not qualitatively change the results. At least one important question remains, however, after reading this article: are underlying shocks becoming more symmetric as well? All the constructed indicators of business cycles belong to the same class. Namely, they represent detrended indicators of economic activity. Hence, shocks and responses to shocks enter the analysis together. Kenen (2001, p. 15) argues that the results of Frankel and Rose (1998) are biased, since trade, a real variable, is not exogenous to fluctuations of another real variable such as economic activity. Kenen (2001) sketches a simple Keynesian framework where the correlation of output changes between two countries is positively related to bilateral trade intensity, not necessarily due to higher symmetry of shocks. Generally, the impact of trade integration on shock asymmetry depends on the type of shock.

Fidrmuc (2001) re-estimates the specification of Frankel and Rose (1998), focusing on a cross-section of OECD countries over the last ten years and working with different frequencies (quarterly data). Aware of Kenen's (2001) criticism, Fidrmuc (2001) reconfirms the interpretation by Frankel and Rose (1998) and bypasses Kenen's criticism. This is done by direct inclusion of intra-industry trade in the regression. Thus, according to the main point of Fidrmuc (2001), it is the particular structure of trade that matters for business cycle transmission.

Using disaggregated trade data, Fontagne and Freudenberg (1999) find evidence that exchange rate variability depresses intra-industry trade, and consequently, as they argue, should lead to a higher symmetry of shocks. Based on historical data, Flandreau and Maurel (2001) argue that there is a positive impact of both monetary arrangements and trade on business cycle correlation.

This analysis of the literature is far from being complete[13]. However, looking at these and other studies not discussed here, one can note a surprising segmentation in research interests. Two entirely separate classes of studies seem to co-exist: those focusing on measuring correlation of shocks, and others concentrating on assessing the link between business cycle fluctuations and trade, the exchange rate and other explanatory variables. More specifically, studies of the first group illustrate static or dynamic patterns of shock correlation, stressing the importance of distinguishing between shocks and responses to shocks. Studies of the second group identify the effects of trade and other variables on various business cycle indicators containing both shocks and responses to shocks. To our knowledge, there are no direct estimates of the effects of integration on shock asymmetry.

In our work we will try to build a bridge between these two groups of studies by confronting time-varying estimates of shock asymmetry with trade and exchange rate variables. Bringing the two classes of studies together gives us a tool for assessing the long-running debate between the proponents of "The European Commission View" and those of "The Krugman View". Before proceeding with the estimates, the following sub-section will briefly clarify our choice of countries.

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[13] There are studies on estimations of the "OCA indices" which infer the readiness of countries to join a monetary union by predicting exchange rate variability. See Bayoumi and Eichengreen (1997) and Horváth and Komárek (2002).

2.3 Some stylized facts from the candidate countries

In this study we focus on the candidate countries, since they represent a kind of "natural experiment" for testing the endogeneity argument of the OCA theory. Indeed, the past decade has been characterized by an increase in the trade openness of the CEECs and their trade and monetary integration with EU member countries. These three factors together, briefly illustrated below, may affect the degree of business cycle co-movement.

In 2001, the ratios of total bilateral trade to GDP represented more than one hundred percent of GDP for eight of the CEECs from our sample. In the remaining two "big" candidate countries, Poland (population 39 million) and Romania (22 million), trade accounted for 63% and 75% of GDP respectively (see Table 1). Compared to 1993, there has been a significant increase in trade openness for the majority of the candidate countries. The two exceptions are Latvia and Lithuania, but these countries had already achieved high shares of trade in GDP during the earlier transition period.

Table 1: Size and degree of openness of the CEECs

Country	[Exports+Imports]/GDP (%)		GDP per capita (USD)		Population (millions)	
	1993	2001	1993	2001	1993	2001
Bulgaria	84	119	1,190	1,603	8.5	7.9
Czech Republic	109	145	3,391	5,551	10.3	10.3
Estonia	144	188	985	3,830	1.5	1.4
Hungary	61	123	3,790	5,215	10.3	9.9
Latvia	130	103	813	3,275	2.6	2.4
Lithuania	173	106	719	3,245	3.7	3.5
Poland	45	63	2,229	4,561	38.5	38.6
Romania	51	75	1,157	1,768	22.8	22.4
Slovak Republic	122	157	2,489	3,794	5.3	5.4
Slovenia	116	121	6,368	10,605	2.0	2.0
CEECs average	103	120	2,313	4,345	10.5	10.4
Germany	45	68	24,120	22,530	81.2	82.4
United States	21	24	25,742	35,367	258.1	284.8

Sources: *Trade and population: IMF International Financial Statistics, author's computations;*
GDP per capita: IMF World Economic Outlook Database.

Table 2 illustrates the shares of trade with the EU and Germany in the total trade of the CEECs. In 2001, the bilateral trade of the CEECs with the European Union varied from roughly 50% of total trade for Lithuania to 70% of total trade for the Czech Republic. For comparison, this is on average higher than the share of the trade of Germany with other EU member countries (54%). Germany itself is an important trade partner for the majority of the CEECs, accounting in 2001 for 20–40 percent of total bilateral trade for half of the accession countries. Overall, we observe an important increase in trade with the European Union and Germany.

Table 2: Shares of trade with the EU and Germany in total trade of the CEECs
**(ordered by decreasing shares of trade with the EU in 2001)**

Country	European Union		Germany	
	1993	2001	1993	2001
Czech Republic	0.52	0.69	0.27	0.38
Poland	0.67	0.68	0.32	0.31
Hungary	0.56	0.66	0.23	0.31
Slovenia	0.62	0.65	0.26	0.23
Romania	0.44	0.64	0.15	0.18
Latvia	0.30	0.55	0.08	0.16
Estonia	0.55	0.55	0.09	0.07
Slovak Republic	0.29	0.54	0.13	0.27
Bulgaria	0.44	0.52	0.13	0.13
Lithuania	0.31[1]	0.49	0.13[1]	0.16
CEECs average	0.47	0.60	0.18	0.22
Germany	0.56	0.54		

Note: [1] *1994 values.*
Source: *IMF Direction of Trade Statistics, author's computations.*

Bilateral trade intensity is another indicator which serves to characterize the extent of trade between countries. Figure 1 shows the total bilateral trade intensity between ten transition countries and EU / Germany over 1993–2001, quarterly. Except for Bulgaria and Slovenia, bilateral trade intensity exhibits upward trend patterns with respect to either Germany or the EU. In the case of Slovenia, bilateral trade intensity has been relatively high since the early 1990s and this indicator has remained practically unchanged over the past decade. For Bulgaria, trade intensity has had a rising tendency since 1997.

Along with trade openness and trade integration, substantial convergence of exchange rates with the euro has been visible. As illustrated in Table 3, in many cases the candidate countries peg their currencies to the DEM (replaced by the euro at the beginning of 1999). Other monetary authorities (e.g. in the Czech Republic and Slovakia, and recently also in Hungary and Poland), who formally follow a free float policy, use the euro as the reference currency in formulating their preferred exchange rate developments. Thus, the actual exchange rate regimes in these countries can be characterized as a managed float with euro-based intervention levels. The actual volatility of exchange rates under this kind of policy has been decreasing over time (Table 4).

Figure 1: Total bilateral trade intensity, 1993–2001

a) Between the CEECs and Germany
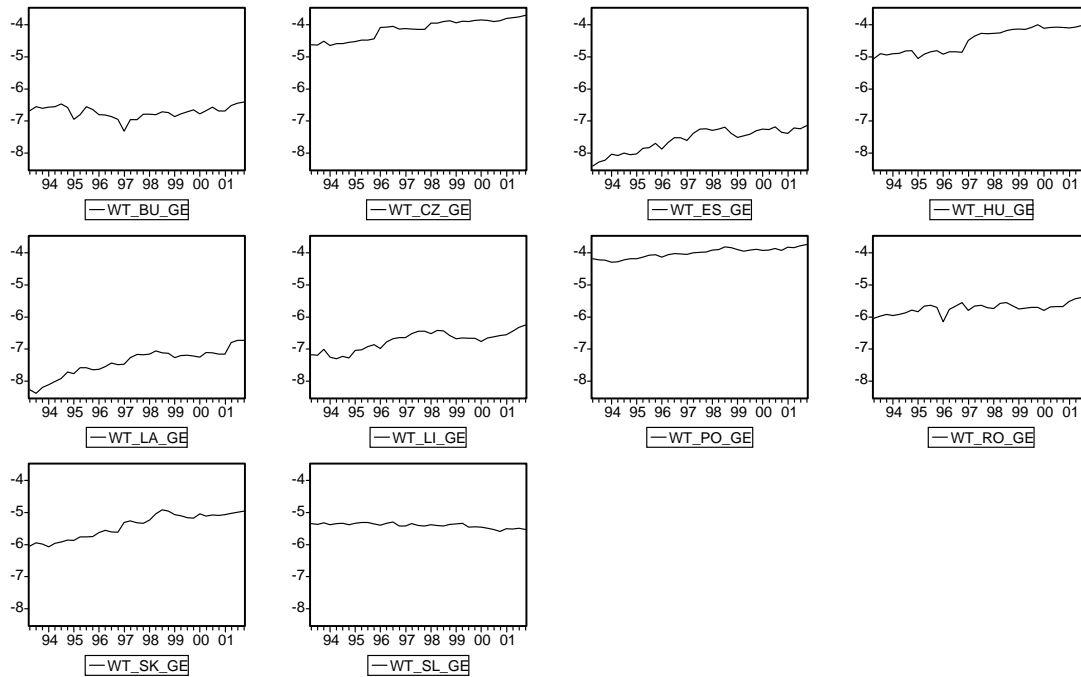
b) Between the CEECs and the European Union
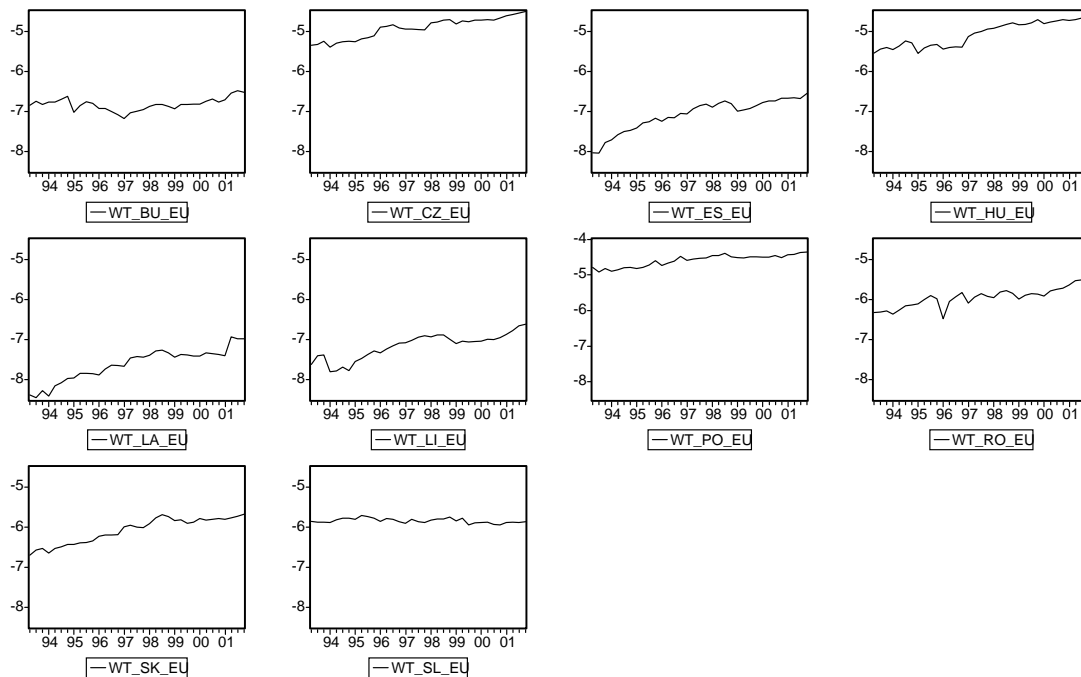
Total bilateral trade intensity is defined according to the following formula (natural logarithm of):

$$TI_{ijt}^{T} = (EX_{ijt} + IM_{ijt})/(EX_{it} + EX_{jt} + IM_{it} + IM_{jt})$$

where i = CEECs, j = Germany/EU, EX_{ijt} = exports from country i to country j, EX_{it} = total exports from country i, and *IM* denotes imports.

Source: *IMF Direction of Trade Statistics, author's computations.*

Table 3: Exchange rate regimes in the CEECs over the last decade

Country	Date	Exchange Rate Regime	Currency Basket / Target Currency	Fluctuation Band
Bulgaria	February 1991	Managed Float		
	1 July 1997	Currency Board	DEM	0%
	1 January 1999	Currency Board	euro	0%
Czech Republic	3 May 1993	Peg	DEM(65%), USD(35%)	±0.5%
	28 February 1996	Peg	DEM(65%), USD(35%)	±7.5%
	26 May 1997	Managed Float	Reference currency DEM replaced in 1999 by euro	
Estonia	June 1992	Currency Board	DEM	0%
	1 January 1999	Currency Board	euro	0%
Hungary	22 December 1994	Crawling Band	ECU(70%), USD(30%)	±2.25%
	1 January 1997	Crawling Band	DEM(70%), USD(30%)	±2.25%
	1 January 1999	Crawling Band	euro(70%), USD(30%)	±2.25%
	1 January 2000	Crawling Band	euro	±2.25%
	4 May 2001	Crawling Band	euro	±15%
Latvia	February 1994	Peg	SDR	±1%
Lithuania	October 1992	Independent Float		
	April 1994	Currency Board	USD	0%
	1 February 2002	Currency Board	euro	0%
Poland	16 May 1995	Crawling Band	USD(45%), DEM(35%), BP(10%), FF(5%), SwF(5%)	±7%
	26 February 1998	Crawling Peg	USD(45%), DEM(35%), BP(10%), FF(5%), SwF(5%)	±10%
	28 October 1998	Crawling Peg	USD(45%), DEM(35%), BP(10%), FF(5%), SwF(5%)	±12.5%
	1 January 1999	Crawling Peg	euro(55%), USD(45%)	±12.5%
	25 March 1999	Crawling Peg	euro(55%), USD(45%)	±15%
	12 April 2000	Independent Float		
Romania	August 1992	Managed Float		
Slovak Republic	14 July 1994	Peg	DEM(60%), USD(40%)	±7%
	1 January 1996	Peg	DEM(60%), USD(40%)	± 3%
	31 July 1996	Peg	DEM(60%), USD(40%)	± 5%
	1 January 1997	Peg	DEM(60%), USD(40%)	± 7%
	2 October 1998	Managed Float	Reference currency euro since 1999	
Slovenia	January 1992	Managed Float		

Sources: *Valachy and Kočenda (2003), Schoors (2001), Halpern and Wyplosz (2001) and Central Europe Weekly (2001, January 18).*

Table 4: Volatility of nominal exchange rates[1] (%)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Bulgaria	n.a.	24.5	5.5	39.7	20.1	77.0	85.6	15.2	0.4	0.0	0.0
Czech Rep.	n.a.	n.a.	n.a.	1.4	1.2	1.0	4.4	4.3	2.9	2.6	2.8
Hungary	8.0	6.2	4.4	9.6	16.0	10.3	5.8	7.9	4.3	1.8	2.3
Poland	6.9	17.3	12.6	14.5	9.5	4.9	5.7	4.7	5.4	3.7	5.6
Romania	94.7	77.5	48.5	41.7	19.2	22.1	36.9	14.8	26.7	13.2	14.8
Slovakia	n.a.	n.a.	n.a.	3.9	1.6	0.9	1.5	3.9	6.7	2.8	1.6
Slovenia	n.a.	n.a.	14.4	8.4	2.1	5.6	3.2	2.0	2.4	3.5	3.4
Estonia	n.a.	n.a.	2.1	0.8	1.6	1.3	1.8	0.5	0.5	0.1	1.0
Latvia	n.a.	n.a.	17.1	13.8	2.5	1.3	3.4	2.0	3.8	6.4	2.6
Lithuania	n.a.	n.a.	n.a.	10.5	6.4	2.4	6.1	3.4	4.4	8.6	4.6
CEECs average	36.5	31.4	14.9	14.4	8.0	12.7	15.4	5.9	5.8	4.3	3.9
USA	5.8	5.8	6.5	3.7	5.9	2.4	6.1	3.4	4.4	8.6	4.6

Note: [1] *Standard deviations in percent from average nominal exchange rates against ECU/euro over preceding two years.*
Source: Author's computations based on the IMF International Financial Statistics, monthly averages

Figure 2 and Table 5 show convergence of GDP-deflator-based inflation rates. Not only have inflation levels decreased, but so has the variability of inflation rates across the CEECs.

Figure 2: Inflation[1] convergence across the CEECs, 1993–2002
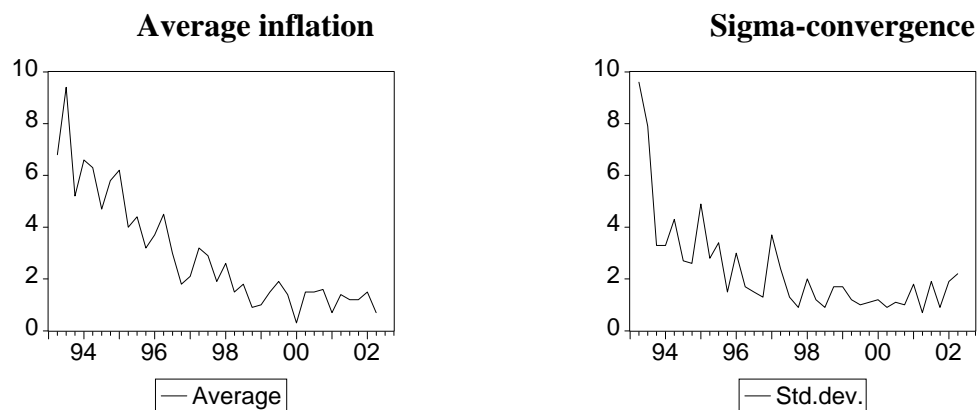
CEECs average quarterly inflation rates (excluding Bulgaria and Romania)

Variability of quarterly inflation rates across CEECs (excl. Bulgaria and Romania)

Note: [1]*GDP-deflator based.*
Source: Author's calculations.

Table 5: Inflation[1] convergence across the CEECs

	1994–1998	1999–2002
CEECs average	6.3	2.0
CEECs: sigma-convergence	7.7	2.6
CEECs average. (excl. Bulgaria and Romania)	3.6	1.2
CEECs (excl. Bulgaria and Romania): sigma-convergence	2.4	1.3
Germany average	0.3	0.2
EU-15 average	0.5	0.5
Euro-area average	0.5	0.4

Note: [1]*GDP-deflator based.*
Source: *Author's computations.*

3. Data and methodology

This section starts with a description of the data set, followed by the empirical methodology, which contains three main procedures: (i) identifying supply and demand disturbances, (ii) constructing time-varying correlation of shocks, and (iii) confronting shock asymmetry with indicators of trade and exchange rate volatility. The last part of the section describes econometric specifications for illustrating the endogeneity argument of the OCA theory.

The sample covers ten accession countries (Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia), plus Germany, the EU-15 aggregate, the United States, Ireland, Portugal, and Spain.

The series of real output (GDP at 1995 prices, in billions of national currency), prices (GDP deflator, rebated to 100 for 1995), and exports and imports (in millions of current US dollars) are quarterly, ranging from 1990:Q1 to 2002:Q2.

The following sources are used: OECD Analytical Database, IMF International Financial Statistics, EIU Country Data, IMF Direction of Trade Statistics, and National Statistical Committees. The OECD is the main source for the series of real output and prices. These data are available in seasonally adjusted form. The remaining output and price series were deseasonalized by applying the U.S. Census Bureau's X11 procedure, the same method as used by the OECD[14]. Data for some accession countries are unavailable prior to 1994. The trade data cover the period up to 2001:Q4.

3.1 Step 1: Identification of shocks

In the first step, we decompose the fluctuations in the macroeconomic aggregates into shocks and responses to shocks. There is no unique identification strategy. We choose a bi-variate structural VAR method proposed by Blanchard and Quah (1989) in their influential *American Economic*

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[14] X11 is a sort of moving-average filtering procedure with time-evolving seasonal factors.

Review paper, in the way that Bayoumi and Eichengreen (1993) apply this decomposition to extract supply and demand shocks from quarterly series of real output and prices. As discussed in section 2.2, such an approach is quite popular in studies of business cycle convergence for developed countries, and there is recent evidence for accession countries as well.

The identification strategy is based on a stylized representation of the economy described by aggregate supply and demand curves. The aggregate demand (AD) curve is negatively sloped in both the short run and the long run, meaning that lower prices increase demanded output. The aggregate supply curve is upward-sloping in the short-run and vertical in the long-run. A positively sloped short-run aggregate supply (SRAS) reflects the existence of nominal rigidities, therefore a nominal variable (prices) has a temporary effect on the real variable (output). Finally, a vertical long-run aggregate supply (LRAS) curve implies full-capacity use of the production factors.

Shocks in this simple model correspond to shifts in the aggregate supply and demand curves away from equilibrium. Supply shocks, which are associated with a shift in the aggregate supply curve, have both short-term and long-term impacts on both output and prices. Demand shocks also have short term effects on both variables. However, since the long-term supply curve is vertical, demand shocks do not have a long-term effect on the level of output. A structural bi-variate VAR decomposition makes it possible to identify supply and demand shocks from the observable movements of output and prices.

Formally, consider stationary variables y_t and p_t, for example, the first differences of logarithmic GDP and logarithmic prices: $y_t = \log GDP_t - \log GDP_{t-1}$ and $p_t = \log P_t - \log P_{t-1}$.

Then the following VAR representation can be estimated:

$$y_t = b_{01} + \sum_{k=1}^{K} b_{11k} y_{t-k} + \sum_{k=1}^{K} b_{12k} p_{t-k} + e_t^y \qquad (1)$$

$$p_t = b_{02} + \sum_{k=1}^{K} b_{21k} y_{t-k} + \sum_{k=1}^{K} b_{22k} p_{t-k} + e_t^p \qquad (2)$$

where e_t^y and e_t^p are white-noise disturbances, b_{ijk} are coefficients, and K is the lag length chosen so that e_t^y and e_t^p are serially uncorrelated[15]. Disturbances e_t^y and e_t^p are not structural, they simply represent unexplained components in output growth and inflation movements. In order to recover structural disturbances, i.e. those having an economic interpretation of supply and demand shocks, the following two relationships are proposed:

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[15] We select K in two ways. First, following Blanchard and Quah (1989) and Babetskii, Boone and Maurel (2002, 2003) we use eight lags, which is equivalent to two years, and perform estimates starting from 1990. Alternatively, we focus on the period since 1993 in order to minimize the impact of "transformational recession" and apply the Akaike and Schwarz information criteria, which suggest two, three or four lags. We set uniformly two and four lags. Finally, we perform diagnostic checking of the residuals for higher-order serial correlation (Ljung-Box test) and normality (Jarque-Bera test). Comparison between the estimates allows us to assess robustness with respect to sample and lag lengths.

$$e_t^y = c_{11}\varepsilon_t^D + c_{12}\varepsilon_t^S \tag{3}$$

$$e_t^p = c_{21}\varepsilon_t^D + c_{22}\varepsilon_t^S \tag{4}$$

where ε_t^D and ε_t^S are demand and supply disturbances respectively. These equations state that the unexplainable components in the movements of output growth and inflation are linear combinations of supply and demand shocks. In matrix form, $e_t = C\varepsilon_t$. The vector of the structural disturbances ε_t can be obtained by inverting matrix C: $\varepsilon_t = C^{-1}e_t$.

In order to recover the four coefficients of matrix C, four restrictions have to be imposed. Knowledge of the variance-covariance matrix of the estimated disturbances ε_t^D and ε_t^S is sufficient to specify three restrictions:

$$c_{11}^2 + c_{12}^2 = Var(e^y) \tag{5}$$

$$c_{21}^2 + c_{22}^2 = Var(e^p) \tag{6}$$

$$c_{11}c_{21} + c_{12}c_{22} = Cov(e^y, e^p) \tag{7}$$

These restrictions on the coefficients of matrix C are directly derived from eq. (3) and eq. (4) using normalization conditions:

(i) the variance of demand and supply shocks is unity: $Var(\varepsilon^D) = Var(\varepsilon^S) = 1$

(ii) demand and supply shocks are orthogonal: $Cov(\varepsilon^D, \varepsilon^S) = 0$

The fourth restriction on coefficients c_{ij} is that demand shocks ε_t^D have no long-term impact on the level of output. To put this restriction into a mathematical form, one should substitute equations (3) and (4) into the VAR system given by eq. (1) and eq. (2), and then express variables y_t and p_t as the sum of the contemporaneous and past realizations of structural disturbances ε_t^D and ε_t^S:

$$y_t = c_{01} + \sum_{k=0}^{\infty} c_{11k}\varepsilon_{t-k}^D + \sum_{k=0}^{\infty} c_{12k}\varepsilon_{t-k}^S \tag{8}$$

$$p_t = c_{02} + \sum_{k=0}^{\infty} c_{21k}\varepsilon_{t-k}^D + \sum_{k=0}^{\infty} c_{22k}\varepsilon_{t-k}^S \tag{9}$$

System (8)–(9) is an infinite moving-average representation of the VAR form (1)–(2). Coefficients c_{ijk} – called impulse response functions – characterize the effect of structural disturbances on the left-hand-side variables after k periods (c_{ijk} can be expressed in terms of the four coefficients of interest c_{ij} and the estimated coefficients b_{ij}, but the algebra is messy). The restriction that the cumulative effect of demand disturbances on output growth is zero, for all possible realizations of demand disturbances, means that $\sum_{k=0}^{\infty} c_{11k} = 0$. This restriction also implies that demand disturbances have no long-term impact on the level of output itself. Indeed, c_{11k}

represents the effect of the demand disturbance ε_{t-k}^D on $y_t = \log GDP_t - \log GDP_{t-1}$, output growth after k periods. Therefore, the sequence $c_{110}, c_{111}, c_{112}, \ldots, c_{11k-1}, c_{11k}$ represents the effect of

$$\varepsilon_{t-k}^D \qquad \text{on}$$

$(\log GDP_t - \log GDP_{t-1}), (\log GDP_{t+1} - \log GDP_t), (\log GDP_{t+2} - \log GDP_{t+1}), \ldots,$
$(\log GDP_{t+k-1} - \log GDP_{t+k-2}), (\log GDP_{t+k} - \log GDP_{t+k-1})$. Hence, the cumulative restriction

$\sum_{k=0}^{N} c_{11k} = 0$ states that the effect of $\varepsilon_{D,t}$ on $(\log GDP_{t-1} - \log GDP_{t+N})$ equals zero, i.e. that the

level of output does not change in the long run: $\log GDP_{t-1} = \log GDP_{t+N}$. It can furthermore be

shown that the restriction $\sum_{k=0}^{\infty} c_{11k} = 0$ translates into the parameters of interest c_{ij} and the

coefficients $b_{ij}(k)$ of the unrestricted VAR system (1)–(2) as:

$$c_{11}\left(1 - \sum_{k=0}^{K} b_{22}(k)\right) + c_{21}\left(\sum_{k=0}^{K} b_{12}(k)\right) = 0 \qquad (10)$$

Restrictions (5), (6), (7), (10) serve to identify four coefficients c_{ij} which, in turn, are used to recover the supply and demand disturbances from the VAR residuals by inverting matrix C: $\varepsilon_t = C^{-1}e_t$.

3.2 Step 2: Calculating "time-varying correlation" of supply and demand disturbances

Following Boone (1997) we use the Kalman filter to compute the "time-varying correlation coefficient" between countries i and j given by b_t:

$$(X_t^j - X_t^i) = a_t^{ijk} + b_t^{ijk}(X_t^j - X_t^k) + \mu_t \qquad (11)$$

$$a_t^{ijk} = a_{t-1}^{ijk} + v_t^a \qquad (12a)$$

$$b_t^{ijk} = b_{t-1}^{ijk} + v_t^b \qquad (12b)$$

where X are the supply or demand shocks, error terms μ and v are white noise disturbances, index i denotes an accession country, j stands for Germany or the EU, and k is the United States. Equation (11) is called the *measurement* or *observation equation*. Coefficients a_t^{ijk} and b_t^{ijk} (denoted as a_t and b_t henceforth in order to facilitate reading) are allowed to vary in time according to (12a) and (12b), which are called *transition* or *state equations*.

The intuition behind this specification is simple. For example, in the presence of perfect correlation of shocks between countries i and j, coefficients a_t and b_t both go to zero. The right-hand side of (11) being equal to zero implies that X_t^i – shocks for an accession country i – are thus explained by X_t^j – shocks for a reference country j (Germany or the European Union). If b_t diverge from zero, then the United States has a stronger effect on country i shocks than the reference country j. The United States is used as a benchmark since it is the major trade partner for the EU and an important trade partner for the CEECs. For a convergence process to be at work, we expect a_t to be close to zero and b_t to decrease over time.

Technically, the Kalman filter represents a recursive algorithm for computing the optimal estimator of unknown parameters a_t and b_t. This is done by maximizing a likelihood function given the information available at time t. The estimator is optimal in the sense that it minimizes the mean square error (MSE). Furthermore, if all disturbances are normal, the Kalman filter provides the maximum likelihood estimator (MLE) of a_t and b_t. Period-averages are used as initial conditions in the Kalman filter recursions. Details on estimations of the representation (11)–(12) are available in Annex A in Boone (1997). For more information, see Harvey (1992).

The main advantage of the method in hand is that it gives optimal estimations of the time-varying coefficients in the presence of structural changes, which is the case with the accession countries. As a drawback, the Kalman filter does not explain why the coefficients change over time; the filter simply draws the time path of the model's parameters. It is the objective of the next sub-section to confront the dynamics of coefficient b_t – an indicator of shock asymmetry – with such potentially important variables as indicators of bilateral trade intensity.

3.3 Step 3: Shock asymmetry and integration – "The European Commission View" versus "The Krugman View"

The endogeneity argument implies that trade integration affects shock asymmetry. The sign of this effect is either positive or negative depending on which view – that of the European Commission (1990) or that of Krugman (1993) – is believed to be true. Basically, we need to determine whether there is a link between the indicators of shock asymmetry and integration. Thanks to the use of the Kalman filter, we are able to determine the degree of shock asymmetry at quarterly frequency. Indicators of trade intensity are available on a quarterly basis as well. Hence, as a starting point, we look at the correlation between the time-varying coefficients of shock asymmetry $\hat{b}(i, j)_t$, estimated from (11), and the actual trade intensity $TI(i, j)_t$:

$$\rho(i, j) = Corr(\hat{b}(i, j)_t, TI(i, j)_t) \tag{13}$$

where i denotes accession country and j stands for Germany or the EU. To perform sensitivity checking, the correlation coefficient $\rho(i, j)$ is calculated for two types of shocks (supply and demand) and three indicators of trade intensity (with respect to exports, imports, and total bilateral trade). A positive correlation coefficient $\rho(i, j)$ would be in accordance with "The Krugman View" (higher trade intensity goes along with higher shock asymmetry), while a negative correlation would support "The European Commission View".

The correlation coefficient, however, does not indicate the direction of causality. Although the endogeneity argument states that trade integration affects shock asymmetry, in either a positive or negative way, the causality can go in the reverse direction, too. For example, a recession in one country (a negative real shock) usually decreases the demand for imported products, thus lowering the volume of imports. In our group of ten transition countries it seems possible to separate or at least to minimize the impact of shocks on trade given the explicit increase in trade integration over the past decade observable in all countries except Bulgaria and Slovenia (see Figure 1). This long-term increase in trade integration between the CEECs and the EU/Germany, driven by structural factors, is not likely to have been caused by shocks. (Yet in the short term, e.g. over the horizon up to several quarters, aggregate shocks might affect trade intensity.) Therefore, we

assume that trade intensity is exogenous to shock asymmetry in terms of the long-run relationship. As an alternative to the simple correlation coefficient, we model the relationship between these two variables in a regression framework:

$$\hat{b}(i,j)_t = c_1 + c_2 TI(i,j)_t + \varepsilon(i,j)_t \qquad (14)$$

For a given pair of countries i and j, the error term $\varepsilon(i,j)_t$ depends on time only. Here another difficulty arises. Note that shock asymmetry $\hat{b}(i,j)_t$ is not an observable variable such as trade intensity $TI(i,j)_t$ but a product of estimation. Strictly speaking, the distribution of $\hat{b}(i,j)_t$ is unknown and the inclusion of $\hat{b}(i,j)_t$ in further regression might be inappropriate; the residuals $\varepsilon(i,j)_t$ are, generally, heteroskedastic and autocorrelated. Therefore, at the very limit, one can stop at calculating the correlation between shock asymmetry and trade intensity. Another option is to treat shock asymmetry as a classical variable, in the spirit of Frankel and Rose (1998), who link fluctuations in real economic activity to trade intensity and other explanatory variables.

Additional insight into the link between trade intensity and shock asymmetry can be obtained from estimating (14) in a panel framework. For a given benchmark country j (the EU or Germany), and a group of candidate countries i (i=Bulgaria, Czech Republic, Estonia, etc), we estimate the following equation (fixed effects):

$$\hat{b}(j)_{it} = c_{1i} + c_2 \log[TI(j)_{it}] + c_{3i}D_i + \varepsilon(j)_{it} \qquad (15)$$

where D_i are country dummies. Due to the unknown distribution of $\hat{b}$, the residual terms, again, are not expected to exhibit the conventional properties. The reason for estimating equation (15) is, nevertheless, to check whether the relationship between trade intensity and shock asymmetry can be described by a common slope plus country-specific effects.

Further sensitivity analysis can be done by including the exchange rate variable in the right-hand side of (15). In fact, according to the theoretical model of Ricci (1997a), exchange rate pegs can transmit shocks from one country to another. We check, therefore, whether the coefficient of trade intensity is affected by augmenting eq. (15) with the exchange rate variable:

$$\hat{b}(j)_{it} = c_{1i} + c_2 \log[TI(j)_{it}] + c_3 ERV_{it} + c_{4i}D_i + \varepsilon(j)_{it} \qquad (16)$$

where ERV_{it} is the exchange rate volatility, calculated as the standard deviation of the nominal exchange rate in candidate country i against the euro over the past 12 months. ERV_{it} is chosen as a proxy for exchange rate pegs to the euro[16].

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[16] This measure artificially increases volatility when a country operates under a crawling peg: changes in the crawl are interpreted as volatility.

Equation (16) implies that exchange rate volatility is exogenous to shock asymmetry: lower volatility is expected to reduce shock asymmetry. The causality, however, may go in the opposite direction. For example, if two countries have similar production structures, which increases the probability of common shocks, then the cost of fixing the exchange rate may be lower compared to countries with very different economies. Shock asymmetry can, therefore, influence the choice of appropriate exchange rate regime. Hence, inclusion of the exchange rate variable as exogenous can potentially bias the results.

To justify the inclusion of exchange rate volatility in eq. (16), we perform Granger causality tests for exchange rate volatility and shock asymmetry to determine which variable, if any, is exogenous. There is no strong support for causality in any of the directions. On the other hand, we have good reasons to believe that using the DEM, and later the euro, as the reference currency in the EU candidate countries is driven by other (e.g. political) factors rather than the level of symmetry of shocks.

Besides, exchange rates can affect shock asymmetry indirectly, via trade: fixing an exchange rate tends to stimulate trade; trade links, in turn, can make shocks more symmetric. If the effect of exchange rates on trade is strong, then the inclusion of the exogenous exchange rate variable might cause a multicollinearity problem, altering the coefficient of trade intensity c_2 or making it insignificant. One more reason for including the exchange rate volatility variable is, therefore, to assess whether it has an effect on trade intensity.

So, in order to assess the robustness of the endogeneity argument of the OCA theory we have at our disposal (i) two types of shocks, (ii) three indicators of trade intensity with respect to two benchmarks (the EU and Germany), and (iii) four empirical specifications (the correlation coefficient (13), time series (14), and panel frameworks (15) and (16)).

4. Results

This section begins with an illustration of the methodology in the Czech Republic case. Using demand shocks as an example, time-varying estimates of shock convergence are derived and then confronted with indicators of bilateral trade intensity. The second part covers supply and demand shocks and their determinants for a large group of EU candidate countries. Sensitivity analysis is performed by considering several estimates of shock asymmetry and indicators of trade intensity[17].

4.1 The Czech Republic case, demand shocks

Figures 3a) and 3b) plot Czech demand shocks compared to German and EU demand shocks respectively.

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[17] Due to space limitations, and to preserve clarity, we report results for the case of supply and demand shocks recovered from the eight-lag VAR system over 1990–2002. Besides, it is for this case that time-varying patterns of supply and demand shock asymmetries between the CEECs and the EU are illustrated in Babetskii et al. (2004). The results based on the estimates over 1993–2002, using two or four lags, do not differ qualitatively and are available upon request.

Figure 3a: German and Czech demand shocks, 1994–2002, quarterly
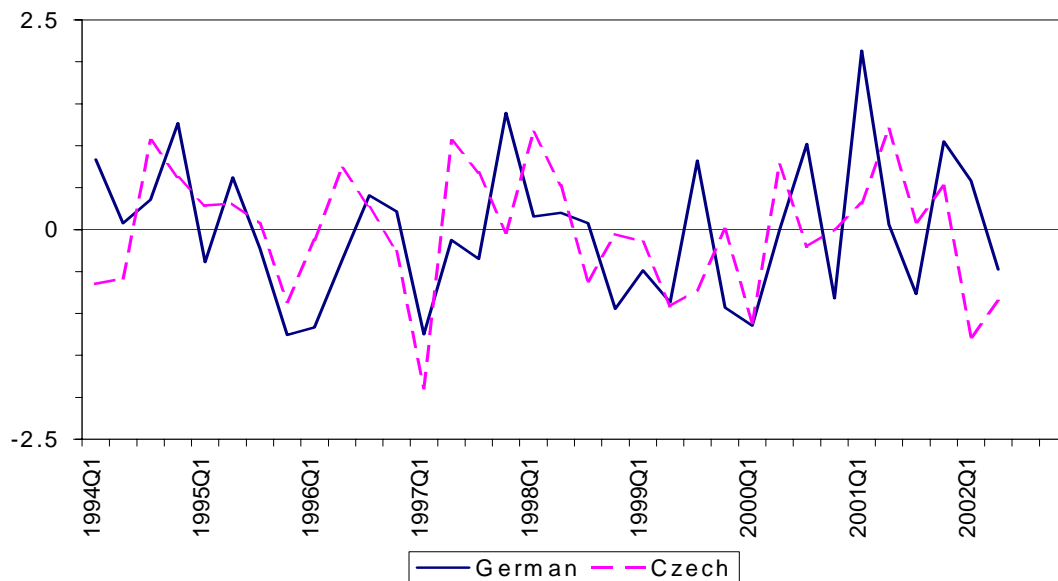
*Figure 3b: EU and Czech demand shocks, 1994–2002, quarterly*
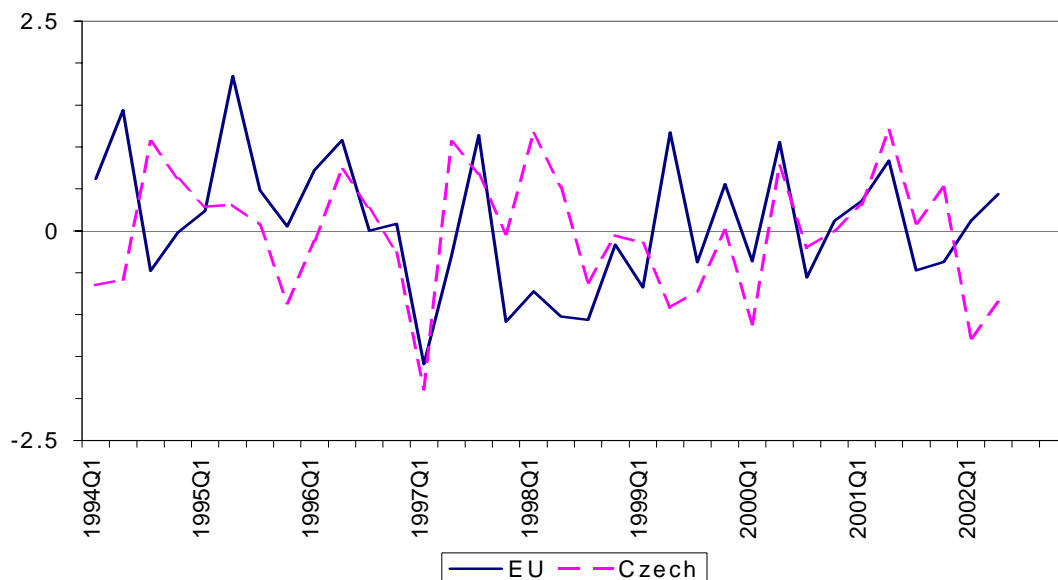
Source: *Author's computations.*

One can see some similarities between the Czech and the EU/German patterns of demand shocks, at least over certain periods. For example, around the beginning of 1997 there is a noticeable negative demand shock observed in the Czech Republic, Germany and the EU. The next question is to quantify the degree of similarity of the shock series co-movements.

Kalman Filter estimates help to draw the "time-varying correlation coefficient" of shock series between the Czech Republic on the one hand and Germany/the EU on the other hand. Estimates of a_t and b_t from (11) over 1994:Q1–2002:Q2 suggest that Czech demand shocks converge to the corresponding German and EU shocks: coefficients a_t decline towards zero, indicating that there is no "autonomous" convergence, and coefficients b_t decrease, meaning that the dissimilarities between the Czech and German/EU shock series diminish over time.

Figure 4: Czech Republic, convergence of demand shocks

Convergence to Germany as opposed to the US
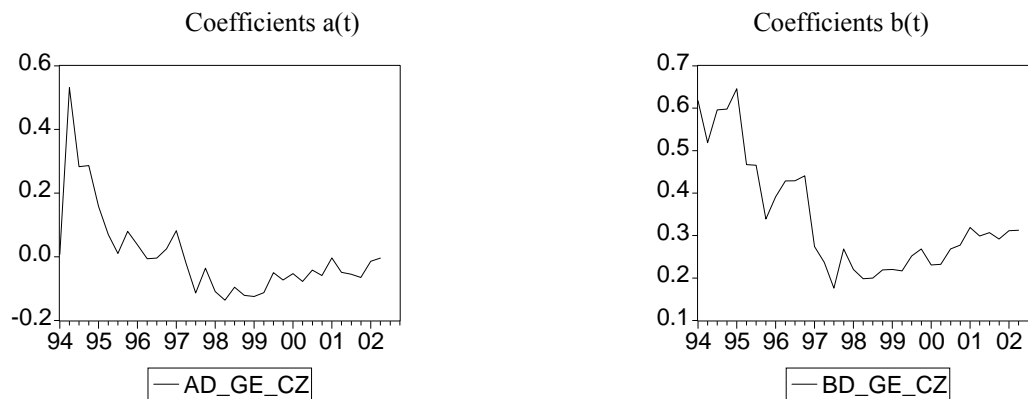
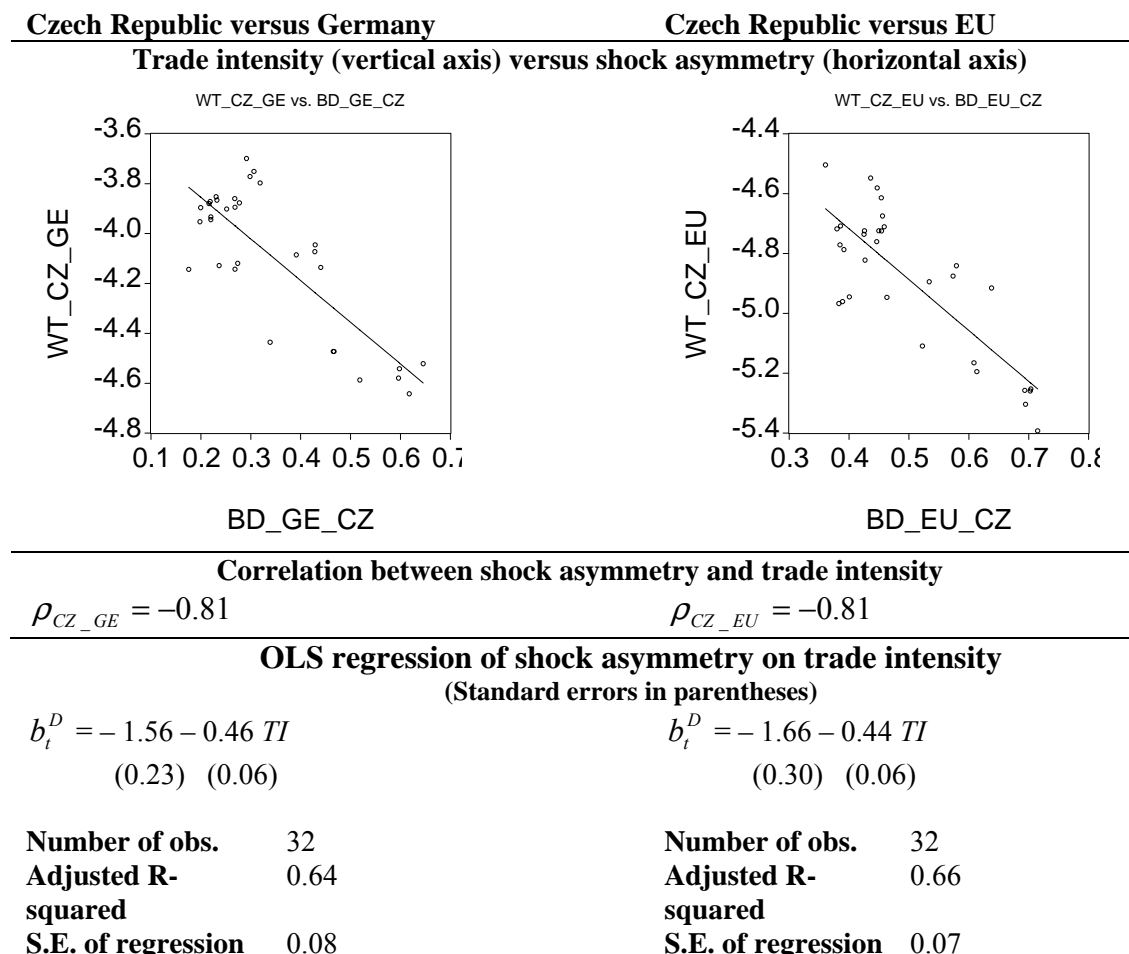**Convergence to EU as opposed to the US**
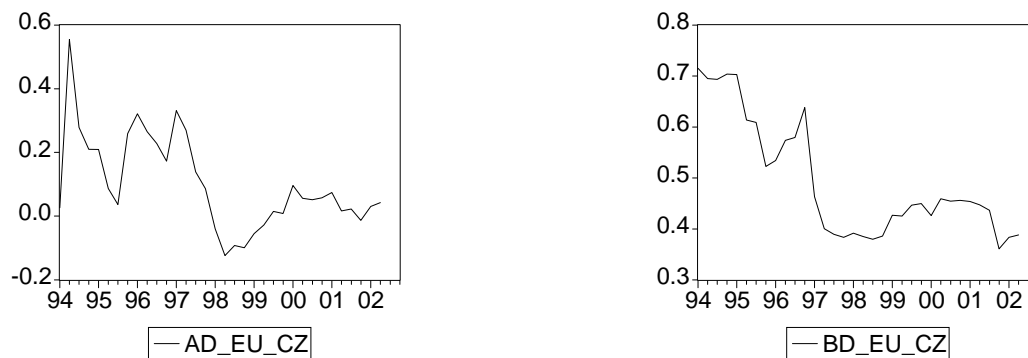
Source: Author's computations.

Note that since eq. (11) is specified in differences, the values of b_t characterize the relative importance of EU/German shocks versus American ones in explaining the Czech shock series. In the case of convergence to Germany, for example, b_t close to zero indicates that Czech shocks are more similar to German than to US shocks. Intuitively, the average value of b_t over 1996–1997 (0.3) approximately corresponds to the weights of the German and US currencies in the basket for the Czech crown (65% DEM and 35% USD) over the same period.

Next, we confront the indicators of shock asymmetry and trade intensity. Figure 5 illustrates a scatter plot of coefficients b_t (horizontal axis) versus total bilateral trade intensity (in logarithms; vertical axis).

There is a strong negative relationship between the asymmetry of demand shocks and trade intensity with Germany, captured by a high correlation coefficient (-0.81) or, alternatively, by a significant slope from an OLS regression (-0.46). Almost identical similar results hold for the Czech–EU case. These results can be interpreted in favor of the argument that trade intensity reduces demand shock asymmetry.

Figure 5: Czech Republic case, link between trade intensity and demand shock asymmetry,
           1994–2001, quarterly

Czech Republic versus Germany	**Czech Republic versus EU**
Trade intensity (vertical axis) versus shock asymmetry (horizontal axis)	

Correlation between shock asymmetry and trade intensity	
$\rho_{CZ\_GE} = -0.81$	$\rho_{CZ\_EU} = -0.81$
OLS regression of shock asymmetry on trade intensity	
(Standard errors in parentheses)	
$b_t^D = -1.56 - 0.46\ TI$	$b_t^D = -1.66 - 0.44\ TI$
(0.23) (0.06)	(0.30) (0.06)

Number of obs.	32	**Number of obs.**	32
Adjusted R-squared	0.64	**Adjusted R-squared**	0.66
S.E. of regression	0.08	**S.E. of regression**	0.07

Source: Author's computations.

4.2 Asymmetry of shocks, trade intensity, and exchange rate volatility

Table 6 reports average values of shock asymmetry over 1994–2002 and two sub-periods. The decreasing averages and variance of the time-varying coefficients b_t from eq. (11) mean that the asymmetry of the underlying shocks diminishes[18]. The results can be interpreted in favor of demand shock convergence, while the pattern of the supply shocks (Table 6b) is rather diverging. Note that the average values of the supply and demand shock asymmetries for the CEECs do not differ much from the corresponding levels for such EU member countries as Ireland, Portugal, and Spain[19].

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[18] It is also verified that the constant term a_t converges to zero for both supply and demand shocks. Results are available upon request.

[19] There is a question of whether these selected EU countries represent a good benchmark. On the one hand, they already share a common monetary policy. On the other hand, the chosen three countries due to their geographical location are said to belong to the EU "periphery". In the long term, the CEECs may be more correlated with Germany/the EU than the "peripheral" countries.

Table 6: Shock asymmetry, 1994–2002[1] (Standard deviations in parentheses)

(a) Demand shocks

	Germany			European Union		
	1994–2002	94–98	99–02	1994–2002	94–98	**99–02**
Czech Republic	0.34	0.39	**0.27**	0.49	0.54	**0.43**
	(0.13)	(0.16)	(0.04)	(0.11)	(0.13)	(0.03)
Estonia	0.41	0.39	0.43	0.36	0.41	**0.29**
	(0.07)	(0.08)	(0.06)	(0.10)	(0.10)	(0.02)
Hungary	0.50	0.52	**0.47**	0.35	0.37	**0.32**
	(0.07)	(0.08)	(0.04)	(0.04)	(0.04)	(0.02)
Latvia	0.44	0.49	**0.37**	0.35	0.45	**0.22**
	(0.11)	(0.12)	(0.05)	(0.16)	(0.14)	(0.07)
Poland	0.60	0.61	**0.60**	0.50	0.63	**0.32**
	(0.09)	(0.11)	(0.06)	(0.19)	(0.12)	(0.08)
Romania	0.72	0.84	**0.54**	0.89	0.93	**0.82**
	(0.35)	(0.39)	(0.16)	(0.42)	(0.39)	(0.47)
Slovakia	0.60	0.68	**0.52**	0.59	0.64	**0.53**
	(0.14)	(0.17)	(0.05)	(0.09)	(0.09)	(0.02)
Slovenia	0.58	0.64	**0.53**	0.78	0.83	**0.71**
	(0.08)	(0.08)	(0.04)	(0.09)	(0.05)	(0.08)
CEECs average	0.52	0.57	**0.47**	0.54	0.60	**0.46**
Ireland	0.50	0.50	0.50	0.45	0.44	0.45
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)
Portugal	0.49	0.49	0.49	0.35	0.35	0.35
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Spain	0.61	0.60	0.61	0.49	0.49	0.49
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

(b) Supply shocks

	Germany			European Union		
	1994–2002	94–98	99–02	1994–2002	94–98	99–02
Czech Republic	0.29	0.08	0.51	0.01	-0.22	0.26
	(0.30)	(0.26)	(0.15)	(0.28)	(0.15)	(0.16)
Estonia	0.66	0.66	0.66	0.72	0.76	**0.68**
	(0.12)	(0.15)	(0.07)	(0.20)	(0.26)	(0.11)
Hungary	0.46	0.45	0.46	0.39	0.43	**0.30**
	(0.09)	(0.11)	(0.07)	(0.14)	(0.14)	(0.09)
Latvia	0.75	0.86	**0.66**	0.34	0.26	0.48
	(0.17)	(0.19)	(0.07)	(0.14)	(0.10)	(0.07)
Poland	0.09	0.07	0.13	-0.02	-0.20	0.23
	(0.11)	(0.12)	(0.07)	(0.26)	(0.13)	(0.16)
Romania	0.25	0.25	**0.23**	0.13	0.05	0.25
	(0.11)	(0.14)	(0.05)	(0.13)	(0.07)	(0.10)
Slovakia	0.72	1.00	**0.47**	0.30	0.10	0.52
	(0.43)	(0.48)	(0.11)	(0.28)	(0.24)	(0.06)
Slovenia	0.58	0.70	**0.47**	0.55	0.72	**0.37**
	(0.16)	(0.15)	(0.07)	(0.37)	(0.45)	(0.12)
CEECs average	0.48	0.51	**0.45**	0.30	0.24	0.39
Ireland	0.36	0.36	0.36	0.42	0.42	0.43
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Portugal	0.43	0.43	0.43	0.45	0.43	0.46
	(0.00)	(0.00)	(0.00)	(0.02)	(0.01)	(0.02)
Spain	0.46	0.46	0.46	0.50	0.50	0.50
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: [1] *Shock asymmetry between CEECs and Germany (EU) is measured by coefficient b_t from Eq. (11). Lower coefficients mean higher symmetry. Values in boldface denote diminishing asymmetry of shocks.*

Source: *Author's computations*.

Table 7: Correlation between shock asymmetry and trade integration, 1994–2001

$$\rho_{ij} = Corr(b_{ijt}, \log(TI_{ijt}))$$

where i = CEECs, j = Germany/EU, t = quarter

for two types of shocks[1] and three indicators of trade intensity[2]

(a) Demand shocks

	Total Germany	Exports Germany	Imports Germany	Total EU	Exports EU	Imports EU
Czech Republic	-0.81	-0.84	-0.76	-0.81	-0.84	-0.74
Estonia	0.32	0.13	0.35	-0.92	-0.86	-0.85
Hungary	-0.73	-0.71	-0.72	-0.70	-0.72	-0.66
Latvia	-0.57	-0.58	-0.54	-0.90	-0.86	-0.88
Poland	-0.46	-0.31	-0.47	-0.76	-0.75	-0.72
Romania	-0.10	-0.14	-0.07	-0.09	-0.07	-0.10
Slovakia	-0.83	-0.76	-0.84	-0.82	-0.79	-0.81
CEECs average	-0.45	-0.46	-0.44	-0.71	-0.70	-0.68

(b) Supply shocks

	Total Germany	Exports Germany	Imports Germany	Total EU	Exports EU	Imports EU
Czech Republic	0.36	0.40	0.30	0.80	0.77	0.76
Estonia	0.56	0.29	0.58	-0.55	-0.44	-0.60
Hungary	0.01	0.02	0.00	-0.74	-0.75	-0.71
Latvia	-0.77	-0.80	-0.70	0.63	0.68	0.56
Poland	0.30	0.09	0.38	0.67	0.77	0.58
Romania	-0.29	-0.32	-0.24	0.58	0.60	0.52
Slovakia	-0.93	-0.86	-0.95	0.51	0.65	0.35
CEECs average	-0.11	-0.17	-0.09	0.27	0.33	0.21

[1]*Supply or demand shock asymmetry* between CEECs and Germany (EU) is measured by coefficient b_t from Eq. (11).

[2]*Trade intensity* is defined with respect to *exports*, *imports*, and *total* bilateral trade according to the following expressions (natural logarithms of):

$$TI_{ijt}^{EX} = EX_{ijt} / (EX_{it} + EX_{jt})$$

$$TI_{ijt}^{IM} = IM_{ijt} / (IM_{it} + IM_{jt})$$

$$TI_{ijt}^{T} = (EX_{ijt} + IM_{ijt}) / (EX_{it} + EX_{jt} + IM_{it} + IM_{jt})$$

where i = CEECs, j = Germany/EU, EX_{ijt} = exports from country i to country j, EX_{it} = total exports from country i, and IM denotes imports.

***Source:** Author's computations.*

Table 8: Effect of trade intensity and exchange rate volatility on shock asymmetry[1]
       (standard errors in parentheses)

a) Demand shocks
Germany

	Total	Exports	Imports	Total	Exports	Imports
Trade intensity	-0.33	-0.34	-0.30	-0.31	-0.32	-0.29
	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)
Exch. rate volatility	–	–	–	4.84	4.55	4.94
				(0.06)	(0.06)	(0.07)
Number of obs.	204	204	204	204	204	204
Adjusted R-sq.	0.47	0.47	0.43	0.59	0.59	0.57
S.E. of regression	0.15	0.15	0.16	0.14	0.15	0.14

EU

	Total	Exports	Imports	Total	Exports	Imports
Trade intensity	-0.27	-0.27	-0.25	-0.28	-0.26	0.30
	(0.06)	(0.05)	(0.07)	(0.06)	(0.06)	(0.07)
Exch. rate volatility	–	–	–	5.17	4.83	5.34
				(0.06)	(0.05)	(0.06)
Number of obs.	204	204	204	204	204	204
Adjusted R-sq.	0.53	0.55	0.56	0.55	0.55	0.55
S.E. of regression	0.17	0.18	0.18	0.19	0.20	0.20

b) Supply shocks
Germany

	Total	Exports	Imports	Total	Exports	Imports
Trade intensity	0.05	0.03	0.05	0.05	0.03	0.05
	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.05)
Exch. rate volatility	–	–	–	-1.58	-1.36	-1.61
				(2.24)	(2.04)	(2.51)
Number of obs.	196	196	196	196	196	196
Adjusted R-sq.	0.67	0.66	0.66	0.65	0.65	0.65
S.E. of regression	0.16	0.16	0.16	0.17	0.17	0.17

EU

	Total	Exports	Imports	Total	Exports	Imports
Trade intensity	0.18	0.14	0.19	0.15	0.11	0.16
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
Exch. rate volatility	–	–	–	1.48	1.71	1.58
				(2.30)	(2.30)	(2.30)
Number of obs.	196	196	196	196	196	196
Adjusted R-sq.	0.58	0.57	0.58	0.55	0.56	0.56
S.E. of regression	0.22	0.22	0.22	0.24	0.24	0.25

[1]: Estimates of Eq. (15) and (16) (OLS, fixed effects):

$$\hat{b}(j)_{it} = c_{1i} + c_2 \log[TI(j)_{it}] + c_{3i} D_i + \varepsilon(j)_{it}$$

$$\hat{b}(j)_{it} = c_{1i} + c_2 \log[TI(j)_{it}] + c_3 ERV_{it} + c_{4i} D_i + \varepsilon(j)_{it}$$

Exchange rate volatility ERV_{it} for candidate country i at quarter t is defined as standard deviations in percent from average nominal exchange rates against ECU/euro over preceding 12 months

Source: Author's computations.

Estimates of shock asymmetry are unavailable for Bulgaria and Lithuania, due to their short GDP time series. On the other hand, we exclude the series of trade intensity for Slovenia due to a lack of variation. Hence, we are left with seven CEECs to analyze the effect of trade on shock asymmetry. Table 7 shows that there is strong negative correlation between trade intensity and shock asymmetry on the demand side: more trade intensity means lower asymmetry. On the supply side, the correlation is close to zero and insignificant (Germany) or positive (EU). A similar pattern follows from the country-by-country estimates of equation (14)[20].

The panel estimates of (15) do not qualitatively change the results. An increase in trade intensity is associated with higher symmetry of demand shocks; the link with supply shocks is ambiguous (Table 8). The results for demand shocks are robust with respect to the three indicators of trade, the two benchmarks (the EU aggregate and Germany), and the estimation method (country-specific correlation coefficients or a panel framework). Demand shock convergence can be interpreted as being due to trade and monetary integration. Since intra-industry trade accounts for a large share of trade for the candidate countries, the total effect of trade on demand shock symmetry is positive. The link between trade intensity and the correlation of demand shocks is similar to the link between trade intensity and output correlation found by Frankel and Rose (1998) and Fidrmuc (2001), among others. This is not surprising, given that demand shocks, by construction, can have short-term effects on output and prices.

On the supply side, asymmetries of shocks characterize the process of catching-up at work: productivity gains in the candidate countries translate into increases in per capita incomes. Supply shocks can be also interpreted in terms of Schumpeterian "innovations", which are perceived as an engine of technological progress[21]. Higher trade intensity due to an increase in intra-industry trade may be associated with more intensive restructuring, whence might follow the observed positive impact of trade on supply shock asymmetry. On the other hand, higher trade intensity is accompanied by lower shock asymmetry in a number of cases; the estimates depend on the estimation method and on whether Germany or the EU is considered as the benchmark.

When exchange rate volatility is added, the coefficient of trade intensity does not change significantly. A decrease in exchange rate volatility is accompanied by demand shock convergence, while no notable effect on supply shocks is observed. The attempts by some candidate countries to fix their currencies to the euro contribute to the synchronization of demand shocks. To the extent that supply shocks have a long-term impact on output, there is no significant impact of nominal exchange rate volatility on supply shock symmetry.

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[20] The results are not shown since in the case of two variables the correlation coefficient and OLS regression give almost the same information.

[21] Schumpeter (1943). See Hénin (1997) and Hospers (2003) for a review.

5. Conclusion

This paper supports the view about demand shock convergence and divergence of supply shocks between the candidate countries, the EU-15, and Germany as alternative benchmarks. Estimated time-varying coefficients of shock asymmetry are then confronted with several indicators of bilateral trade intensity and exchange rate volatility. The results for demand shocks support Frankel and Rose's (1998) endogeneity argument, according to which international trade links synchronize business cycles. In terms of demand shocks, countries are more likely to satisfy criteria for monetary union membership *ex post*, as economic integration deepens. On the supply side, the link between shock asymmetry and trade integration is ambiguous. Higher trade intensity may be accompanied by both supply shock symmetry and asymmetry. Nevertheless, there are a number of considerations which complicate the interpretation of the results.

First, there is no consensus in the literature on which shocks, i.e. supply or demand, are more relevant for assessing the costs of joining the EMU[22]. The optimum currency area theory says that the more symmetric are the shocks (implying both supply and demand disturbances) between countries, the less costly is forgoing an autonomous monetary policy[23]. The empirical studies do not make a clear point either. Often there is simply no discussion of the importance of various types of shocks. Two different points of view equally exist. For example, for Fidrmuc and Korhonen (2001, p. 21) supply shocks are "more relevant in assessing the costs and benefits of different exchange rate regimes. Supply shocks have permanent output effects, whereas demand shocks have only transitory effects." On the other hand, according to Babetskii, Boone and Maurel (2004), the absence of supply shock convergence is not necessarily bad from the point of view of EMU memberships. Emerging countries, by fixing nominal exchange rates, have simply to let productivity gains translate into inflation differentials.

Second, the relationship between business cycle indicators (e.g. the correlation of de-trended economic activity) and supply and demand shocks is not straightforward. For example, Fidrmuc and Korhonen (2001) mention the puzzling behavior of Slovenia, which has highly correlated business cycles with the euro area but poorly correlated both demand and supply shocks. Given that business cycles consist of a mixture of shocks and responses, the same level of business cycle synchronization can be observed in two opposite cases: similar shocks and similar responses, and asymmetric shocks and asymmetric responses. The Slovenian example illustrates the last case. Generally, it is also difficult to quantify the impact of policy-induced responses to exogenous shocks on the estimation results (see Kenen, 2001).

Due to the above problems, and given that there is a relatively low robustness of the results among different studies, the policy recommendations should be mentioned with caution. One interpretation of the results is that that pegging national currencies to the euro or even entering the EMU would not be so costly for the candidate countries in terms of the costs associated with

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[22] See Gros and Thygesen (1999, pp. 277–280) for a discussion of the effects of various shocks in the context of the OCA theory.

[23] Mundell (1961) and McKinnon (1963) use an example of export demand shocks to illustrate the basic OCA principles. Kenen (1969) makes a further distinction between demand and technology disturbances.

demand shock asymmetry. Indeed, the EU candidate countries are characterized by levels of supply and demand shock asymmetries comparable to those for present EU member countries such as Ireland, Portugal, and Spain. However, one should bear in mind that a closed economy approach does not allow us to distinguish between domestic and foreign shocks. Therefore, we may observe more convergence or more symmetry than in the case of "pure domestic" shocks.

Furthermore, the importance of the OCA criteria to the analysis of membership in a monetary union should not be overemphasized. The degree of symmetry of contemporaneous shocks is only one aspect of the costs associated with monetary union membership. There might be other costs of EMU accession of at least the same importance as dissimilarity of shocks, for example, the incompatibility of the current Maastricht inflation criteria with the catching-up objective[24]. The still existing substantial asymmetries, in terms of shocks, among the present EMU countries suggest that this is probably not the most important criterion. Another way of looking at shock asymmetries is to recall the risk-sharing argument proposed by Mundell (1973) and recently discussed by McKinnon (2002, p. 344)[25]. Asymmetric shocks are not necessarily bad: "asset holding for international risk sharing is better served by a common currency spanning a wide area – within which countries or regions could be, and perhaps should best be, quite different."

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[24] See Buiter and Grafe (2002).
[25] See also Nuti (2002).

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Discussion of the paper:
Ian Babetski: EU Enlargement and Endogeneity of some OCA Criteria: Evidence from the CEECs

presented at the ECFIN Research Conference, October 7-8, 2004

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Motivation and methodology of the paper
Business cycle synchronization is usually regarded as one of the main OCA (Optimum Currency Area) properties, because if cycles are synchronized, the cost of foregoing the possibility of using counter-cyclical monetary policy is minimized. This issue gets into the center of interest with the CEEC countries' future joining of the EMU.

The paper underlines two opposing views on the effect of integration on business cycle synchronization: (1) The 'EC view' claims that cycles will become more synchronized as integration advances, which hypothesis is generally called as the 'endogeneity hypothesis'; (2) 'Krugman's view', who showed in the example of Massachusetts that integration could lead to specialization, hence less synchronization. The aims of the paper are (1) to check the temporal change in business cycle synchronization for the new EU members in 1990/4-2002, (2) to draw conclusions on the possible validity of the two opposing views for these countries, (3) to relate business cycle synchronization to some economic variables like trade and exchange rate volatility.

To this end, the paper performs econometric analysis in three steps.
First, the paper estimates, country by country, a bivariate VAR model including GDP growth and inflation to recover supply and demand shocks. This methodology is originated from the seminal work of Blachard-Quah (1989).
In the second step the paper estimates time-varying correlation coefficients between EU's and individual country's shock, using the supply and demand shocks obtained in the first step,
Finally, the time-varying correlation coefficients are related to trade and exchange rate volatility in a panel framework.

Main Results
The main results of the paper are the following. Demand shocks correlate in most CEECs at a similar level to Ireland, Spain, and Portugal and the correlations have increased in most CEECs, but not in Ireland, Spain, and Portugal over the pervious years. Supply shock correlation is similar (and even on average larger) than demand shock correlation (although the paper seems to emphasize that supply shock correlation is smaller), but supply shock correlations have not increased over time. Demand shock correlation is well related to trade and exchange rate volatility, but supply shock correlation is not related to trade.

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Comments
We organize our comments along five main lines.

1. Motivation of the paper

Our first comment is a general comment related to the theoretical background and is relevant for all papers studying business cycle correlation for drawing conclusions on optimum currency areas, including our paper on synchronization (Darvas-Szapáry 2004).

First, we know that Krugman's lesson from Massachusetts *is* a true lesson: the case study provides a demonstration when monetary union led to specialization and when a common shock affected the US economy, it had a much stronger effect on Massachusetts leading to longer and more painful adjustment period. Hence, monetary union led to specialization and less synchronization, although no one would have suggested a separate currency for Massachusetts.
In fact, the US economy prospers well with varying regional business cycles, as was shown, for example, by the Five Tests study by HM Treasury (2003). This is because financial market integration, price and wage flexibility and labor market mobility can help the economy to adjust to idiosyncratic shocks. The US experience shows that these traditional OCA criteria could be more useful indicators for deciding on possible joining a monetary union than the past business cycle correlations.
One should also ask the question whether analysis of past CEECs data could be informative for the future. The author aims to discriminate between two opposing views on the effects of integration on business cycle synchronization using data for 1990/94-2002. First of all, the two possible processes are not exclusive: a mixture of the two can take place at the same time in an economy and by econometric techniques proposed by the author one will only measure the 'net' effect of the two. In addition, whether conclusions drawn for this period could be informative for developments during the future monetary union memberships of these countries is an open issue.

2. Measuring shocks[1]

The paper relies heavily on the identification of shocks, all further calculations crucially hinge in this first step. In fact, the adopted Blanchard-Quah (1989) shock identification was very popular in the literature, for example, Fidrmuc-Korhonen (2004) in a survey article listed thirteen papers using this methodology for studying shocks of the CEECs.

The method starts with a reduced form VAR estimation for inflation and output growth and imposes one restriction to identify structural shocks: demand shocks have no long-run effect on output (but has on prices in contrast to the claim of the paper).
There are several important general problems with this methodology, already identified in the literature. For example, Faust-Leeper (1997) strongly criticized the technique because of three main problems:
1) Long-run restrictions are imposed to data from finite samples,[2]
2) Shock aggregation: too few (namely two here) identified shocks might be mixtures of the underlying ones, and even if the underlying shocks satisfy the economic criteria

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[1] This section draws on some preliminary results of our ongoing research, Darvas-Horváth (2004).
[2] A possible solution to this problem could be the recent sign restriction shock identification method popularized by, e.g., Uhlig (1999), Canova-De Nicoló (2002), and Peersman (2004).

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(e.g. underlying demand shocks has no long-run effect on output), both identified shocks might be mixtures of *all* underlying shocks,

3) Time aggregation: the technique assumes that the identified shocks are independent; although at quarterly frequency policy can respond to supply shocks as well, invalidating the independence assumption.

Cooley-Dwyer (1998) added further important critiques of the techniques. First, they showed that the so called 'technical assumptions' behind the Blanchard-Quah approach could have strong effects on the results. Second, they showed that the technique is not robust to model specification. This result was achieved by setting up theoretical models satisfying the assumptions behind the technique, simulating data from the known data generating process, and estimating impulse responses of shocks identified by the BQ-technique for simulated data. The results indicated that estimated impulse responses differed in some case markedly from the true impulse responses.

Unfortunately these econometric problems are not referred to in the paper, nor in other papers surveyed in Fridmuc-Korhonen (2004).

In addition to the general weaknesses of this type of SVARs, there is a special problem in the CEECs. The methodology requires stationary variables, however, at least inflation in the analyzed period showed a clear trending behavior (Figure 1).

Figure 1: CEEC Inflation rates, January 1993 – December 2003
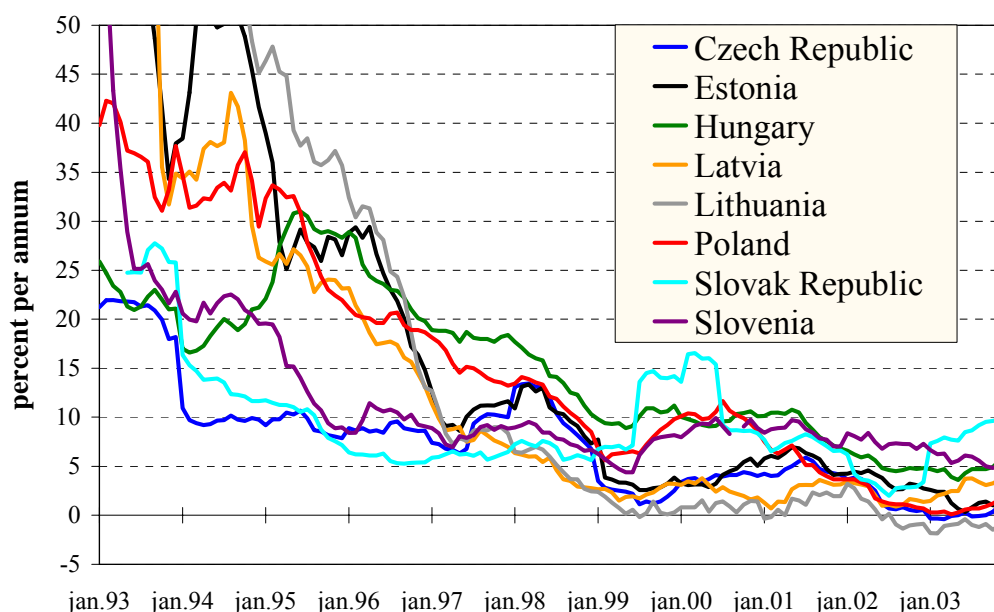
Source: IMF, *International Financial Statistics*

In order to check the stability of the inference, we performed a simple analysis. We calculated the correlation between CEECs and EMU supply and demand shocks in the period 1998-2001 using different sample periods. That is, we first estimated the VARs for 1995Q1-2001Q4, identified shocks (both for EMU and for the country under study) and calculated correlation between shocks of the EMU and the country under study for 1998Q1-2001Q4. Next, we estimated the VAR model for 1995Q1-2002Q1 and calculated correlation of shocks

for the same 1998Q1-2001Q4 period. We continued the lengthening of the sample observation one-by-one so that finally we estimated a VAR for 1995Q1-2003Q4 and calculated correlation coefficients for the same 1998Q1-2001Q4 period. By this procedure we obtained nine estimates for the correlation in 1998Q1-2001Q4. The results for four countries are shown in Figure 2.

Figure 2: Correlation of supply and demand shocks of CEECs and the EMU in 1998Q1-2001Q4, by estimating the VAR for different sample periods
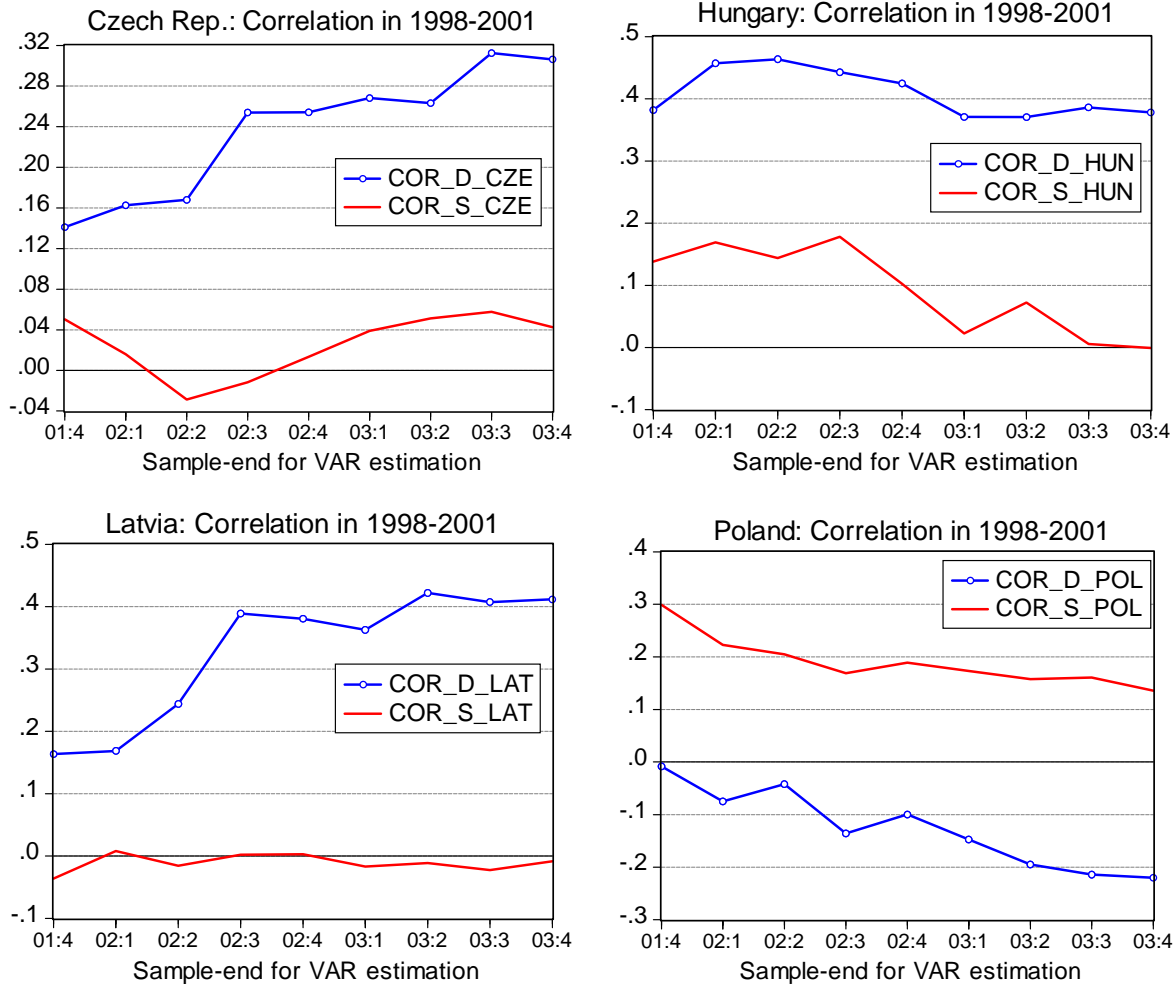
The figures clearly indicate that lengthening the sample alters inference for the past substantially in some cases.

3. Time-varying correlations

The paper estimated the following time-varying coefficient model with maximum likelihood using the Kalman-filter:

$$\varepsilon_t^{(EU)} - \varepsilon_t^{(AC)} = a_t + b_t\left(\varepsilon_t^{(EU)} - \varepsilon_t^{(US)}\right) + \mu_t$$

where $\varepsilon_t^{(i)}$ is the shock identified, i=EU for EMU, i=AC for the new member under study, and i=US for the USA; a_t and b_t are time-varying coefficients and μ_t is the error term.

We found this specification disputable. The paper gives no motivation why US data is included as part of the regressor. However, many papers indicated the emergence of a 'world business cycle', in which case the regressor tends to be zero. When the EMU and USA shocks are perfectly correlated, then the regressor is zero and model cannot be estimated. In practice, it is unlikely that shock identification for the EMU and the USA will lead to exactly the same shocks, but when shocks in these two main economic area tend to be similar, the adopted equation is meaningless. We suggest the following simpler specification instead::

$$\varepsilon_t^{(AC)} = a_t + b_t \varepsilon_t^{(EU)} + \mu_t$$

In addition to the specification issue above, this second step relies on the maximum likelihood estimation of the state-space representation evaluated with the Kalman-filter. In our experience, Kalman-filtering of state space models is very sensitive to initial conditions (for the mean and variance of latent variables). However, the author even does not mention the issue of such a problem and not at all mentions how initial conditions were selected. Maximum likelihood estimation also turned to be sensitive to the starting values of the parameters of the model, which are also ignored in the paper. Due to the problems we listed above, we think that sensitivity analysis (to initial conditions and starting values) is indispensable for gaining proper believe in the results.

Let us highlight a strange result of the paper, which likely reflects the problems with initial conditions and starting values. The time-varying parameters for Ireland, Portugal, and Spain are constant over time with (close to) zero standard errors (see Table 6 in the original paper) both for demand and supply shocks. In our experience these result usually emerge when the ML estimate of some variance parameter turne to be zero. A sensitivity analysis could reveal whether the zero-variance results are robust to initial conditions and starting values, and the author also should perform formal tests for parameter stability before using the time-varying technique.

4. Underestimated standard errors

The paper performs econometric analysis in three steps and in the second and third steps derived measures (and not observed values) from previous steps are used as the dependent variable. However, thee multi-level approach used in the article does not appropriately account for the uncertainty in the first and second level parameter estimates when obtaining parameter estimates and standard errors in the second or third stage. In finite samples, this leads to underestimation of the standard errors in the second and even more in the third stage. This problem had been recognized by another presenter at the Conference (Marianne Baxter) who proposed to account for the possible measurement errors into the model.

5. Panel approach

In the third stage of analysis fixed effect models are used to relate measures of asymmetry to trade and exchange rate volatility in a panel framework. In doing this, slope coefficient heterogeneity is not addressed, while in the presence of heterogeneity, FEM estimates may be meaningless (Hsiao, 1986, p. 7). F-tests should precede the choice of possible panel models that can capture different level of heterogeneity (Hsiao, 1986, Chapter 2, p. 11-24). Another possible tool for the investigation of heterogeneity when the cross-sections are relatively few is cross-validation (Beck, 2001).

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The Puzzles on International Comovement: The Role of International Trade and Non-Competitive Banking

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Abstract

To study the international transmission of business cycles among big countries, I extend a standard two-country RBC model through the introduction of trade in goods, a non-competitive banking sector and endogenously countercyclical markups in the market for loans. Using non-competitive behavior in the financial sector to explain the international transmission of shocks is a novel feature of the model. It also produces a financial accelerator with interesting policy implications. In the calibration exercise I offer a potential solution to the "consumption - output" or "quantity" anomaly and I match the cross-country comovement of investment and employment and the countercyclicality of net exports.

1 Introduction

Which are the channels through which business cycles in one country are transmitted to other countries? This is a major subject within the literature on international economics and a significant amount of research has been devoted to it. Unfortunately, there is still no clear answer to the question of what determines business cycle comovement.

In particular, there are important discrepancies between the data and what models with complete markets predict regarding the international co-movement of macroeconomic aggregates. These discrepancies were first identified by Backus, Kehoe and Kydland (1992) for the United States and the OECD countries. They have been labeled "anomalies" when proved robust to various changes to parameter values and model structures. The discrepancies are two. First, in the data, correlations of output across countries are larger than analogous correlations for consumption. With only a few exceptions, previous work[1] obtains consumption cross-country correlations that significantly exceed output correlations. This inconsistency has been labeled the consumption / output anomaly or the quantity anomaly. Second, investment and employment comove across countries in the data, while most models predict negative values for their cross-country correlation. Many candidates have been suggested to propose a solution to these puzzles, but no consensus has been built on what is the best way to explain them.

To study the international transmission of business cycles among big countries and to propose a potential solution to the anomalies, in this paper I introduce two elements into an otherwise standard two-country dynamic general equilibrium model. First, I expand the standard model by allowing for trade in two different goods. Having two goods and specialization in production provides both demand and a terms of trade channels to the in-

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[1]See Appendix B for a table summarizing the literature's results.

ternational transmission of productivity shocks. When a positive shock hits one of the countries, the other faces an increased demand for the good it produces, which is an imperfect substitute for the shocked country's good, and some of the benefits spill over to the rest of the world[2]. Terms of trade change too and imply a positive wealth effect for the foreign country. My modeling is consistent with the recent empirical results in Baxter and Kouparitsas (2004), who show that while bilateral trade is robust in explaining comovements, other variables typically used by the literature are not. However, previous work has shown that trade in goods is not enough to account for the positive correlation of macroeconomic aggregates across countries.

Second, I model financial market frictions through the introduction of a non-competitive banking sector and endogenously countercyclical markups in the market for loans. Here, I base my modeling on empirical evidence characterizing capital production and the banking sector in the United States economy, which is documented in Olivero (2004). Using non-competitive behavior in the financial sector to explain the international transmission of shocks is a novel feature of the model[3]. It also produces a financial accelerator coming from the supply side of the loans market that has not been previously modeled to my knowledge. Investment is financed by price setting banks with market power, that make cheaper loans available in good times. This has interesting policy implications due to its macroeconomic impacts: With markups in the market for credit being countercyclical, credit becomes

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[2]Stockman and Tesar (1998) and Heathcote and Perri (2002) show how multiple goods can generate cross-country output correlations that are more consistent with the data.

[3]Rotemberg and Woodford (1995) highlight the importance of including imperfect competition in theoretical models, by noticing its impact on the relationship between output, the labor input and wages. Given that many of the puzzles in macroeconomics relate to these three variables, they advocate for the incorporation of imperfectly competitive product markets in models of real business cycles. Here, I model imperfect competition in credit markets.

more expensive in bad times; as a result, firms may delay investment and production decisions and the recession may be made even worse and longer. This should call for stabilization policies to be made more effective in economies where these markups are more countercyclical.

In models with perfectly functioning credit markets and no exogenous restrictions to capital mobility, capital would flow from the rest of the world into the country where productivity is relatively higher. This gives rise to the negative cross-country correlations of factors of production and to the very low cross-country output correlations generally obtained in theoretical models. Conversely, in this economy financial imperfections prevent capital from flowing from the rest of the world into the relatively more productive economy, and help to get cross-country comovement for investment, employment and output.

Consistent with empirical evidence, in the model entrepreneurs operate an increasing returns to scale technology for capital production, they need outside financing to build the capital stock, and these funds are obtained from an oligopolistic banking sector. This "global" oligopolistic banking sector collects deposits from households and lends to entrepreneurs in both countries. Banks set an interest rate on loans which exceeds the opportunity cost of funds. I will interchangeably refer to the difference between the interest rates on loans and deposits as the spread, price-cost margin or net interest margin (NIM) in the financial sector[4].

Increasing returns to scale allow for the elasticity of the demand for credit to be positively related to investment and for markups in the non-competitive banking industry to be endogenously countercyclical. With a falling market power and a lower markup in the economy that has benefited from a positive productivity shock, the cost of credit falls relative to standard models that lack this friction. This impacts capital production, employment and the

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[4]I borrow this last term from Saunders and Schumacher (2000).

marginal utility of consumption in a way such that the rate of return on domestic deposits ends up being countercyclical. Banks start using local deposits, which are now cheaper for them, to finance both domestic and foreign loans, which makes the foreign rate on deposits fall too. The cost of credit falls in the foreign country and drives an increase in both their investment and employment. A strength of the paper is that restrictions to the international mobility of financial capital arise from the endogenous behavior of real interest rates and its implications for the allocation of the global supply of credit among countries in a decentralized economy.

The paper relates to earlier work that has used restrictions to international capital flows to get increased cross-country correlations of output and factors of production. For example, Heathcote and Perri (2002) model an economy where risk-sharing is completely prohibited; Kollman (1996) and Baxter and Crucini (1995) study economies where risk sharing is restricted by allowing agents to trade in only one risk-free financial asset; Kehoe and Perri (2002) study enforcement constraints that limit countries to keep the autarky level of utility below that of financially integrated economies; and Kollman (1996) introduces adjustment costs to investment. My work is also embedded into the literature that has appealed to imperfectly competitive product markets as a mechanism for the international transmission of productivity shocks (Ubide (1999), Cook (2002) and Head (2002)).

With a few exceptions, the literature has been relatively unsuccessful at explaining the puzzles. Previous work has been able to only reduce the magnitude in which the cross-country correlation of consumption exceeds that of income. Regarding the international comovements of investment and employment, the most successful papers have reproduced at most one of them. I propose a potential solution to the quantity anomaly in the calibration exercise, and I obtain positive cross-country correlations of investment and employment. I do so while still reproducing other stylized facts of the US and

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OECD economies, namely, the countercyclicality of net exports, the real interest rate and NIMs for the banking industry, and the positive cross-country correlation of bank spreads.

My results are robust to several checks performed on the structure of the model. First, conclusions hold for a model where non-competitive banks can get only domestic deposits, while still lending to both countries. Second, endogenously countercyclical markups can be obtained with constant returns in the production for capital, and either deviating from the Cobb-Douglas assumption for goods production or modeling procyclical entry in the banking industry. Third, the qualitative results stay unchanged for a model with Cobb-Douglas preferences.

By delivering endogenously countercyclical markups, the paper is related to the literature that challenges the traditional industrial organization approach according to which markups are procyclical. This literature is composed by only a few papers that address theoretical ways to deliver this countercyclicality (Rotemberg and Saloner (1986), Gali (1994), Ravn, Uribe and Schmitt-Grohé (2004)).

I proceed as follows. I show the data's stylized facts in Section 2. In Section 3 I present a review of the previous work addressing the anomalies. I develop the model in Section 4, and analyze the intuition about the key forces driving the model's results in Section 5. In Section 6 I show the calibration and simulation results. I conclude in Section 7. In Appendix A I discuss two alternative ways to obtain endogenously countercyclical markups for the banking industry. I also present and solve a slightly different model with a CES production function for goods. There I show how endogenously countercyclical banking markups can also be obtained just by deviating from the Cobb-Douglas specification and the isoelastic demand for credit that it implies. In Appendix B I present a chart with a detailed review of the literature.

2   The Data

In Table 1 I report cross-country correlations between the main macroeconomic aggregates for OECD countries and the United States (US), calculated using OECD Quarterly National Accounts and OECD Main Economic Indicators (MEI) data for the 1960-2002 period[5]. As it can be seen there, output, investment, employment and consumption are all positively correlated across countries. Consumption correlations are lower than output correlations.

Table 1: The Data on International Comovement	
$\rho(C,C^*)$	0.3311
$\rho(Y,Y^*)$	0.4496
$\rho(I,I^*)$	0.4151
$\rho(L,L^*)$	0.2167

Notes: Correlations between the United States and Europe for logged and
Hodrick-Prescott filtered data. The sample period is 1960:I - 2002:II.
Source: OECD Quarterly National Accounts and OECD MEI data available
in Fabrizio Perri's webpage.

Worthy of note is the fact that, as discussed in Heathcote and Perri (2003), business cycles in the US have become less correlated with those of the other OECD countries over time[6]. Correlations calculated for the 1970-1990 period

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[5]Data available in Fabrizio Perri's web page (http://pages.stern.nyu.edu/ fperri/research.htm). European data refer to the following 15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and United Kingdom. Data for employment between 1972.1 and 1983.4 is only for the following subgroup: Austria, Finland, France, Germany, Italy, Norway, Spain, Sweden and United Kingdom. Data for employment between 1962.1 and 1971.4 is only for the following subgroup: Finland, Germany, Italy, Sweden and United Kingdom.

[6]Heathcote and Perri (2003) can account for this by a combination of changes in the nature of real shocks and an increase in US financial integration. The estimated process for TFP shocks changes very little. Increased risk-sharing tends to reduce the international comovement of investment through permitting intertemporal specialization in production.

by Backus, Kehoe and Kydland (1992) are 0.51 for private consumption, 0.66 for output, 0.53 for investment and 0.33 for employment.

Figure 1 shows the positive comovements referred to above.

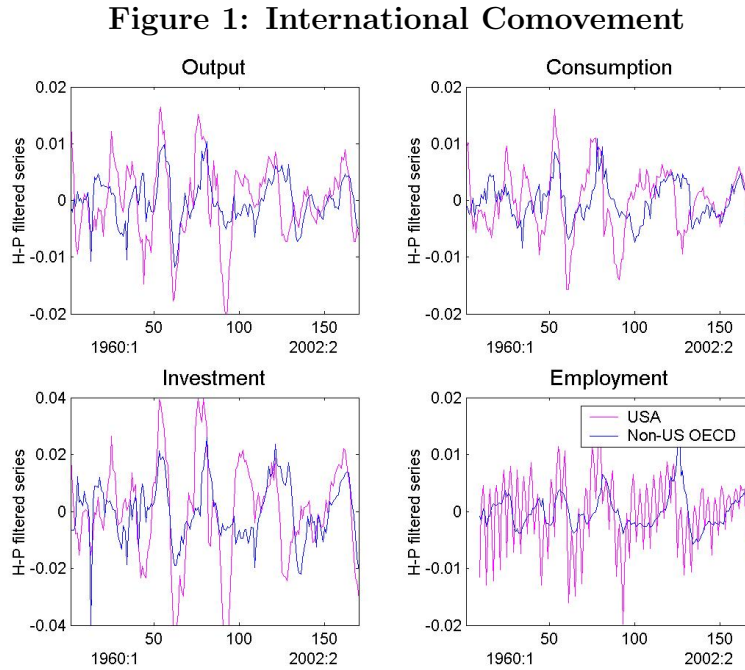**Figure 1: International Comovement**

Table 2 shows the cross-country correlations between the macroeconomic aggregates for the US and some European economies. As shown there, the consumption/output anomaly and the comovement of investment and employment across countries are still present when analyzing each country in particular.

There are also some credit markets stylized facts that I want to reproduce

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More integration also leads to decreased cross-country consumption correlations because of lower substitutability between home and foreign goods, a stronger home-bias in consumption and higher willingness to substitute consumption intertemporally.

Table 2: The Data on International Comovement

Country	$\rho(C,C^{US})$	$\rho(Y,Y^{US})$	$\rho(I,I^{US})$	$\rho(L,L^{US})$
Australia	-0.13	0.6	0.21	-0.17
Austria	0.45	0.54	0.57	0.58
Canada	0.46	0.81	0	0.5
France	0.42	0.46	0.22	0.36
Germany	0.64	0.85	0.66	0.6
Italy	0.04	0.49	0.39	0.11
Japan	0.49	0.66	0.59	0.48
Switzerland	0.48	0.48	0.38	0.43
UK	0.42	0.64	0.46	0.68

Source: Baxter (1995).

	$\rho(C,C^{US})$	$\rho(Y,Y^{US})$	$\rho(I,I^{US})$	$\rho(L,L^{US})$
France	0.432	0.4901	0.4861	-
Italy	0.2756	0.4911	0.352	0.2743
UK	0.8333	0.913	0.9553	0.7656

Data are on the correlations between the United States and Europe for logged and Hodrick-Prescott filtered data for 1980-1995.

Source: United Nations Common Database.

by modelling a non-competitive banking sector. Net interest margins (NIMs) or bank spreads, defined as the difference between the interest rates on loans and deposits, are countercyclical in the US. In Europe, the same is true for Germany and the United Kingdom (see Table 3 for the data and spread specifications). The countercyclicality of NIMs is also documented in Olivero (2004). There I show that a 1% percentage point increase in the growth rate of GDP per capita lowers bank spreads by 0.24 percentage points in the United States economy. This is true even when controlling for the impact on spreads of countercyclical monetary policy, default risk, capital structure and branching regulations, and changes to market concentration measures among other factors.

In the American economy additional evidence that the degree of market

power is inversely related to the level of economic activity can be found by looking at the number of banking institutions and branches. They are both procyclical. The correlation of the number of commercial banks branches to GDP is positive and equal to 0.13. That of the number of banking institutions to GDP equals 0.24. The evolution of the number of banking institutions and branches is plotted in Figure 2. My setup will not rely on this procyclicality though. The number of banks is exogenous in the theoretical model. Given that interstate branching was completely unrestricted only after June 1997 in the US, these correlations were calculated also separately for the 1967-1996 and 1997-2000 periods. It can be seen in Table 3 that banking institutions and branches are both procyclical in these two periods.

Another indicator is given by the inverse relationship between measures of market concentration and GDP. Using the Report of Condition and Income data[7], I calculated the Herfindahl-Hirschman index (HHI)[8] for the deposits and loans markets. As shown in Table 3, both indexes have a slight negative correlation with detrended GDP.

Thus, for the US economy there is substantial evidence that market power in the banking industry is inversely related to GDP. Nevertheless, it is important to highlight that neither of the last two facts is crucial to the mechanisms at work in my theoretical model. There the number of banks and the degree of concentration in the entire industry are fixed at business cycle frequencies. I only rely on countercyclical markups to get my results. I still interpret countercyclical markups as evidence of the degree of market power falling with GDP given that in Olivero (2004) I document that this countercyclicality is a feature of the US data even after controlling for several other issues that might make the markup fall with the level of aggregate economic activity.

Moreover, the countercyclicality of price-cost margins could arise from

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[7]These data are available quarterly for US banks from 1976 to present.

[8]The HHI is given by the sum of squared market shares for individual banks.

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Figure 2: USA Banking Institutions and Branches
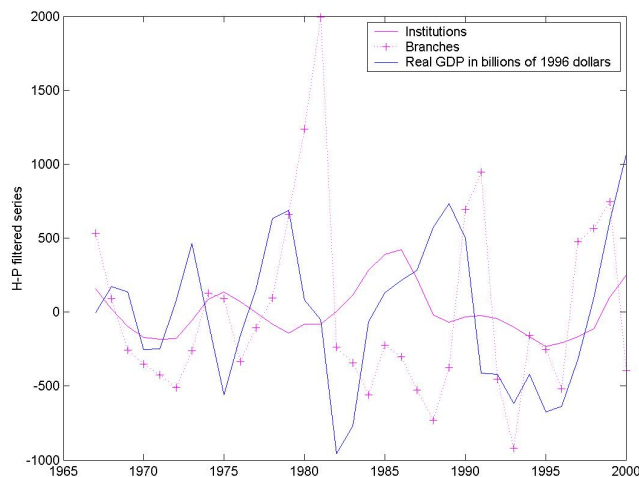
costs of collusion increasing with GDP as in Rotemberg and Saloner (1986), from banks' costs over the interest rate on deposits falling over the cycle, or from a procyclical price elasticity of the demand for credit. Although the driving force of this cyclical behavior is not crucial to my model, I choose the third in line with my interpretation of the data mentioned in the previous paragraph. Moreover, in the theoretical model, it is increasing returns to scale for producers of capital what allow me to obtain a procyclical enough elasticity. There is substantial evidence of increasing returns in the investment sector[9].

There is also evidence that real interest rates are countercyclical in both the United States and Europe (Prescott et al (1983), Plosser (1987), Fama and French (1989), King and Watson (1996) and Seppala (2000)). My model

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[9]This evidence is documented in Antweiler and Trefler (2000), Harrison (2003) and Maioli (2003) among others.

will be able to match this behavior too.

The last issue that I want to look at in the calibration exercise is the cross-country correlation of banks spreads. I calculated this statistic for alternative measures of NIMs in the European banking sector and for particular OECD countries (Germany and the United Kingdom). As shown on Table 3, except for the case of Germany, banks price-cost margins comove across countries.

Standard international real business cycle models with only one good and complete financial markets fail to reproduce the comovement refered to above. They predict negative cross-country correlations for investment and employment; a very low cross-country correlation for output, driven mainly by the correlation of the exogenous process assumed for total factor productivity; and a perfect (or close to perfect) correlation for consumption levels. That is, predicted consumption correlations are always higher than those for output, what has been labeled the quantity anomaly.

In this paper I am able to reproduce the positive correlations in the data, the ranking between consumption and output correlations, and the countercyclicality of net exports. My results also match the countercyclicality of real interest rates and of bank spreads and the positive comovement of bank spreads across countries.

Table 3: Banking Sector Stylized Facts

Spread Correlation with Output	
USA	
Spread = (Bank prime − certificate of deposits rate)	-0.41
Spread = (Bank prime − 3 month Treasury Bill rate)	-0.21
European Countries	
Germany (Current account credit - 3 month deposit rate)	-0.29
United Kingdom (Lending rate - deposit rate)	-0.13
Interest Rates	
USA: $\rho(r, GDP)^a$	-0.27
United Kingdom: $\rho(r, GDP)^b$	-0.17
USA: Market Concentration	
ρ(**number of branches, GDP**)	
$1967 - 2000$	0.13
$1967 - 1996$	0.15
$1997 - 2000$	0.22
$\sigma_{branches}/\sigma_{GDP}$	2.14
ρ(**number of banking institutions, GDP**)	
$1967 - 2000$	0.24
$1967 - 1996$	0.12
$1997 - 2000$	0.98
$\sigma_{bankinginstitutions}/\sigma_{GDP}$	0.32
ρ(**HHI, GDP**)	
HHI for deposits	-0.06
HHI for loans	-0.02
Cross-Country Correlation of Spreads	
With European spread (for up to 3 months deposits and loans rates)	0.4441
With European spread (for up to 1 year deposits and loans rates)	0.1228
With Germany	-0.147
With UK	0.1646

Source: Board of Governors of the Federal Reserve, FDIC and Report of Condition and Income for US data and International Financial Statistics for European data.

US data on interest rates is quarterly for 1967.I to 2003.I. European data on interest rates is quarterly for 1996.I to 2003.I. Data on number of institutions and branches is annual for 1966-2000.

a Taken from King and Watson (1996).

b Based on Seppala (2000) for the correlation between the one-year real interest rate and the cyclical component of real GDP per capita.

3 Background Literature

Several papers have looked at various determinants of the international transmission of business cycles and tried to explain these discrepancies between the cross-country correlations in the data and what benchmark models with complete markets predict. They have done this through very different modelling strategies, including credit market imperfections, imperfect competition in input markets, household production, government spending entering preferences and shocks to beliefs among others.

My paper is most closely related to two different strands of this literature: The work using credit market frictions to explain the puzzles, and the literature on imperfect competition in goods markets as a source of international propagation of shocks.

The most influential papers within the first strand are Baxter and Crucini (1995), Kollman (1996), Heathcote and Perri (2002) and Kehoe and Perri (2002).

Baxter and Crucini (1995) use a two-country, single-good model of an economy where only non-contingent bonds can be traded. Their model predicts high output correlations and low consumption correlations. However, they find that incomplete markets modify the predictions of the standard RBC model only when productivity in each country follows a random walk without international spillovers and with correlated innovations. This is not exactly consistent with empirical estimations of the process followed by total factor productivity in the US and OECD economies.

Kollman (1996) develops a single good model with adjustment costs to investment. Market incompleteness is given by the fact that only debt contracts (risk-free bonds) can be traded in asset markets. As a result, agents are less able to offset the effects of idiosyncratic shocks, and consumption across countries is less correlated than under complete markets. However, he

gets negative investment and employment cross-country correlations.

Heathcote and Perri (2002) build a two-country, two-good model, but one of financial autarky where risk sharing is completely prohibited. Autarky helps them get cross-country consumption, output, investment and employment correlations similar to those in the data.

Kehoe and Perri (2002) endogeneize market incompleteness. They solve some of the anomalies between theoretical predictions and the data through the introduction of imperfectly enforceable international loans in a two-country, one-good model. The credit market imperfection comes from the requirement that each country prefer the allocation it receives when participating in international financial markets relative to the autarky one. This friction helps to account for the discrepancies more than does exogenously restricting available trade in assets. One of the key mechanisms that work to get an increased output correlation is given by the severe restrictions that the enforcement constraints impose on risk-sharing and international investment flows. As regards consumption, the correlation across countries is reduced because risk-sharing is not feasible if the enforcement constraints are to be met. The restrictions that these constraints impose on financial capital mobility do not arise from arbitrage arguments in a decentralized economy[10]. The strength of this paper lies on the endogeneity of financial markets incompleteness. Risk sharing is not exogenously restricted as in most of the models.

This paper is also embedded within the literature on imperfectly com-

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[10]Kehoe and Perri (2002) show how to decentralize this economy. Private agents act competitively in an economy with capital income taxes and take as given the government's default decisions on foreign debt. With both such instruments-debt default and capital income taxes-the constrained efficient allocations can be decentralized. When the capital income tax is set appropriately, it both aligns the intertemporal marginal rates of substitution of the private agents with those of the planner and makes private agents internalize the external effect generated by investment (Kehoe and Perri (2002)).

petitive goods markets as a mechanism for the international transmission of productivity shocks. Rottemberg and Woodford (1991, 1992 and 1995) use countercyclical markups as a propagation mechanism, but they do not specifically address the international RBC puzzles. Head (2002) explains comovements with procyclical product inventions. In a small open economy model, Schmitt-Grohe (1998) models countercyclical markups to explain the transmission of US interest rate and trade shocks to the Canadian economy. Ubide (1999) introduces government spending entering households' preferences, imperfect competition in the goods markets, indivisible labor and complete markets in an international business cycle model. Exogenous shocks affect technology, markups and government spending in his model, and he concludes that markup fluctuations alone are not able to reproduce the main stylized facts[11], and that government spending shocks are needed to match the data. Among the several specifications he estimates, the best results are obtained for a model with exogenous government spending and markup shocks. He does not get positive comovements for all variables in a variable markups model driven just by technology shocks. Ubide argues in his paper that imperfect competition is key in models of international business cycles and that it should be endogenized. This paper will endogenously model imperfect competition in the financial sector, something to my knowledge not previously done in the context of the International RBC literature.

Specially relevant is Cook (2002), with an imperfectly competitive dynamic general equilibrium setup. He models procyclical sequential market entry for final goods producers in a market characterized by Cournot competition with free entry. This acts as an international transmission mechanism for productivity shocks because, with trade in differentiated goods, a productivity increase in one economy leads to additional business formation in the

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[11]They reproduce cross-country correlations, but predict countercyclical consumption and productivity.

other country through demand spillovers. Business formation brings countercyclical markups, what leads to an expansion in employment, investment and production in both economies. Sequential entry and a first-mover advantage to incumbents are needed to obtain markups that are elastic enough to cause international comovement. An alternative framework with simultaneous entry does not work. Cook (2002) abstracts from firms' financing issues and credit market imperfections.

In Table 4 I summarize the results of the papers reviewed here. Boxes around the numbers indicate that either the consumption / output anomaly is solved, positive cross-country correlations are obtained for investment and/or employment or the countercyclicality of net exports is reproduced.

In an extended table in Appendix C I present the literature's main results. There I include simulation results for both the papers reviewed here and some others that try to solve the anomalies with models not directly related to mine. The goal there is to show the vast work on these puzzles and the relative lack of success in finding a solution to them.

I improve over previous work by being able to solve the anomalies while still reproducing the countercyclicality of net exports, bank NIMs and real interest rates.

Table 4: The Literature Results

	ρ(C,C*)	ρ(Y,Y*)	ρ(I,I*)	ρ(L,L*)	ρ(NX/Y,Y)
Data	**0.3311**	**0.4496**	**0.4151**	**0.2167**	**-0.37**
Backus et al model	0.88	-0.21	-0.94	-0.94	0.01
Baxter-Crucini (1995)[1a]	0.95	0.04	0.02	-0.7	0.65[8]
Baxter-Crucini[1b]	0.92	0.06	0.12	-0.67	0.65[8]
Baxter-Crucini[2a]	0.89	-0.41	-0.92	-0.91	−0.18[8]
Baxter-Crucini[2b]	-0.28	0.54	-0.5	-0.56	−0.28[8]
Kollman (1996)[3]	0.38	0.1	-0.12	-0.12	-0.07
Ubide(1999)	0.73	0.26	-0.15	0.32	−0.55[8]
Ubide (1999)[4]	0.82	0.91	0.85	0.91	−0.22[8]
13- Lubik (2000)[5a] - TFP shocks	0.42 - 0.79	0.61 - 0.77	0.89 - 0.99	-	-0.14 - 0.01
13- Lubik (2000)[5b] - TFP and money shocks	0.33 - 0.71	0.51 - 0.66	0.78 - 0.96	-	-0.15 - -0.01
Heathcote-Perri (2002)	0.85	0.24	0.35	0.14	0
Cook (2002)	0.284	0.521	0.188	0.884	-
Head (2002)[6a]	0.81	0.485	0.343	0.293	-0.187
Head (2002)[6b]	0.853	0.486	0.451	0.302	0.085
Kehoe-Perri (2002)	0.29	0.25	0.33	0.23	0.27
Alesandria-Choi(2004)[7]	0.2	0.43	0.39	0.64	-0.43
This paper - GHH U	0.6657	0.8047	0.8607	0.6132	-0.7592
Cobb-Douglas U	0.708	0.9922	0.8975	0.5862	0.1433

1a- *Baxter and Crucini (1995): Complete markets Backus et al parameterization of TFP process.* **1b-** *Idem with only noncontingent bonds.* **2a-** *Complete markets Unit root in productivity without spillovers.* **2b-** *Idem with only noncontingent bonds.*

3- *Kollman (1996): Only risk-free debt contracts. Adjustment costs to investment.* **4-** *Ubide (1999): With exogenous G and markup shocks.* **5-** *Lubik (2000): A two-sector, multiple-good, monetary business cycle model with price stickiness in the non-traded sector.* **6a-** *Head (2002): Purely country-specific shocks and IRS, which operate through changes in the world-wide variety of intermediate goods (trade in varieties-induced link).* **6b-** *Constant returns to variety and strongly correlated technology shocks, Corr(e1, e2) = 0.7.* **7-** *Alessandria-Choi (2004): A complete markets economy with trade in differentiated intermediate goods and fixed costs to exports. Firms subject to idiosyncratic shocks.* **8-** *NX in this case.*

4 The Model

I extend a standard two country dynamic, general equilibrium model by introducing international trade in two imperfectly substitutable goods, and a credit market friction given by the fact that entrepreneurs need to finance capital production with loans, and that these are granted by an oligopolistic banking sector.

There is a representative household, a representative firm and a representative entrepreneur in each country. A "global" oligopolistic banking sector collects deposits and lends to both economies.

I present the setup for the home country in this section. Analogous optimization problems apply to all agents in the foreign country. I use stars to denote foreign country variables.

4.1 The Households

A continuum of households choose consumption of domestic and imported goods, labor and bank deposits in each of the N banks (D^i for $i = 1,...,N$) to maximize expected lifetime utility given by

$$\max_{C_t, L_t, D_{t+1}^i} E_0 [\sum_{t=0}^{\infty} \tilde{\beta}_t U(C_t, L_t)] \tag{1}$$

$$\tilde{\beta}_0 = 1 \tag{2}$$

$$\tilde{\beta}_{t+1} = \tilde{\beta}_t (1 + \tilde{C}_t - \tilde{L}_t^\omega)^{-\phi} \quad t \geq 0 \tag{3}$$

where $\tilde{\beta}_C < 0$ and $\tilde{\beta}_L > 0$. The fact that the discount factor is endogenous induces stationarity for the asset holdings in this incomplete markets model where idiosyncratic shocks imply wealth redistributions between the two countries. I model the discount factor as a function of average consumption ($\tilde{C}$) and labor ($\tilde{L}$), which the individual household takes as given. In equilibrium:

$$\tilde{C}_t = C_t \tag{4}$$

$$\tilde{L}_t = L_t \tag{5}$$

Preferences are of the Greenwood, Hercowitz, Huffman (GHH) type and represented by

$$U(C, L) = \frac{(C - L^\omega)^{1-\sigma}}{(1 - \sigma)} \tag{6}$$

with $\sigma > 1$ being the coefficient of relative risk aversion that also pins down the intertemporal elasticity of substitution. The specification for preferences implies no wealth effects for labor supply.

C represents the domestic consumption aggregator over goods produced in the home country (good 1, x_1) and in the foreign country (good 2, x_2). It is given by

$$C = [\varepsilon x_1^\rho + (1 - \varepsilon) x_2^\rho]^{1/\rho} \tag{7}$$

The foreign aggregator C^* is represented by an analogous expression where ε is replaced by $(1-\varepsilon)$. These aggregators are of the constant elasticity of substitution (CES) type, so that the elasticity of substitution between domestic and foreign goods is not restricted to be unitary, which is consistent with the data. Also, perfect substitutability and a linear aggregator would imply that agents would consume only the good that is relatively cheaper. There would be no demand spillovers that increase cross-country output correlations, and that would prevent the model from reproducing the consumption patterns of both local and imported goods.

The two-good model provides both a demand and a terms of trade channel to the international transmission of shocks. Each country exogenously

specializes in the production of one of the goods[12].

Each household's budget constraint is given by

$$x_{1,t} + T_t x_{2,t} + \sum_{i=1}^{N} D_{t+1}^i = (1 + r_{t-1}) \sum_{i=1}^{N} D_t^i + w_t L_t + \pi_t^f + \pi_t^e + \frac{1}{2} \sum_{i=1}^{N} \pi_t^{bi} \quad (8)$$

where T_t are terms of trade or, equivalently, the relative price of the foreign good in terms of the domestic good (the numeraire), D^i is domestic household's deposits in each of the N oligopolistic global banks. Domestic (foreign) deposits are denominated in units of good 1 (2). Domestic households own the domestic goods producing firms and entrepreneurs, and earn dividends on them. I assume here that households in each country own one half of the global banks. This fraction is assumed constant at business cycle frequencies. Firms, entrepreneurs and banks profits are all rebated to households in a lump-sum fashion[13].

Households have access to risk-free deposits. The interest rate on deposits earned by domestic households is denoted by r[14].

Each household is subject to a borrowing constraint that at all dates prevents it from engaging in Ponzi schemes. The constraint is

$$\lim_{j \to \infty} E_t q_{t+j} \sum_{i=1}^{N} D_{t+j+1}^i \geq 0 \quad (9)$$

where the superscript i denotes each of the N banks in this economy and where

$$q_t = \frac{1}{\prod_{k=1}^{t}(1 + r_k)} \quad (10)$$

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[12]The pattern of production specialization is not endogenized through neither comparative advantage nor Heckscher-Ohlin theories. This exogenous specialization simplifying assumption is standard in the literature.

[13]Firms profits are zero in equilibrium.

[14]By the risk free assumption, r_{t-1} is in the information set of period t-1.

4.2 The Final Good Sector

Competitive firms in the economy produce a final good operating a constant returns to scale Cobb-Douglas technology. They demand labor and hire capital to maximize profits. Labor is country-specific and it earns a wage rate w. Capital is rented at a cost r^K from entrepreneurs who produce the economy's capital stock. The representative firm's problem[15] is given by

$$\max_{L_t,K_t} \pi_t^f = Y_t - w_t L_t - r_t^K K_t \qquad (11)$$

subject to a Cobb-Douglas production technology

$$Y_t = A_t F(K_t, L_t) = A_t K_t^\alpha L_t^{1-\alpha} \qquad (12)$$

where total factor productivity (A_t) follows an AR(1) in logs process

$$log(A_{t+1}) = \Lambda log(A_t) + \varepsilon_{t+1} \qquad (13)$$

where

$$A_t \equiv (A_t, A_t^*) \qquad (14)$$

is part of the state vector of the model. Λ is a matrix of coefficients and $\varepsilon_t = (\varepsilon_t, \varepsilon_t^*)$. The off-diagonal elements of Λ define the spillovers from one country to the other. The elements of ε_t are serially independent, multivariate, normal random variables with contemporaneous covariance matrix V. TFP processes are related across countries through the off-diagonal elements of both Λ and V.

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[15]An implicit assumption here is that agents cannot own physical capital in the foreign country.

4.3 The Investment Sector

A continuum of entrepreneurs produce the economy's capital stock. They finance capital production with loans obtained from oligopolistic banks at a risk-free rate R, and rent their output to producers of final goods at a rate r^K.

Based on evidence documented by Antweiler and Trefler (2000)[16], Harrison (2003)[17] and Maioli (2003)[18] among others, I model an investment process characterized by increasing returns to scale external to the entrepreneur.

The representative entrepreneur's problem is therefore given by

$$\max_{d^E_{t+1}, i_t, k_{t+1}} \Pi^E = E_0[\sum_{t=0}^{\infty} \tilde{\beta}_t \frac{\lambda_t}{\lambda_0} \pi^E_t] \tag{15}$$

$$s.t.$$

$$\pi^E_t = r^K_t k_t - i_t + d^E_{t+1} - (1 + R_{t-1})d^E_t, \tag{16}$$

$$d^E_{t+1} \geq \Omega i_t, \tag{17}$$

$$k_{t+1} = z_t i_t + (1 - \delta)k_t, \tag{18}$$

$$z_t = f(I_t) \quad f'(I_t) > 0 \tag{19}$$

Entrepreneurs use the same discount factor as the households that own them. k and i stand for capital and investment for each entrepreneur, respectively. λ denotes the shadow value of wealth for the household, d^E stands

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[16] Antweiler and Trefler (2000) find evidence of constant returns to scale for sectors like apparel, food, fishing and agricultural goods, textiles and electricity, and of increasing returns to scale for other sectors like petroleum and coal products, pharmaceuticals, electric and electronic machinery, iron and steel basic industries, instruments and non-electrical machinery.

[17] Harrison (2003) finds that returns to scale are increasing in the investment sector. For consumption, her study indicates decreasing to constant returns, with evidence of a positive external effect.

[18] Maioli (2003) estimates returns to scale for 22 French industries and finds that they are generally higher for sectors like minerals, gas, metals and electric and mechanical products than for typical consumption goods.

for the loans amount. The parameter Ω denotes the fraction of investment that needs to be externally financed. Given that the interest rate on loans is strictly positive and bigger than the discount rate for the entrepreneur, the borrowing constraint in (17) binds in equilibrium.

By this condition, I impose the need for banks in the economy[19]. If Ω, the debt to investment ratio, was treated as an endogenous variable, it would optimally be zero. Given that my results do not hinge at all on the way in which I justify the existence of banks, my results should be robust to other ways of imposing the existence of banks, like monitoring costs, liquidity provision, etc[20].

In equilibrium

$$i_t = I_t \tag{20}$$

$$k_t = K_t \tag{21}$$

This specification does not imply increasing returns to the capital production process for entrepreneurs. This production process features an externality not internalized by entrepreneurs when they take their production decisions. Therefore, increasing returns apply only at the aggregate level[21].

What is key here is that this implies that the price elasticity of the demand for loans is increasing in the equilibrium amount of credit, and the interest rate markup charged by the banking sector is countercyclical.

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[19]By doing this I am implicitly assuming that entrepreneurs face an infinite cost of going directly to the households to finance that fraction Ω of investment.

[20]An alternative way to interpret this constraint is the following: If banks provide some sort of services essential for production together with the loans, a fraction Ω of investment has to be financed externally to get those services, even if entrepreneurs could finance it with their own current earnings.

[21]z is a function of the aggregate level of investment I, not of individual investment by each entrepreneur in the economy.

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4.4   The Banking Sector

There are N "global" or world oligopolistic banks with branches in each of the countries, that take deposits from both domestic and foreign households and lend to both entrepreneurs. As in Cetorelli and Peretto (2000), they are Cournot oligopolists and they face a downward sloping demand for funds and affect the price of loans when taking their credit supply decisions.

Banks have market power in the market for loans, but behave competitively when taking deposits from households in the economy, they have no oligopsonistic power[22].

Each of the N banks' optimization problem is given by[23]

$$\max_{D^i_{t+1}, D^{i*}_{t+1}, l^i_{t+1}, l^{i*}_{t+1}} \Pi^{Bi} = E_0[\sum_{t=0}^{\infty} \tilde{\beta}_t \frac{\lambda_t}{\lambda_0} \pi_t^{Bi}] \tag{22}$$

$$s.t.$$

$$\pi_t^{Bi} = D^i_{t+1} + T_t D^{i*}_{t+1} - l^i_{t+1} - T_t l^{i*}_{t+1} + (1 + R_{t-1}(l^i_t))l^i_t$$
$$+ (1 + R^*_{t-1}(l^{i*}_t))T_t l^{i*}_t - (1 + r_{t-1})D^i_t - (1 + r^*_{t-1})T_t D^{i*}_t,$$

$$\sum_{i=1}^{N} l^i_{t+1} = d^E_{t+1}, \tag{23}$$

$$\sum_{i=1}^{N} l^{i*}_{t+1} = d^{E*}_{t+1}, \tag{24}$$

$$D^i_{t+1} + T_t D^{i*}_{t+1} = l^i_{t+1} + T_t l^{i*}_{t+1} \tag{25}$$

l^i (l^{i*}) denotes the loans to the domestic (foreign) country by bank i. d^E (d^{E*}) is the total volume of loans for the whole domestic (foreign) economy, so that the second and third constraints are the definition of the aggregate

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[22]Having banks with market power in the market for deposits also would make my results stronger and the markup even more countercyclical. In that case, both the demand for loans by entrepreneurs and the supply of deposits by households become more elastic with increases in the level of aggregate economic activity, and the markup in the market for credit falls even more.

[23]i superscripts are used to denote each of the individual banks.

demand for loans by the investment sector in each country. The fourth constraint is the balance sheet equation for each bank.

Banks make their lending decisions and set an interest rate on loans R. Entrepreneurs face it and set the rental rate on capital r^K.

As already discussed, an increase in total factor productivity, which increases the firm's demand for capital and hence, the entrepreneur's demand for credit, raises the price elasticity of the demand for credit, lowering the markup and the cost of credit relative to standard models that lack this friction. As a result, the equilibrium level of capital increases by more than in standard models. With highly autocorrelated technology shocks, this in turn implies a countercyclical return on domestic deposits. By the arbitrage performed by global banks, interest rates on foreign deposits start falling too. This drives down the cost of credit in the foreign country and stimulates their investment, employment and output.

4.5   Model's Solution

The first order conditions for the representative household's optimization problem are given by

$$(C_t - L_t^\omega)^{-\sigma} = \lambda_t \tag{26}$$

where λ_t is the shadow value of wealth for the representative household and it equals the marginal utility of consumption.

The intratemporal condition for the allocation of consumption between domestic and foreign goods is given by equation (27).

$$\frac{\varepsilon}{(1-\varepsilon)}(\frac{x_{1,t}}{x_{2,t}})^{\rho-1} = \frac{1}{T_t} \tag{27}$$

The Euler equations for consumption, which govern the optimal allocation of total consumption over time in each country are

$$\frac{(C_t - L_t^\omega)^{-\sigma}}{p_t^C} = [1 + \tilde{C}_t - \tilde{L}_t^\omega]^{-\phi}(1 + r_t)E_t[\frac{(C_{t+1} - L_{t+1}^\omega)^{-\sigma}}{p_{t+1}^C}] \quad (28)$$

$$\frac{(C_t^* - L_t^{*\omega})^{-\sigma}}{p_t^{*C}} = [1 + \tilde{C}_t^* - \tilde{L}_t^{*\omega}]^{-\phi}(1 + r_t^*)E_t[\frac{(C_{t+1}^* - L_{t+1}^{*\omega})^{-\sigma}}{p_{t+1}^{C*}}] \quad (29)$$

where:

$$p_t^C = (\varepsilon + (1 - \varepsilon)T_t^{1-\Gamma})^{1/(1-\Gamma)} \quad (30)$$

$$p_t^{C*} = ((1 - \varepsilon) + \varepsilon T_t^{1-\Gamma})^{1/(1-\Gamma)} \quad (31)$$

$$\Gamma = \frac{1}{1 - \rho} \quad (32)$$

By p_t^C and p_t^{C*} I denote the price of the consumption aggregator in terms of domestic goods (the numeraire) in the home and foreign country respectively. They are a price index built as a weighted average of the price of the numeraire and the terms of trade (T_t).

Equation (33) determines household labor-leisure choices.

$$\omega L_t^{\omega-1} = \frac{w_t}{p_t^C} \quad (33)$$

The firm's problem gives the standard inverse demand functions for labor and capital:

$$w_t = A_t(1 - \alpha)K_t^\alpha L_t^{-\alpha} \quad (34)$$

$$r_t^K = A_t\alpha K_t^{\alpha-1}L_t^{1-\alpha} \quad (35)$$

The following expression is derived from the first order conditions for the entrepreneur's problem:

$$\frac{(1 - \Omega)}{z_t} = \tilde{\beta}_t E_t\frac{\lambda_{t+1}}{\lambda_t}[r_{t+1}^K + \frac{(1 - \Omega)(1 - \delta)}{z_{t+1}} - \frac{(1 + R_t)\Omega}{z_t} + \tilde{\beta}_t\frac{\lambda_{t+1}}{\lambda_t}\frac{(1 + R_{t+1})\Omega(1 - \delta)}{z_{t+1}}]$$
$$(36)$$

This equation says that the cost of borrowing has to equal the marginal revenue obtained by the entrepreneur from the borrowed funds, which is given by the future marginal productivity of capital. This productivity is in turn affected by increasing returns to scale in the production of capital.

The bank's optimization problem results in the pricing function for loans:

$$\tilde{\beta}_t E_t[\frac{\lambda_{t+1}}{\lambda_t}[(1 + R_t)(1 + \frac{\varepsilon_{R,t}}{N}) - (1 + r_t)]] = 0 \tag{37}$$

where ε_R is the reciprocal of the elasticity of the demand for loans by entrepreneurs. Basically, this condition is equating each bank's marginal revenue to its marginal cost.

There is also a no-arbitrage condition for deposits arising from the bank's problem, which reads:

$$\tilde{\beta}_t E_t[\frac{\lambda_{t+1}}{\lambda_t}[(1 + r_t) - (1 + r_t^*)\frac{T_{t+1}}{T_t}]] = 0 \tag{38}$$

When the economy becomes more productive, the demand for loans increases and ε_R falls, such that the markup falls. As a result, bank spreads behave countercyclically in this model, which is consistent with the empirical evidence. In a way that will become clearer later this implies a fall in the return on deposits in both economies, which allows me to obtain positive cross-country comovements of investment, employment and output.

4.5.1 Market Clearing

The market clearing conditions are defined by the equations below. World output of each good is devoted to consumption and investment, so that the market clearing conditions in the goods markets are:

$$x_{1,t} + x_{1,t}^* + I_t = A_t F(K_t, L_t) \tag{39}$$

$$x_{2,t} + x_{2,t}^* + I_t^* = A_t^* F(K_t^*, L_t^*) \tag{40}$$

In each country households' labor supply has to equal firms labor demand. Capital markets have to clear and capital demand by firms has to equal the capital supply implied by the entrepreneur's Euler equation. Similarly, the aggregate demand for loans by the investment sector has to equal the supply by the N banks in the economy.

4.5.2 Equilibrium

The recursive equilibrium in this economy is defined by value functions for the home and foreign households, for the home and foreign entrepreneurs and for the each of the global banks; decision rules for consumption, labor supply and savings for the home and foreign households; decision rules for labor and capital demand for the home and foreign firms; decision rules for investment and borrowing for the home and foreign entrepreneurs; decision rules for the supply of loans for each of the banks; and prices $(p_t^C, p_t^{C*}, T_t, w_t, w_t^*, r_t^K, r_t^{K*}, r_t, r_t^*, R_t, R_t^*)$ that satisfy the following conditions:

- The home and foreign households' FOCs;
- the home and foreign firms' FOCs;
- the home and foreign entrepreneurs' FOCs;
- the banks' pricing equations;
- the world resource constraints for both goods;
- the market clearing conditions for the labor, capital and loans/deposits markets; and
- the no-Ponzi constraint on deposits in each country.

5 How Does the Model Work?

The intuition about how the key mechanism in the model works is made clear by solving analytically for some of the variables in the deterministic steady state of the model. As I will show with the numerical results, the main novel force that allows me to get positive cross-country correlations for employment, investment and output is given by endogenously countercyclical markups for the oligopolistic banking industry.

In this section I derive an expression for the price elasticity of the demand for credit. I show that it is directly related to the level of investment demand. Therefore, when a positive productivity shock hits the economy, both investment and the demand for credit rise. The elasticity of that demand also increases, and implies a lower markup for the oligopolistic banks that provide investment financing, due to a falling degree of market power.

In the steady state the reciprocal of the elasticity of the demand for credit is given by

$$
\varepsilon_R = \frac{\partial(1+R)}{\partial d^E} \frac{d^E}{(1+R)} \tag{41}
$$

$$
= \frac{((1+\theta)\frac{\alpha(\omega+\alpha)-(\omega+\alpha-1)}{(\omega+\alpha-1)} + \theta)I^\theta}{\frac{(1-\Omega)}{\tilde{\beta} r^K} - z} \tag{42}
$$

It can be shown that $\frac{\partial \varepsilon_R}{\partial I} < 0$ for the model calibrated to the US economy. Denoting:

$$
\nu = \frac{\alpha(\omega+\alpha)-(\omega+\alpha-1)}{(\omega+\alpha-1)} < 0 \tag{43}
$$

$$
\vartheta = (1+\theta)\nu + \theta < 0 \tag{44}
$$

$$
\mu = I^{\theta-1}\left(\frac{-(1-\Omega)\nu(1+\theta)}{\tilde{\beta}^2 r^K z} - \theta\right) > 0 \tag{45}
$$

$$\frac{\partial(\varepsilon_R)}{\partial I} = \theta I^{\theta-1}\vartheta(\frac{(1-\Omega)}{\tilde{\beta}r^K} - z) - I^{\theta}\vartheta\mu < 0 \qquad (46)$$

A model with an isoelastic demand for credit is nested in this one. It corresponds to $\theta = 0$ and $\Omega = 1$, so that the elasticity of demand is constant and equal to $\varepsilon_R = \frac{(1-\alpha)(\omega+\alpha)-1}{(\omega+\alpha-1)}$. Here banks' markups are constant over the cycle. Results for this case show that the key feature in this model that allows to solve the quantity anomaly and to reproduce the co-movements of employment and investment, is not the oligopolistic structure of banking per se, but the endogenously countercyclical NIMs.

When the domestic economy experiences a positive productivity shock, the demand for loans increases, the markup falls and the banking industry becomes more competitive. This is consistent with the US banking sector stylized facts presented in Section 2 and with the empirical evidence documented in Olivero (2004).

Therefore, the cost of credit falls with respect to standard models that lack this friction. With highly autocorrelated technology shocks, the degree of oligopolistic power is lower in the future than currently. Agents know this and that the cost of investing will be lower in the future. Consequently, the ratio $\frac{C_{t+1}}{C_t}$ falls and the ratio $\frac{U'(C_{t+1})}{U'(C_t)}$ increases with respect to standard models. This, together with the fact that in this model there is a wedge between the interest rate on deposits and the marginal productivity of capital, implies a countercyclical rate of return on deposits.

The non weak separability of preferences also plays a role here. With a decreasing market power, the quantity of capital increases over time relative to standard models without this friction. The marginal productivity of labor increases and leisure falls over time, again relative to standard models. The marginal utility of consumption increases over time and works to get a countercyclical return on households' savings[24].

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[24]Prescott et al (1983), Plosser (1987), Fama and French (1989), King and Watson

Given that r represents the opportunity cost of funds for banks, countercyclical r and spreads imply a strongly countercyclical cost of credit. A fall in r makes banks use local deposits, which are now cheaper for them, to finance both domestic and foreign loans. By arbitrage, the interest rate on foreign deposits r^* falls too and drives down the cost of credit in the other country. This encourages higher investment and allows for employment and output to increase in the foreign country too.

6 Numerical Solution

6.1 Calibration

I calibrate the model to match some of the post-war stylized facts of the USA and OECD economies. The time period is a quarter. The parameter values are shown in Table 5.

The parameter ω matches the price elasticities of labor supply in the US and OECD countries. In the consumption aggregators, ε is chosen to match the share of imported goods in total consumption. The parameter ρ governs the elasticity of substitution between local and foreign goods in consumption. It implies a 0.9 elasticity as in Heathcote and Perri (2002). In the production function, α represents the constant output share of the remuneration to capital.

I calibrate the function z_t to the following form:

$$z_t = I_t^\theta \tag{47}$$

The parameters governing the capital production process Ω and θ, match a 0.25 investment share of output in the deterministic steady state. Also, the value chosen for θ is consistent with the evidence for slight increasing returns in the investment sector found by Harrison (2003).

_____

(1996) and Seppala (2000) provide evidence on the countercyclicality of real returns.

Table 5: Calibration

Utility function and budget constraint	Consumption aggregator
$\omega = 1.6$	$\varepsilon = 0.85$
$\sigma = 2$	$\rho = $ -1/9
ϕ (-elasticity of the discount factor with respect to its argument) $= 0.1$	
Goods production function	
$\alpha = 0.36$	
Production function for capital	
$N = 2$	
$\delta = 0.04$	
$\Omega = 0.25$	$\theta = 0.04$
TFP Process (Backus et al)	
$\lambda_{11} = \lambda_{22} = 0.906$	
$\lambda_{12} = \lambda_{21} = 0.05$	
$\sigma^2(\varepsilon_t) = \sigma^2(\varepsilon_t^*) = (0.0085)^2$	$\rho(\varepsilon, \varepsilon^*) = 0.25$
A * denotes foreign country's parameters.	

6.2 Results

The model has no closed form solution and has to be solved using a numerical algorithm. The assumption that the shocks to the economy are not significantly big make log-linearization around a symmetric steady state a valid method[25].

A well-known fact in two country models with incomplete asset markets is that temporary shocks can have permanent effects because of the international wealth redistributions that arise with country-specific shocks. Here I obtain stationarity by allowing for an endogenous discount factor for households. However, agents do not internalize their effect on the discount factor[26].

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[25] The model was solved numerically using the log-linearization codes available in Professors Stephanie Schmitt-Grohe's and Martin Uribe's web pages.

[26] This is because the discount factor is modelled as a function of the averages, and not the individual, consumption and employment.

6.3 GHH Preferences

In this section I present the results for the benchmark model with GHH preferences. Some key features about how the general equilibrium works arise from the simulations.

A positive technology shock to the home country increases its marginal productivity of both labor and capital. Therefore, both factors of production increase on impact. With no wealth effects on labor supply, labor increases even with the positive wealth effect of the shock implied by market incompleteness. As a result, home output increases as well. There is also a positive terms of trade effect for the foreign country. From the supply side, goods produced in the foreign country (which is relatively less productive) become more expensive. From the demand side, the home country is now wealthier and it increases the demand for both types of goods, increasing it relatively more for home goods[27], what makes the latter more expensive. In the numerical results, I see the first effect dominating over the second.

I present my simulation results in Table 6. The second column shows results for the model with both the trade channel and oligopolistic banking. Correlations for employment and investment are positive; consumption and output also comove. The consumption correlation is lower than for output, what provides an explanation to the quantity anomaly.

The results also replicate the countercyclicality of net exports, which is another stylized fact of international real business cycles[28]. I am also able

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[27]This is because of the way in which I calibrate the consumption aggregator, with a higher share of domestic goods for any level of consumption.

[28]There are two opposite forces affecting the capital account after a positive TFP shock to one of the countries. On the one hand, foreign assets held by domestic households increase due to the interest rate effect. A lower interest rate in the relatively more productive economy makes banks use this economy's deposits to finance foreign investment. On the other hand, foreigners' holdings of domestic assets increase due to the productivity effect. The numerical results indicate that the second effect is more powerful, what makes the capital account procyclical (and the current account, countercyclical)

Table 6: Simulation Results with GHH Preferences

	Data	2 goods olig. banks	2 goods comp. banks	1 good olig. banks
Cross-country Correlations				
$\rho(C,C^*)$	0.3311	0.6657	-0.7426	0.3922
$\rho(L,L^*)$	0.2167	0.6132	0.7841	-0.0706
$\rho(I,I^*)$	0.4151	0.8607	-0.7528	-0.9543
$\rho(Y,Y^*)$	0.4496	0.8047	-0.2008	-0.0706
$\rho(\text{spread},\text{spread}^*)$	0.1228 / 0.4441	0.9224	-	-0.2508
Domestic Correlations				
$\rho(NX/Y,Y)$	-0.37	-0.7592	-0.5818	0.2325
$\rho(C,Y)$	0.8734	0.9872	0.8974	0.9649
$\rho(L,Y)$	0.5494	0.9901	0.3115	1
$\rho(I,Y)$	0.9245	0.8637	0.7982	0.1137
$\rho(r,Y)$	-0.27^a	-0.5621	-0.5884	0.4969
$\rho(\text{spread},Y)$	-0.41 / -0.21	-0.7724	-	-0.5011
Standard Deviations				
$\sigma(C)/\sigma(Y)$	0.8	0.8693	1.7815	0.7867
$\sigma(L)/\sigma(Y)$	0.88	0.4995	0.6439	0.6452
$\sigma(I)/\sigma(Y)$	2.61	1.9534	2.6186	5.4553
$\sigma(T)/\sigma(Y)$	2.88	0.5551	2.3833	-

Source: Idem Table 1.

C: consumption, Y: output, I: investment, L: employment, NX: net exports, r: real interest rate on deposits.

a: Taken from King and Watson (1996).

to match the countercyclicality of real interest rates and banks' spreads, and the positive cross-country correlation of the latter.

There is one dimension in which the model does not perform well. The standard deviation of the terms of trade is too low with respect to the data. This is another anomaly identified by the literature and labelled the "price variability" anomaly by Backus, Kehoe and Kydland (1994).

Cross-country consumption correlations significantly lower than those implied by standard models result from a combination of several key elements of the model: The imperfect risk sharing implied by incomplete financial markets, a terms of trade effect and non weakly separable preferences.

Sensibilizations performed on the parameter Ω show that it does not significantly alter the cross-country correlations of macroeconomic aggregates. It does affect the contemporaneous correlation of r and the spread with domestic output, though.

A relevant exercise is to show how results change for two alternative scenarios. First, for a two-good model with perfectly competitive banks and no frictions in the capital production process, i.e. assuming constant returns to scale in the capital production process. Second, for an oligopolistic banking economy but with only one good, that is, for a case with no trade channel. I show the results for these experiments on the third and fourth columns of Table 6, respectively. The purpose is to highlight the importance of both the trade in goods channel and credit market frictions working together to explain the anomalies.

In the first alternative scenario, for the perfectly competitive banking model, the cross-country correlations for investment, output and consumption are still negative, even with the trade channel working there. I interpret these results as suggestive of imperfect competition in the banking sector being crucial to explain the anomalies. Net exports are still countercyclical in this case. This is in line with previous research, which has shown that this

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fact can be reproduced in models of incomplete markets only when a terms of trade effect is present.

Results for the second scenario show that trade in goods is important in explaining the puzzles. Even with countercyclical bank spreads, with no trade, the cross-country correlation of investment is negative. Labor and output are also negatively related across countries in this case. With no terms of trade effect, net exports are procyclical.

In Figure 3 I show impulse response functions for employment, investment, capital, output and consumption to a one standard deviation shock to the home country's total factor productivity. Home total factor productivity experiences a 1% increase on impact. Foreign productivity also increases, given that there are significant international spillovers according to the specification assumed for the process followed by productivity.

The positive correlation across countries for all the main macroeconomic aggregates is evident from these plots[29]. Employment jumps in the domestic economy, but it falls on impact in the foreign one. Foreign productivity is increasing only slightly and the positive terms of trade effect makes p^{C*} increase, so that the foreign real wage falls. With no wealth effects on labor supply, foreign labor falls on impact. Investment increases in the home country on impact, while foreign investment rises only with a lag. While foreign productivity increases and the cost of credit falls, the negative impact on employment seems to be imposing an offsetting force on the marginal productivity of capital in the foreign country, such that investment does not rise on impact. As a result, both output and consumption increase domestically and fall in the foreign country. The impulse response for r^* shows that it increases. This, together with the increase in p^{C*} and the falling cost of credit (R^*) drive the initial decline in C^*.

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[29]The highest Eigenvalue in the system equals 0.97, which drives the high persistence in the variables observed in the impulse response functions.

Figure 3: Impulse Response Functions
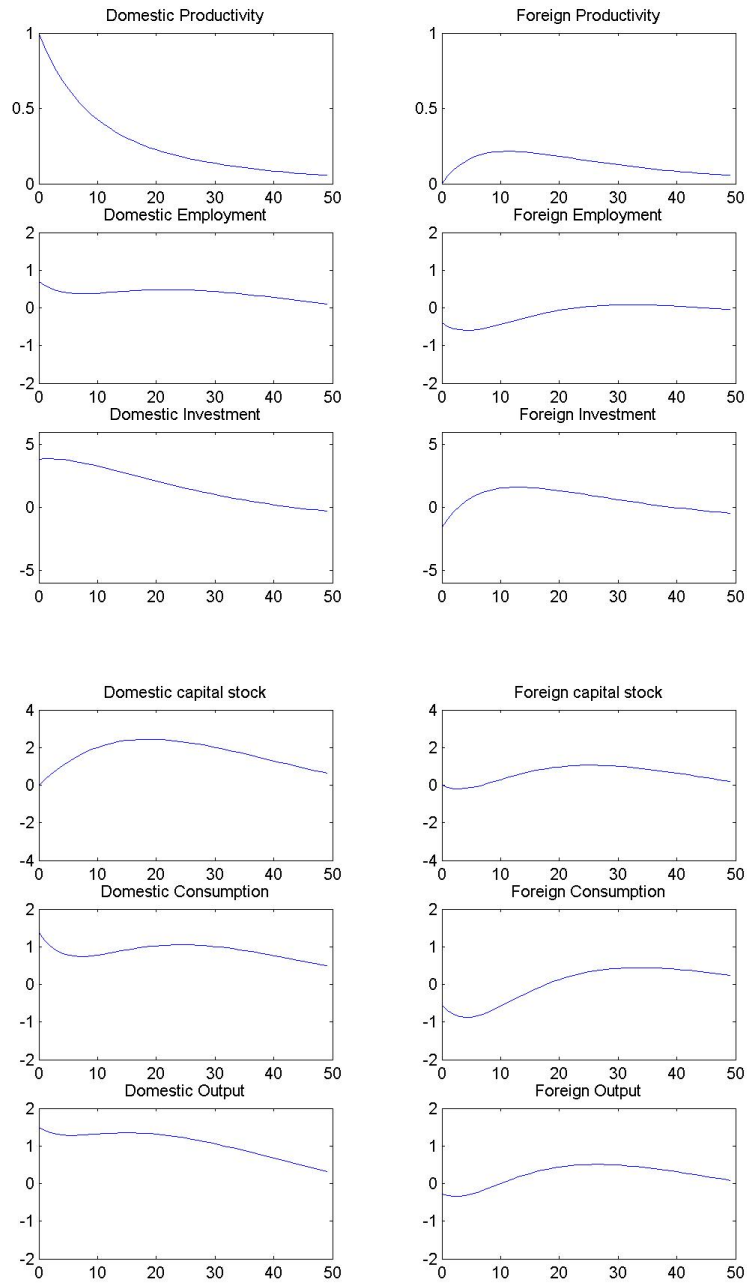
6.4 Cobb-Douglas Preferences

In this section I develop a robustness check of the benchmark model. I now specify Cobb-Douglas household preferences of the following form:

$$U(C, L) = \frac{(C^\mu (1 - L)^{1-\mu})^{1-\sigma}}{(1 - \sigma)} \tag{48}$$

where the parameter μ pins down the share of consumption and it is calibrated to 0.4. The results for this alternative framework are in Table 7.

Conclusions regarding the anomalies stay the same. I still obtain positive comovement for investment and employment, and the cross-country correlation of consumption falls below that for output.

With these preferences, the model performs a little bit better in terms of the volatility of the terms of trade, although it cannot match the data yet.

Table 7: Simulation Results with Cobb-Douglas Preferences

	Data	Benchmark model
Cross-country Correlations		
ρ(C,C*)	0.3311	0.708
ρ(L,L*)	0.2167	0.5862
ρ(I,I*)	0.4151	0.8975
ρ(Y,Y*)	0.4496	0.9922
ρ(spread,spread*)	0.1228 / 0.4441	0.943
Domestic Correlations		
ρ(NX/Y,Y)	-0.37	0.1433
ρ(C,Y)	0.8734	0.046
ρ(L,Y)	0.5494	0.2
ρ(I,Y)	0.9245	0.8111
ρ(r,Y)	-0.27	-0.9122
ρ(spread,Y)	-0.41 / -0.21	-0.5209
Standard Deviations		
σ(C)/σ(Y)	0.8	1.8623
σ(L)/σ(Y)	0.88	1.5587
σ(I)/σ(Y)	2.61	4.993
σ(T)/σ(Y)	2.88	1.412

Source: Idem Table 6.

7   Concluding Remarks

To study the international transmission of business cycles among the USA and OECD countries, in this paper I extend an otherwise standard two-country RBC model through the introduction of trade in goods and credit market frictions. Endogenously countercyclical markups in the market for credit are the key novel force working in the model. By doing so, I am able to explain the discrepancies in the International RBC literature identified by Backus et al (1992). I obtain positive comovement of consumption, output, investment and employment across countries, and propose a potential solution to the quantity anomaly. Simulations for a one-good model and for a setup with perfectly competitive banking are indicative of the importance of the trade in goods channel and countercyclical markups working together to determine the international transmission of business cycles.

A novelty of the paper is to model a financial accelerator coming from the supply side of the loans market, which to my knowledge has not been previously studied. With countercyclical markups for the oligopolistic banking sector, the cost of credit increases in bad times. As a result, firms may delay investment and production decisions and the recession may be made even worse and longer. This has interesting policy implications and gives additional support to stabilization policy in economies where credit spreads are more countercyclical.

One main direction for further research arises from this paper. It provides a framework appropriate for the study of the impact of banking sector and interest rate regulations on the supply of credit and on the cycle. Moreover, my main modeling structure can be used to study other issues related to the international transmission of business cycles. Specifically, the model can be applied to answer more policy oriented research questions related, for example, to current account issues and optimal exchange rate regimes.

Appendix A: Alternative Modeling Ideas

Based on evidence by Harrison (2003) and others, an increasing returns capital production process is the way I chose in the main body of the paper to obtain countercyclical markups for the banking sector. In this appendix I present alternative ways to get that the perceived elasticity for each bank falls with GDP, even with no special frictions in the capital production process.

First, the number of banks in the economy can be made endogenous. With fixed costs of production, entry will occur in the banking sector until the point at which profits for the marginal entrant are zero. Thus, a zero-profit condition and a pricing equation for each bank together determine the equilibrium quantity of banks.

$$\max_{D_{t+1}^i, D_{t+1}^{i*}, l_{t+1}^i, l_{t+1}^{i*}} \Pi^{Bi} = E_0[\sum_{t=0}^{\infty} \tilde{\beta}_t \frac{\lambda_t}{\lambda_0} \pi_t^{Bi}] \tag{49}$$

$$s.t.$$

$$\begin{aligned}
\pi_t^{Bi} = \; & D_{t+1}^i + T_t D_{t+1}^{i*} - l_{t+1}^i - T_t l_{t+1}^{i*} + (1 + R_{t-1}(l_t^i))l_t^i \\
& + (1 + R_{t-1}^*(l_t^{i*}))T_t l_t^{i*} - (1 + r_{t-1})D_t^i - (1 + r_{t-1}^*)T_t D_t^{i*} - \phi
\end{aligned}$$
$$\tag{50}$$

where ϕ denotes a fixed cost of operation for each bank.

An increase in the number of banks lowers profits for each of the banks by lowering the interest rate on loans and the demand for credit for each bank. Therefore, an opportunity for additional entry arises in expansions, when the demand for loans increases. This would predict a procyclical number of banks, which is consistent with the empirical evidence for the US economy presented in the data section.

In this model, ε_R is constant, but ε_R/N is still countercyclical.

The Model with CES Goods Production

A second way to get countercyclical markups is through a model in which the number of banks is still exogenously given, and where goods are produced using a CES production function.

This model economy has a representative firm that builds the capital stock and operates a constant elasticity of substitution technology[30] for producing goods. The firm borrows from oligopolistic banks at the rate R to finance its investment projects.

The production function is given by

$$Y_t = A_t(aK_t^\theta + bL_t^\theta)^{1/\theta} \tag{51}$$

where $\theta < 1$ and $1/(1 - \theta)$ is the elasticity of substitution between capital and labor.

The capital accumulation process is particular in the sense that investment takes no time to build the capital stock and there is full depreciation. Therefore,

$$I_t = K_t \tag{52}$$

Also, as a shortcut and for simplicity, I assume here that loans equal a given fraction of investment and that they are paid back in the same period, such that the price of investment is $(1 + R)$. Therefore,

$$d_t^f \geq \Omega I_t \tag{53}$$

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[30]CES production technologies imply variable factor shares. However, in the numerical simulations I calibrate the parameters a and b such that in steady state the labor (capital) share is 0.64 (0.36). With log-linearization as the numerical method used to solve the model, results are local and, as a result, shares in the transition do not differ significantly from those assumed in the more standard Cobb-Douglas problems with constant factor shares.

where d^f stands for the loans amount. This constraint will always bind in equilibrium given that the cost of external financing for the firm is higher than that of using its own sales income.

The firm's problem is then static: it maximizes instantaneous profits in every period subject to (51)-(53).

$$\max_{L_t, I_t, d_t^f} \pi^f = Y_t - w_t L_t - (1 + R_t)d_t^f - (1 - \Omega)I_t \tag{54}$$

which can be reduced to

$$\max_{L_t, d_t^f} \pi^f = Y_t - w_t L_t - (1 + \Omega R_t)d_t^f \tag{55}$$

$$s.t.$$

$$Y_t = A_t(aK_t^\theta + bL_t^\theta)^{1/\theta} \tag{56}$$

The household's and the banks' optimization problems are the same as in the benchmark economy.

The firm's inverse demands for labor and capital are now given by

$$w_t = A_t b(aK_t^\theta + bL_t^\theta)^{1/\theta-1}L_t^{\theta-1}, \tag{57}$$

$$(1 + \Omega R_t) = A_t a(aK_t^\theta + bL_t^\theta)^{1/\theta-1}K_t^{\theta-1} \tag{58}$$

It can be easily shown that the reciprocal of the price elasticity of the demand for credit is now

$$\varepsilon_{R,t} = (1 - \theta) + (\theta - 1)\frac{K_t}{Y_t}\frac{\partial Y_t}{\partial K_t} \tag{59}$$

Also, the elasticity of the demand for credit is procyclical in this case too. To show this, I calculate the derivative of ε_R with respect to the investment level, and show that it is negative for $\theta > 0$.

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$$\frac{\partial \varepsilon_R}{\partial I} = \frac{\partial \varepsilon_R}{\partial K} = (\theta - 1)(\frac{\partial Y}{\partial K}\frac{1}{Y} + \frac{K}{Y}\frac{\partial^2 Y}{\partial^2 K} - \frac{K}{Y^2}(\frac{\partial Y_t}{\partial K_t})^2) \qquad (60)$$

$$\frac{\partial \varepsilon_R}{\partial I} = \frac{\partial \varepsilon_R}{\partial K} = (\theta - 1)\frac{\theta abK^{\theta-1}L^\theta}{(aK^\theta + bL^\theta)^2} < 0 \qquad (61)$$

Thus, banks' markups are still countercyclical, with no capital production frictions and with the number of banks in the economy being exogenously fixed.

Calibration

I choose a and b to match a 0.64 labor share and a 0.36 capital share in the steady state. The parameter θ equals 0.3. This implies an elasticity of substitution between capital and labor of around 1.5, which is in line with the empirical evidence.

The calibration for the rest of the parameters follows that in the benchmark model.

Table 8: Calibration - CES Goods Production	
Utility Function and Budget Constraint	**Consumption Aggregator**
	$\varepsilon = 0.85$
$\omega = 2$	$\rho = \rho^* = -1/9$
$\sigma = 2$	
Goods Production Function	
$a = 0.36$	$b = 0.64$
$\theta = 0.3$	
Production Function for Capital N = N* = 2	$\Omega = 0.3$
TFP Process (Backus et al) $\lambda 11 = \lambda 22 = 0.906$	$\lambda 12 = \lambda 21 = 0.088$
$\text{Std}(\varepsilon) = \text{Std}(\varepsilon^*) = 0.0085$	$\text{Corr}(\varepsilon,\varepsilon^*) = 0.25$

In Table 9 I show simulation results for the model with both trade in goods and oligopolistic banking, and for alternative formulations where either one of these two forces does not operate.

The qualitative results are the same as in the benchmark model. I obtain positive cross-country comovement for all macroeconomic aggregates and I propose a potential solution to the quantity anomaly when both effects work in the model. Importantly, my simulations match the countercyclicality of real interest rates and the trade balance observed in the data. Also, bank spreads comove here as in the data.

Regarding the volatility of terms of trade, the benchmark model with CES production still delivers a standard deviation that falls short of the value in the data, but the wedge is smaller than that obtained by previous work including my benchmark model.

As expected, results for a 1-good economy show lower output comovement and higher consumption comovement. With competitive banking, both consumption and employment are negatively correlated across countries. Also, the interest rate on deposits is now procyclical. Again, I interpret these results as evidence of the importance of both trade in goods and endogenous and countercyclical banking sector markups for finding a solution to the Backus et al. anomalies and to understand the channels through which business cycles are transmitted between the US and the OECD countries.

Table 9: Simulation Results: CES Goods Production

	Data	2 goods oligop. banking	2 goods comp. banking	1-good oligop. banking
Cross-country Correlations				
ρ(C,C*)	0.3311	0.2637	-0.6319	0.7574
ρ(L,L*)	0.2167	0.7051	-0.3259	0.1739
ρ(I,I*)	0.4151	0.9707	0.1574	0.2624
ρ(Y,Y*)	0.4496	0.8747	0.0555	0.2491
ρ(spread, spread*)	0.1228 / 0.4441	0.9972	-	0.1172
Domestic Correlations				
ρ(NX/Y,Y)	-0.37	-0.1783	-0.3168	0.1788
ρ(C,Y)	0.8734	0.8316	0.9145	-0.6409
ρ(L,Y)	0.5494	0.9845	0.9966	0.9992
ρ(I,Y)	0.9245	0.9849	0.998	1
ρ(r,Y)	-0.27	-0.2627	0.7195	0.7845
ρ(spread,Y)	-0.21/-0.41	0.649	-	0.4323
Standard Deviations				
σ(C)/σ(Y)	0.8	0.3881	3.0087	0.4133
σ(L)/σ(Y)	0.88	0.4692	2.7481	0.1446
σ(I)/σ(Y)	2.61	3.0887	0.6538	5.0283
σ(T)/σ(Y)	2.88	1.1582	3.4743	-

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Appendix B: Summary of the Literature Results

In the following table I summarize the literature results.

Table 10: The Literature Results

	ρ(C,C*)	ρ(Y,Y*)	ρ(I,I*)	ρ(L,L*)	ρ(NX/Y,Y)
Data	**0.3311**	**0.4496**	**0.4151**	**0.2167**	**-0.37**
Benchmark Backus et al	0.88	-0.21	-0.94	-0.94	0.01
BKK with transport costs	0.89	-0.05	-0.48	-0.48	0.23
BKK - no risk sharing	0.56	0.08	-0.31	-0.31	-
1-Tesar (1993)	0.44 - 0.97	0.48 - 0.7	-	-	-
2a-Baxter and Crucini (1995)	0.95	0.04	0.02	-0.7	0.65[21]
2b-Baxter and Crucini (1995)	0.92	0.06	0.12	-0.67	0.65[21]
3a-Baxter and Crucini (1995)	0.89	-0.41	-0.92	-0.91	-0.18[21]
3b-Baxter and Crucini (1995)	-0.28	0.54	-0.5	-0.56	-0.28[21]
4- Boileau (1996)	0.5	0.52	-0.48	0.6	-
5- Kollman (1996)	0.38	0.1	-0.12	-0.12	-0.07
6- Kollman (1996)	0.51	0.18	-	-	-
7- Kollman (1996)	0.28	0.14	-	-	-
8- Roche (1996)	0.78	-0.07	-	-	-0.34

Table 11: Table 10 Continued

Table (cont.)	ρ(C,C*)	ρ(Y,Y*)	ρ(I,I*)	ρ(L,L*)	ρ(NX/Y,Y)
9- Canova and Ubide (1998)	0.72	0.78	0.27	0.8	-0.32^{21}
10- Guo et al. (1998)	0.44	0.98	-	-	-0.009
11- Stockman and Tesar (1998)	0.25	0.52	-	-	-0.48^{21}
12a- Ubide (1999)	0.73	0.26	-0.15	0.32	-0.55^{21}
12b- Ubide (1999) - G shocks and imp. comp.	0.82	0.91	0.85	0.91	-0.22^{21}
13- Lubik (2000) - TFP shocks	0.42 - 0.79	0.61 - 0.77	0.89 - 0.99	-	-0.14 - 0.01
13- Lubik (2000) - TFP and money shocks	0.33 - 0.71	0.51 - 0.66	0.78 - 0.96	-	-0.15 - -0.01
14- Heathcote and Perri (2002)	0.85	0.24	0.35	0.14	0
15- Cook (2002)	0.284	0.521	0.188	0.884	-
16- Hairault (2002)	0.71	0.29	0.08	0.25	-0.49^{21}
17a- Head (2002)	0.81	0.485	0.343	0.293	-0.187
17b- Head (2002)	0.853	0.486	0.451	0.302	0.085
18- Kehoe and Perri(2002)	0.29	0.25	0.33	0.23	0.27
19- Alesandria and Choi(2004)	0.2	0.43	0.39	0.64	-0.43
20- Olivero(2003)	0.99	0.32	0.42	0.37	-0.13

Notes:

1- Tesar (1993): A model with complete financial markets and stochastic fluctuations in the output of non-traded goods. She concentrates on the high correlation between savings and investment, the low cross-country correlation between consumption growth rates and the home bias in investment portfolios.

2a- Baxter and Crucini (1995): Complete markets - Backus et al parameterization of TFP process. **2b- Baxter and Crucini (1995):** Only noncontingent bonds - Backus et al parameterization of TFP process.

3a- Baxter and Crucini (1995): Complete markets - Unit root in productivity without spillovers. **3b- Baxter and Crucini (1995):** Only noncontingent bonds - Unit root in productivity without spillovers.

4- Boileau (1996): A two-country, single-traded good RBC model with endogenous growth and a non-market (and non-traded) sector. Financial markets are complete and international externalities in production are modeled. A positive productivity shock to the home country induces mobile factors of production to reallocate across sectors and countries. The sectoral reallocation from household production to market production in each country compensates for the international reallocation. Employment is positively correlated across countries as a result. The shocks to non-market production reduce the cross-country correlation of consumption.

5- Kollman (1996): Only risk-free debt contracts can be traded in asset markets. Adjustment costs to investment. The main purpose is to show how this helps reduce cross-country consumption correlations.

6- Same as in 5 with fixed hours.

7- Same as in 5 with high risk aversion.

8- Roche (1996): A one-good economy, countries produce a non-specialized traded good and households derive utility from public goods. Shocks to both productivity and government spending. The latter act as additive exogenous preference shocks. Households deriving utility from exogenous government purchases has important implications for the countercyclicality of the trade balance.

9- Canova and Ubide (1998): A model with a non-traded sector and financial claims traded internationally. Disturbances to both market and household technologies. With the non-market sector using capital, after positive shocks, reallocations of capital from the non-traded to the traded sector makes the cross-country correlation of market investment less negative. Autocorrelated shocks with international spillovers. Cross-sector, cross-country spillovers as well as inter-sector, intra-country spillovers are set to zero.

10- Guo and Sturzenegger (1998): An increasing returns to scale economy with no contingent claims markets and shocks to both productivity and "beliefs". The latter affect the consumption Euler equation.

11- Stockman and Tesar (1998): A two-sector model with traded (each country specializes in the production of one good) and nontraded goods. There is also trade in financial assets. Shocks to technologies and tastes with particular features for taste shocks. Taste shocks are needed to explain the anomalies, productivity shocks are not enough. I report here their results for Case 6 (taste shocks to home-produced goods, correlated across goods), their best results.

12- Ubide (1999): A model with government spending entering preferences. Imperfect competition in the goods markets (modeled exogenously), competitive behavior in the factors market, indivisible labor, and complete asset markets. He models technology, markups and government spending exogenous shocks. Markup fluctuations alone are not able to reproduce the main stylized facts ; government spending shocks are needed. They follow other studies (Ravn (1997) and Rottemberg and Woodford (1995)) for the calibration of the process followed by government spending and markups. They don't estimate a VAR for productivity, government spending and markups. Among the several specifications he estimates, the best results are gotten for a model with government spending and markup shocks. He doesn't get positive comov

13- Lubik (2000): A two-sector (tradeables and non-tradeables), multiple-good, monetary business cycle model with price stickiness in the non-traded sector. On the one hand, positive technology shocks in one country lower the terms of trade and stimulate production abroad. On the other, price stickiness causes the terms of trade (of the country that has undergone a monetary expansion) to improve, and this leads to a contraction of foreign economic activity. The model features incomplete asset markets and adjustment costs to investment.

14- Heathcote and Perri (2002): A two-good model with two countries in financial autarky.

15- Cook (2002): A model with risk-free debt, imperfect competition and procyclical sequential market entry for Cournot final goods producers. With trade in differentiated goods, a productivity increase in one economy leads to additional business formation in the other country through demand spillovers. Business formation brings countercyclical markups, what leads to an expansion in employment, investment and production in both economies.

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16- Hairault (2002): After the economies are shocked, expected returns to labor market search change and induce movements in search and recruiting activities. Given the cross-country correlation of technology shocks, domestic and foreign firms start searching labor at the same time. Employment increases in both countries and this helps to partially curtail the capital outflows from the country not benefiting from the shock.

17a- Head (2002): Purely country-specific shocks and increasing returns to scale, which operate through changes in the world-wide variety of intermediate domestic and foreign goods that produce a final consumption - investment good in each country. An increase in one country's variety of producer goods raises TFP for both economies simultaneously. What works here is a "trade in varieties-induced link". **17b- Head (2002):** Constant returns to variety and strongly correlated technology shocks, $\text{Corr}(\varepsilon_1, \varepsilon_2) = 0.7$.

18- Kehoe and Perri (2002): They endogeneize market incompleteness through imperfectly enforceable international loans in a one-good model. The credit market imperfection comes from the requirement that each country prefer the allocation it receives when participating in international financial markets relative to the autarky one.

19- Alessandria and Choi (2004): They develop a model with complete asset markets, firm heterogeneity, and fixed entry and continuation costs in export markets. Monopolistically competitive firms each producing a differentiated intermediate good are subject to idiosyncratic technology shocks. In each country final goods are produced in a competitive market using domestic and imported intermediate goods. An increase in home TFP lowers the fraction of domestic firms that stop to export due to the fact that with lower production costs, they are better willing to pay the fixed costs of shipping goods abroad. Foreign producers of intermediates, who face a higher demand, start entering export markets ad deferring exit. So, an increase in domestic productivity triggers an increase in capital accumulation in the domestic economy and an increase in the absorption of foreign varieties. Foreign production increases as a result. Home consumption increases initially, while foreign consumption falls on impact. That allows for a reduced cross-country correlation of consumption.

20- Olivero (2003): A model with trade in goods, government expenditure affecting preferences and distortionary taxation.

21- Net exports (NX) in this case.

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How Pervasive is the World Business Cycle?[*]

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Abstract

The paper tries to establish whether the business-cycle fluctuations across countries are due to a single world business cycle, to a diversity of regional business cycles or a combination of both. The methodology used does not impose any a priori hypothesis about regional composition. If regional business cycles exist the region composition would be estimated from the data used. The study was done for two different samples: the first comprises 26 OECD countries and the other 59 countries. The results indicate that for the OECD sample there are two common components and for the World sample there are three, but none of them specific to a geographical region. The only division is between developed and developing countries.

Keywords: International Business Cycles, Approximate Factor models, Common Components

JEL classification: C33, E32, F41

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1 Introduction

This paper looks at the question of whether there is a world business cycle and/or a number of regional business cycles. This question has, already, been the issue of several papers and has been under renewed attention. The main reasons of this new interest are the creation of the EMU and the slowdown at the beginning of the 21st century.

The creation of the EMU led to an interest in whether the business cycles of European countries were or not synchronized, and therefore, if a single monetary policy could fit all. The studies done concluded for existence of a core and a periphery. However, they raised the question if the national business cycle synchronization is the reflex of a truly European Business Cycle, or just the reflex of a World Business Cycle. That kind of question was the subject of Artis and Zhang(1997) and Artis(2003).

The slowdown verified in 2000/2001 was expected to be constrained to the USA economy, but it spread to most of the developed economies, indicating that those economies are linked. This raised the question of weather the synchronization observed was a reflex of a world business cycle or just a coincidence and if the links between economies have or not increased. To answer this questions several papers studied the synchronization of the G7 business cycles: Gregory and Head(1997), Andreano and Savio(2002), Helbling and Bayoumi(2003), Bordo and Helbling(2003). Other studies were more ambitious and tried to include more countries, Lumsdaine and Prasad(2003) included all OECD countries, Kose et all.(2003) used data from 1960 to 1990 to 60 countries and Mansour(2003) used the GDP data for 113 countries from 1961 to 1989. However, the studies that try to cluster the countries into regions do not try to estimate the world and the regional cycles and their importance on the national cycles. The ones that try to estimate the world business cycle and its importance for each country either do not take into account regional cycles, or if they do, as Kose et all.(ibidem) and Mansour(ibidem), they assume the regions rather than estimating them from the data.

This paper tries to cluster the countries into regions and, at the same time, estimate the world and regional cycles as well as the importance of each for each country studied. To get a truly world picture I used two country samples from 1970 to 2001: 26 OECD countries and a world sample of 59 countries. In order to perform the study I used a approximate factor model for which the asymptotic distribution theory was developed by Bai(2003). To the best of my knowledge

this particular method was not used before to study this question. Other studies have used factor models, but of a different sort: Helbling and Bayoumi (idem) and Mansour(ibidem) used a dynamic general factor model (DGFM) proposed by Forni et all..(2002), Kose et all.(ibidem) used a Bayesian method described in Otrok and Whiteman(1998), Lumsdaine and Prasad(ibidem) used a time-varying weighting method.

The main advantages of the factor model used in this paper is that the estimators have an asymptotic distribution, rendering possible to do inference over them (which is not possible in the DGFM or in the Lumsdaine and Prasad's approach), and we do not have to assume region composition before hand.

The structure of the paper is the following: the next section describes the econometric model used; the following shows the empirical results for the OECD countries and for a world sample comprising 59 countries and the final one concludes the paper.

2   Econometric Model

To address the problem of existence of a world business cycle and/or regional business cycles I used the estimated business cycles of real GDP, Consumption and Investment constructed from the difference of two HP filters as is discussed in Artis et all. (2003). Having estimated those business cycles I used an approximate factor model for which the inferential theory was developed by Bai(2003). The model is represented by:

$$
\begin{aligned}
X_{it} &= \lambda_i' F_t + e_{it} = C_{it} + e_{it} \qquad (1) \\
i &= 1, 2, 3, ..., N \\
t &= 1, 2, 3, ..., T
\end{aligned}
$$

where X_{it} represents the value of the ith series business cycle at time t, λ_i is the loading vector $r \times 1$, F_t is a vector $r \times 1$ representing the value of r factors at time t and e_{it} is the idiosyncratic component of the series at time t.

In this framework and under the assumption A described in Bai (ibidem), this factor model allows F_t to be dynamic such that $A(L)F_t = \epsilon_t$. However the relationship between X_{it} and F_t is static[1].

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[1] A more general factor model where the relationship between X_{it} and F_t can be dynamic

The first problem to solve is to decide the number of factors that should be included in the model. Bai and Ng(2002) have shown that the number of common factors can be consistently estimated by using one of the following information criteria[2]:

$$IC(1) = \log(V(r,\widehat{F})) + r\left(\frac{N+T}{NT}\right)\log\left(\frac{NT}{N+T}\right) \qquad (2)$$

$$IC(2) = \log(V(r,\widehat{F})) + r\left(\frac{N+T}{NT}\right)\log\left(C_{NT}^2\right)$$

$$IC(3) = \log(V(r,\widehat{F})) + r\frac{\log\left(C_{NT}^2\right)}{C_{NT}^2}$$

$$\text{where} \quad : \quad C_{NT} = \min\{N,T\}$$

$$V(r,\widehat{F}) = \min_\Lambda \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}(X_{it} - \lambda_i' F_t)^2 \qquad (3)$$

$$\Lambda \text{ is the matrix of loadings}$$

However, if there is too much cross heteroskedasticity those IC estimate too many common factors when used in finite samples, even after the series are standardized[3].

Therefore in order to reduce this problem, instead of using all the individual business cycles estimated for each series, I constructed for each country a business cycle index that summarizes the fluctuations observed. That index is also constructed from a factor model imposing the existence of a single common component:

$$X_{it}^c = N_{it}^c + \varepsilon_{it}^c = a_i^c(L)Ind_t^c + \varepsilon_{it}^c \qquad (4)$$

To estimate Ind_t^c, instead of using the same procedure of the approximate factor model, I calculated it from a weighted sum of the estimated cycles of each series imposing that the idiosyncratic elements of each series to be independent $(corr(\varepsilon_i^c; \varepsilon_j^c) = 0, i \neq j$; being ε_i^c a $T \times 1$ vector):

$$Ind_t^c = \sum_{i=1}^{N} w_i^c X_{it}^c \ , \ t = 1,2,3,...,T \qquad (5)$$

---

is the DGFM described by Forni et all.(2002).

[2] To estimate the number of common components we have to fix the maximum number of common factors we allow. The methodology used was to start at $Rmax = 2$ and increase it until one of the Infomration Criteria (IC) indicates a smaller value than the selected $Rmax$.

[3] A small montecarlo simulation presented in appendix C exemplifies the problem.

So the problem is to calculate the weights (w_i^c). To do that, I followed the methodology purposed by Forni and Reichlin(2001). This methodology looks for the weights that minimize the "size" of the idiosyncratic components with respect to the national component. Being Γ the covariance matrix of ε_{it}^c and Σ the covariance matrix of the variables, the problem is to minimize:

$$\frac{var(w'\varepsilon^c)}{var(w'X^c)} \tag{6}$$

If we take the logs of equation (6) and minimize in order to w the FOC is:

$$\Gamma^{-1}\Sigma w = \gamma w \tag{7}$$

So the weights are given by the eigenvector of $\Gamma^{-1}\Sigma$ associated with the biggest eigenvalue.

Σ is know but Γ is not known and it has to be estimated. In a first step I equalized the diagonal elements of Γ to the diagonal elements of Σ. Then estimated equation (5) by OLS, using the Akaike information criteria to decide for the optimal number of lags. From the estimated residuals (idiosyncratic components of each series) I estimated Γ.

Once the indexes Ind_t^c are obtained, we can use the model described by equation (1) to estimate the r common factors that affect the different national indexes.

$$
\begin{aligned}
Ind_t^c &= \lambda_c' F_t + e_{ct} \tag{8} \\
c &= 1, 2, 3, ..., N \\
t &= 1, 2, 3, ..., T
\end{aligned}
$$

Then, I used the estimated factors to estimate the loadings by[4]:

$$
\begin{aligned}
\widehat{\Lambda}' &= \frac{F'Ind}{T} \tag{9} \\
\text{where} \quad &: \quad \widehat{\Lambda} \text{ is the loadings matrix} \\
&\quad Ind \text{ is the } t \times c \text{ national indexes matrix} \\
&\quad F \text{ is the } t \times r \text{ factors matrix}
\end{aligned}
$$

---

[4]Note that the scale of the loadings and of the factors cannot be obtained independently, therefore I normalized the variance of the factors such that $(F'F)/T = I_r$.

At this point I tested at 90% confidence level if the loadings should be zero[5] and reestimated equation (9) setting to zero all the loadings that did not reject the null.

To check for the importance of each factor we can do the variance decomposition of the indexes:

$$var(Ind^c) \quad = \quad var\left(\sum_{r=1}^{R}\lambda_{cr}.F_r + e_c\right) \Leftrightarrow \tag{10}$$

$$\Leftrightarrow \quad var(Ind^c) = \sum_{r=1}^{R} var\left(\lambda_{cr}.F_r\right) + var(e_c) \Leftrightarrow$$

$$\Leftrightarrow \quad 1 = \frac{var(\lambda_{c1}.F_1)}{var(Ind^c)} + \frac{var(\lambda_{c2}.F_2)}{var(Ind^c)} + ... + \frac{var(\lambda_{cR}.F_R)}{var(Ind^c)} + \frac{var(e_c)}{var(Ind^c)}$$

where : Ind^c, F_r and e_c are $t \times 1$ vectors

and λ_{cr} is the loading of factor c associated with the factor r

The last equality results from the estimation procedure of the approximate factor model. The method imposes that $(F'F)/T = I_r$, (F is a $t \times r$ matrix and I_r is an identity matrix of order r) the factors are orthogonal, and so the variance of the sum is equal to the sum of the variances.

Moreover, the factors are standardized, their variance is equal to one, so the importance of each factor is given by:

$$\frac{var(\lambda_{cr}.F_r)}{var(Ind^c)} = \frac{(\lambda_{cr})^2}{var(Ind^c)} \quad ; \quad r = 1, 2, 3, ..., R \tag{11}$$

If there is a regional business cycle, how do we decide for it's existence and region composition? As said before regions are not assumed, their existence has to be inferred from the data. The method used is to compare the importance of a factor for each country using equation (11). If the ratio estimates that the factor is only important for a limited number of countries than we are in the presence of a regional factor, and the set of countries is said to be the region *in strictu sensus* that commoves together. If the factor is important for a large subset of countries, then the component is a global one and part of the world business cycle. As for benchmark I will use the ratio value of 20% to say that a factor is important for a certain country. To be certain that a region exists the results have to be stable across time, this is, the estimated factor and it's

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[5] This testing was done using the asymptotic inferential theory presented by Bai(2003)

pattern of ratios has to be similar if we consider the whole sample or just a sub-period.

A second definition of region will be in *latus sensus*. In this case even if we do not find a regional factor, the countries may have a different dependence structure from the common components found. To check for the existence of this kind of regions we will perform a cluster analysis to check how similar are the countries

3 Results

This section will present the estimated results. It is divided in three subsections. The first describes the data used and the transformations made. The following shows the results obtained for the OECD countries and the last presents the results obtained for a larger sample of 59 countries.

3.1 Data used

The data used were those for Gross Domestic Product (GDP) calculated from the expenditure view, the Household consumption (HC) and the Gross Fixed Capital Formation (GFCF), at constant prices (base year: 1990). All the series were collected from 1970 to 2001 at annual frequency.

Two points should be justified: the use of annual data rather than data at a higher frequency and the choice of household consumption rather than total consumption or private consumption. The justification in both cases is availability of the series for as many countries and time span as possible. Quarterly data is not available for all OECD countries since 1970, and even if we would use a shorter interval some OECD countries only have quarterly data since the late 80's, making the time dimension too short. As for the use of household consumption the justification is the same for developing countries: in order to get as many countries as possible the use of household consumption allow us to use data of more countries than if we used total consumption or private consumption. For the OECD countries we could use total consumption or private consumption, however, the use of household consumption allow to perform a closer comparison between the two groups studied.

For the OECD countries the data were taken from the OECD Main Economic Indicators 2003 Database, and for the non-OECD countries the data were taken from the WTI 2003 Database from World Bank, selecting those that we could

get a complete data set from 1970 to 2001. A complete list of the countries used is given in appendix A.

Finally, to estimate the business cycle indexes of each series I choose to retain the fluctuations from two to eight years. This interval follows the one that Baxter and King (1999) adopt, between 6 and 32 quarters.

3.2 Results for the OECD countries

This section presents the results for the OECD sample. It is divided into five subsections. The first one estimates the number of factors to be included in the model, the next subsection presents the estimated factors and the relative importance of each for each country. The third subsection discusses stability issues in order to assess which estimated factors are stable for different periods. The following subsection clusters the countries together to check if they form well defined regions or not and the final one summarizes the results found.

3.2.1 Estimating the number of common factors

When we analyze the estimated business cycle indexes of each country[6] we realize that there are some regularities common to most countries: a trough around 1973, coinciding with the first oil crisis, an other around 1981, and a third trough at the beginning of the nineties. This coincidences make us suspect the OECD countries are linked by a world business cycle. However, those coincidences are not common to all countries, nor the variations are felt on a equal basis by all countries. Therefore we could also assume that, beyond to a common factor and idiosyncratic shocks, some countries can be affected by some regional linkages.

To be certain of our suspicions, we have to perform a closer analysis. To apply the model of equation (8) we need to know how many factors should be included in our analysis. The ICs depicted in equations (2) using the procedures of footnote 2 to select the $Rmax$ give the following results:

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[6]The estimated cycles were not included in the present version of the paper due to space constraints. The graphics are available from the author.

Table 1 - Number of Common Factors

	Standardized Data	Non Standardized Data
IC1	$6(Rmax)$	$6(Rmax)$
IC2	5	$6(Rmax)$
IC3	$6(Rmax)$	$6(Rmax)$

As argued before (see appendix C) we realized that if there is too much cross-heteroskedasticity in the idiosyncratic components the ICs applied to non-standardized data almost always select the Rmax. As regarding the standardized data, even if the ICs almost always estimate a number of common factors bigger than the true number, the IC2 is the one closer to the true number[7]. Therefore we continued the study using standardized data. Therefore to help in our selection we can, also, look at the ratio of eigenvalues. That ratio gives the percentage that each eigenvector of the matrix XX' is able to explain the common variation of the series.

Table 2

Eigenvalue	1	2	3	4	5
Ratio	0.3566	0.1480	0.1058	0.0881	0.0647
Eigenvalue	6	7	8	9	10
Ratio	0.0478	0.0358	0.0311	0.0226	0.0213

From table 2 we see that the first eigenvector can explain 35.66% of the common variation of the series. If we use 5% as a limiting value, we realize that we should include up to 5 factors in our model. From the two analysis I opted to perform the study with 5 factors explaining the variations of the business cycles indexes. The main reason was that the 3 first factors only explain 61% of the fluctuations of the variables, as the five first explain up to 76%[8] Second, if too many factors are included that should be apparent from the importance of

---

[7]In appendix B we can see if the estimated idiosyncratic components are in fact cross-heteroskedastic or not. However, from appendix C we can realize that if we standardize data whenever the idiosyncratic components are cross-homoskedastic the ICs on standardized data usually estimate a number bigger than if we use non-standardized data. The results of table 1 give some support to standardize the data.

[8]These values are smaller than those estimated by Helbling and Bayoumi(2003). Those authors using the methods of Forni et al.(2002) found that the first factor would explain 60% of the variation and the three first factors would explain about 90%. Those results are for GDP data of the G7 countries. However, when they add other series their values decrease to 44% and 71% respectively.

But, we can expect that the more countries/series are used, smaller are the estimated ratios as we add more sources of idiosyncratic variation.

Figure 1: Percentage of the national cycles explained by the five first factors
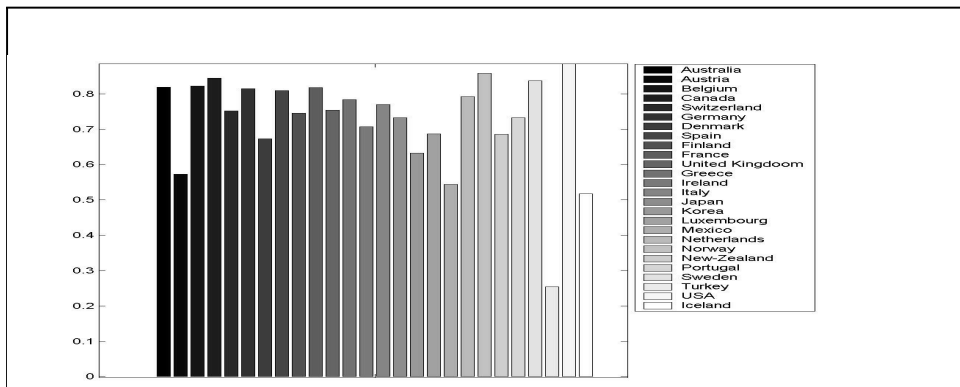
each factor in the variation of the business cycle of the countries, this is, if the last factor is only important to one country, being the importance to the others only marginal than that factor is capturing a country business cycle and not a common component. At that time the model can be restricted[9].

3.2.2   Estimation results

The first question is how much the first five factors explain the volatility of the national business cycles. Figure 1 shows that only Turkey has a small percentage explained by the common components. Austria, Mexico and Iceland have a somewhat low percentage, however in any case above 50%.

Figure 2 depicts the estimated factor associated with the biggest eigenvalue. The dotted lines are the 90% confidence level band for the estimated value. At this point we should stress that assumptions A-H described in Bai(2003) are needed to compute the confidence interval of the factors when $N, T \rightarrow \infty$ (this is the weaker condition imposed). Of importance is assumption H, it imposes that the residuals of equation(8) are homoskedastic and not serial correlated[10].

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[9] At this point we should note that we do not need to reestimate the model, as the estimated factors are orthogonal, the estimated loadings for the first n factors are equal if we use n or $n + m$ factors . However the same is not true to the estimated variance-covariance matrixes and, hence,for the confidence intervals. Restricting the model would lead to wider confidence intervals.

[10] From those assumptions is clear that cross-section heteroskedasticity and cross-section correlation are still allowed, thus the model continues to be an approximate factor model.

In this sample I performed a white test to detect heteroskedasticity. With the exception of

Figure 2: First estimated factor
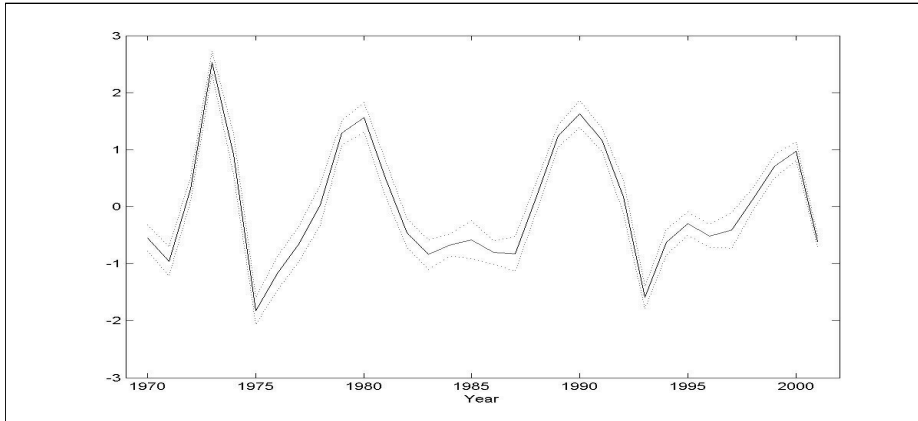
This is:

$$E(e_{ct}.e_{cs}) = 0 \text{ , if } t \neq s \text{ and } E(e_{ct}^2) = \sigma_c^2 \tag{12}$$

From table 2 we realized that the first factor explains almost 36% of the variation of the countries indexes. From figure 2[11] we realize that this first common component captures most of the stylized facts of the world business cycle described in the literature. It peaks in 1973, 1980, 1990 and 2000, reaches a trough in 1975, 1983/6, 1993 and also reflects the slowdown at the beginning of the new millennium.

Kose et all. (2003) using annual data from 1961 to 1990 of 60 countries found troughs in 1975 and 1982 and a slowdown in the end of the sample.

Gregory et all. (1997) studying the G7 countries with quarterly data from 1970:1 to 1993:4 found recessions in 1975, 1982 and a slowdown in the early

one series all accepted the null of homoskedasticity at 10% significance level. All accepted the null at 5%.

As for autocorrelation, doing a LM test for AR(1), all but one accepted the null at 5%, all acepted the null at 1%. However some of the series seemed to be AR(2). In this case the asymptotic distribution of the factors is only valid when $\sqrt{N}/T \to 0$. In our sample $N = 26 \to \sqrt{N} \approx 5$ which is much smaller than $T = 32$. The use of the asymptotic distribution is still plausible, as long as assumptions A-G of Bai(idem) are satisfied.

[11] The method is not able to estimate the factors themselves, but a rotation of them (HF_t).Therefore in this study I assumed that the loadings of the factors should be positive in the majority of the G7 countries, and multiplied the estimated eigenvector by -1 every time that the estimated loadings would not obey to that assumption. In the case all G7 countries loadings are zero, I kept the estimated factor.

Figure 3: First factor importance
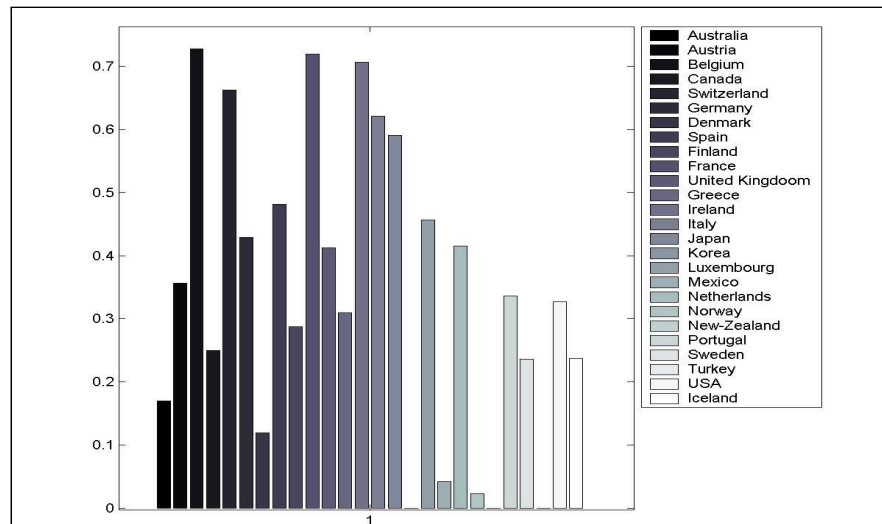
nineties, upturns in early and late seventies and late eighties. They also found during the mid-eighties a long period where the cycle was below the zero level.

Helbling and Bayoumi (2003) when estimating the G7 weighted gap using GDP quarterly data from 1973 to 2000 found troughs in 1974, 1982, 1986 and 1992 and peaks in 1978/1979, 1985, 1990 and 2000. Their sample end also depicts a slowdown, even if it is much smaller than the one depicted in figure 2.

It seems that this first factor is in line with estimations found in the literature, however this does not mean that it is the word business cycle. For that we have to know how important is this first factor to the business cycle of each country. Does it affect all countries (being it a global component) or just some. Figure 3 depicts the ratio calculated in equation (10) for the first component.

From that figure we can see that the first factor is not important for the variance of the national business cycles of Korea, New-Zealand and Turkey. Its importance for Mexico and Norway is marginal and for Australia and Denmark is small (less than 20%).

For some countries its importance is more than 50%. That group includes Belgium, Switzerland, France, Ireland, Italy and Japan.

So it seems that this first factor is important for the majority of the countries (for 19 out of 26 it accounts for more than 20% of the volatility), moreover all

Figure 4: Variance decomposition of factors 2 to 5
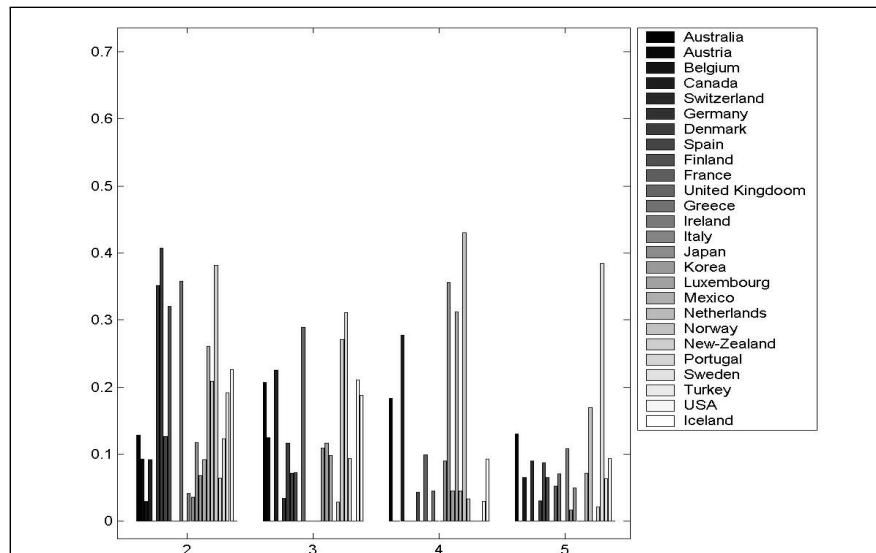
of them (except for Norway, although its importance is marginal) have positive loadings[12] .However to say that it depicts the world business cycle (and not just a component of it) we should check what is the importance of other factors.

Figure 4 shows the ratios of the variance decomposition for the other 4 estimated factors. We can see that the second factor explains more than 20% of the national business cycles indexes for Germany, Denmark, Finland, Greece, Netherlands, Norway, New Zealand and USA. This factor is more important than the first to Denmark, Finland, Norway, New-Zealand, Korea, Mexico and Turkey. However its importance for the last three countries is still small (between 10 and 20%). The effects are also very mixed as it has a positive loadings for Germany,Denmark, Greece, Netherlands, Norway, USA, Austria, Japan and Korea. For the other countries the loading is zero or negative.

The third factor accounts to more than 20% volatility for Australia, Canada, United-Kingdom, New-Zealand, Portugal and the USA. And almost 20% to Iceland. It seems that this factor accounts for some kind of an Anglo-Saxon region. When compared with the first factor its importance is quite smaller to UK and the USA, but more or less equal to the other countries (with the

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[12]The estimated loadings, as well the 95% and 90% confidence level intervals are available from the author upon request.

Figure 5: Estimated Factors for the OECD sample
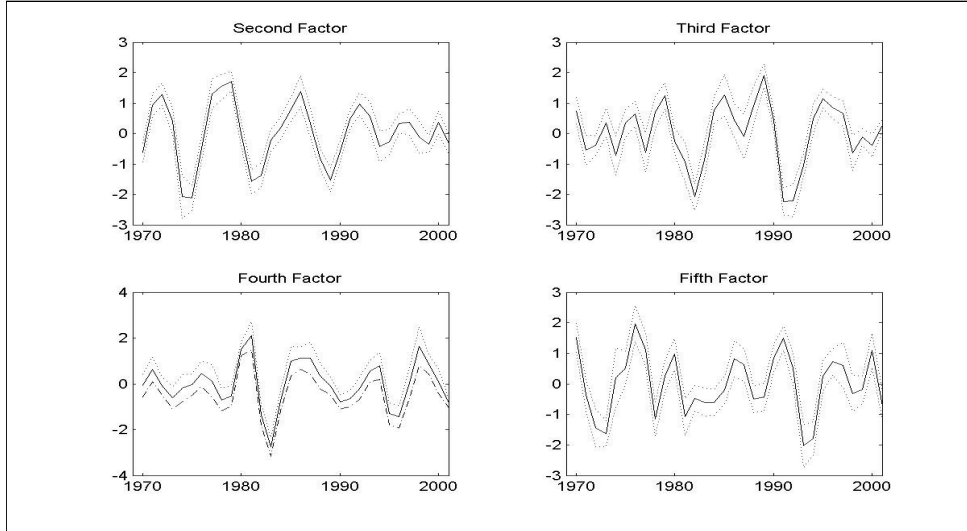
exception of New Zealand that was not affected by the first factor).Moreover for all Anglo-Saxon countries the loadings of the third factor are positive, as for Portugal and Iceland they are negative.

The factor 4 is important for Canada, Korea, Mexico, Norway. For all of them is the most important factor. Only for Korea is the loading negative.

Finally for factor 5, it is only important for Sweden. However for Australia and Norway it explains between 10% and 20% of the variance of the national business cycles[13]

After checking for which countries is each factor important we should see what is the evolution through time of each one of those factors. This analysis can help us in understanding why those factors affect different countries as well as why some of them have contrary effects on different countries. In figure 5 we can check the evolution of the second, third, fourth and fifth estimated factors.

As the first factor, the second common component also captures the effects of the first and second oil crisis (it reaches troughs in 1974/75 and 1981). Contrary

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[13]Remember that from the number of factors discussion in section 3.1.1 we kept 5 factors on the basis of the argument that if the 5th factor was only important for one country it could be dropped.

This 5th factor is important only for Sweden, but it also affects other countries in a non-negligible way, therefore I opted to keep it in the analysis.

to the first factor it depicts a peak in 1986, a trough in 1989 followed by a peak in 1992. From 1992 onwards it fluctuates around the zero value.

As for the third factor it peaks in 1979, 1985, 1989 and 1995 and reaches troughs in 1982 and 1991/1992 So it seems that this factor is only capturing the second oil the downturn on the beginning of the nineties and the recover afterwards.

From this analysis it seems that the world business cycle can be depicted by the first and second factor. The first factor has an important effect in almost all countries, we will call it the first component of the world business cycle. The second factor also has worldwide effects, although its effects are not as uniform or all-encompassing as the effects of the prior one. It seems that is a German-USA area of influence, as it makes the countries around Germany (Austria, Denmark, Netherlands and Norway) and USA to commove together. Anyway we can say that is a second component of the world business cycle.

The third factor seems a Anglo-Saxon factor, as the fourth and fifth affect a very restricted number of countries.

However this reading of the results should be complemented with an analysis of the stability of the factors for different time frames and dismiss those that are not stable (as they are showing some association for some time frames and not for others,and therefore are not permanent to the world cycle) and try to get a measure of how countries group. Those issues are dealt in the next sections.

3.2.3   Stability issues

In this kind of model we can think on three kinds of stability issues. The first issue is whether observed factors are the same through time: this is, we can think that at some point in time a common factor might disappear or a new common component might appear. A second issue is, even if the common factors are the same, their relative importances in explaining the common variations may vary. Finally, even if the factors and their relative importance are the same, for a particular country the factor loadings may vary and therefore alter the variance decomposition. The next three subsections will address this three different issues. In order to perform those comparisons we estimated the model for the sub-period 1970 to 1990 with five factors and compare with the results obtained for the complete data set[14].

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[14]It should be referred that there is no formal test of this issues in the literature. Therefore this section is based in comparing the results of both time samples. However, as the loadings

Are the common factors the same? The next five graphs compare the five estimated factors for the sample from 1970 to 1990 with those estimated for the whole sample (figure 6 to figure 10).

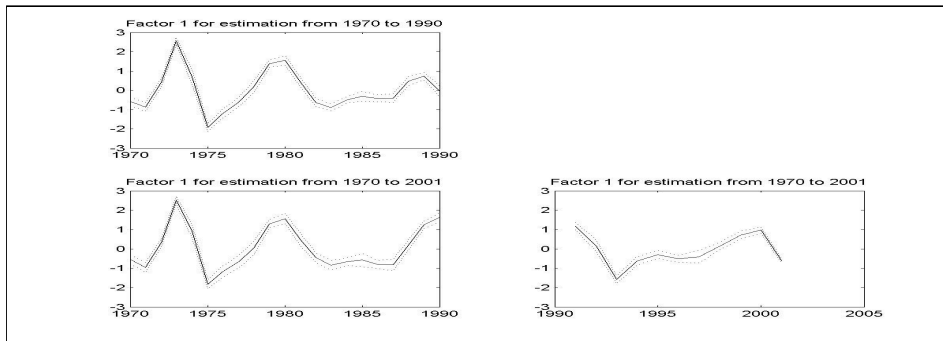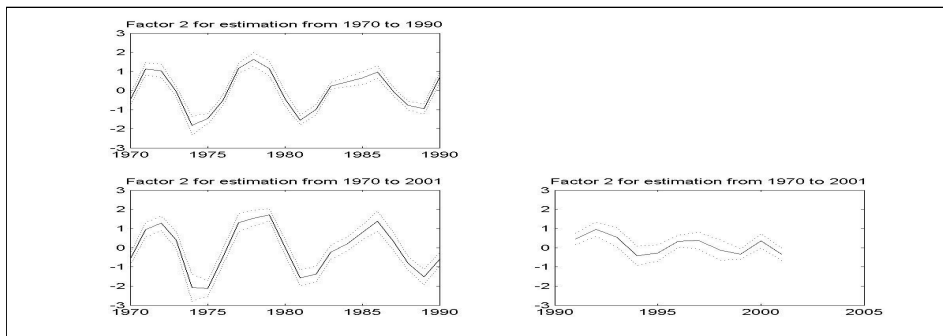Figure 6: Comparision of the first estimated factor

Figure 7: Comparision of the second estimated factor

From figures 6 and 7, we can see that the first and second estimated factors are more or less equal if we use the whole data or just the data from 1970 to 1990. There is only a deviation in the end of the sample for the first factor, this is, the whole sample estimation reveals a peak on 1990 as the sub-sample estimates peaks before, while in 1990 we would be already in a recession phase.

However that difference can be due to estimation problems at the end of the sample. We should not forget that the factors are obtained from the detrended

and the factors have an asymptotic distribution it should be possible to develop a kind of stability test for those estimations. This is left for future work.

Figure 8: Comparision of the third estimated factor
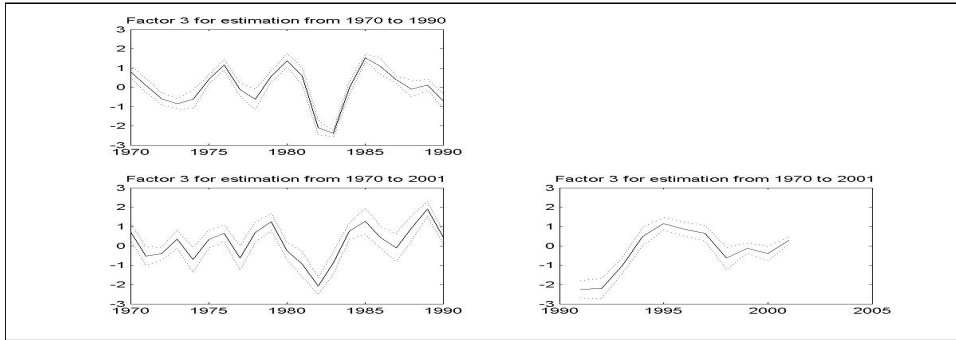
Figure 9: Comparision of the fourth estimated factor
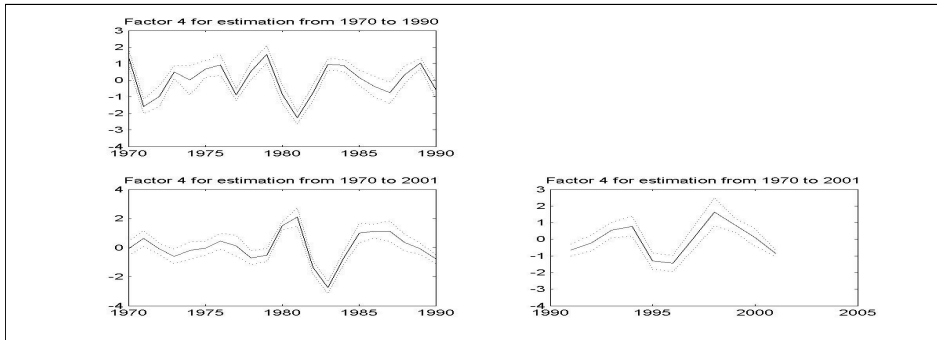
Figure 10: Comparision of the fifth estimated factor

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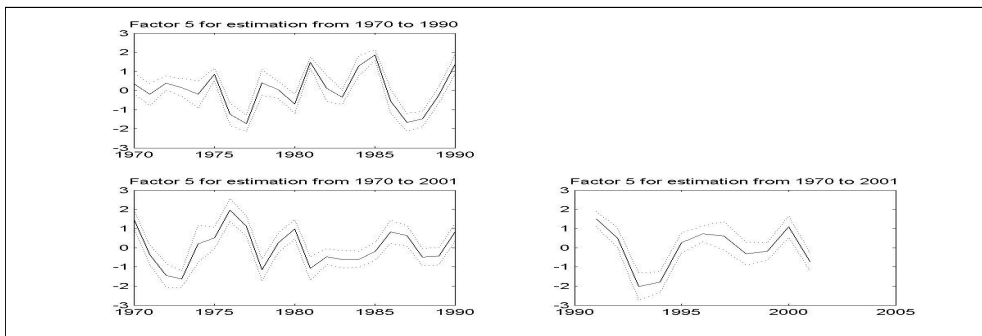
data using a band-pass filter, therefore when estimating for the sub-sample 1970-1990 we are ignoring the future path of the variables, so the estimations at the end of the sample can be rather volatile. Also, the second factor estimations at the end of the sample for the restricted period deviates somewhat from the estimations of the whole period

Nevertheless, we can consider that the estimations of the two first factors are relatively stable.

A different picture arises from the estimations of the third, fourth and fifth factors. The third factor still reflects the fluctuations of the beginning of the eighties, however before and after that period there is no resemblance. As for the fourth and fifth factor the estimations for different periods do not reflect any resemblance[15].

It seems that those latter estimated factors, that were reflecting regional linkages, are not captured in the same way. As we will see in the subsection below the countries more affected by them are also different. Therefore we can conclude that regional linkages importance have changed through time. Therefore the model is, in both time frames, capturing the three stronger regional linkages of the period considered.

Is the relative importance of the factors unaltered? A second point is to know how important is each factor in explaining the common variation. The next table gives the ratio of importance of each eigenvalue:

Table 3

Eigenvalue	1	2	3	4	5
Ratio - Sample 1970-1990	0.3396	0.2292	0.1144	0.0789	0.0567
Ratio - Sample 1970-2001	0.3566	0.1480	0.1058	0.0881	0.0647
Eigenvalue	6	7	8	9	10
Ratio - Sample 1970-1990	0.0459	0.0388	0.0293	0.0219	0.0165
Ratio - Sample 1970-2001	0.0478	0.0358	0.0311	0.0226	0.0213

From table 3 we can see that after the fifth eigenvalue, the relative importance of each factor is less than 5%. However from the fourth eigenvalue small

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[15] Remember than in each case we estimate a rotation of the factors. However in these cases there was no rotation that would allow us to say that they were depicting the same movements. Cross-regressing the factors of both samples there was only strong associations between the first factor of both samples and between the second factor of both samples.

variations on their relative importance can easily put them on either side of the 5% decision value. As seen before the fourth and fifth estimated factors have little resemblance when estimated in different time ranges.

The third factor still accounts for 11.5%, a value close to the 10.5% of the whole sample, and as seen before both estimations reflect in this value the fluctuations of early eighties.

Finally, the first factor importance in explaining the common variance is more or less the same (34% vs. 35.6%), however the second factor has a quite smaller value on the whole sample (14.8% vs. 22.9%).

However to take any conclusion we should, also, analyze the importance of each factor in explaining the volatility of each national business cycle.

Variance decomposition stability. The next five graphics (figure 11 to 15) compare the variance decomposition of the national business cycles for the 1970-1990 sample (top graphic) with the 1970-2001 sample (bottom graphic).

Figure 11: Comparision of the variance decomposition for the first factor
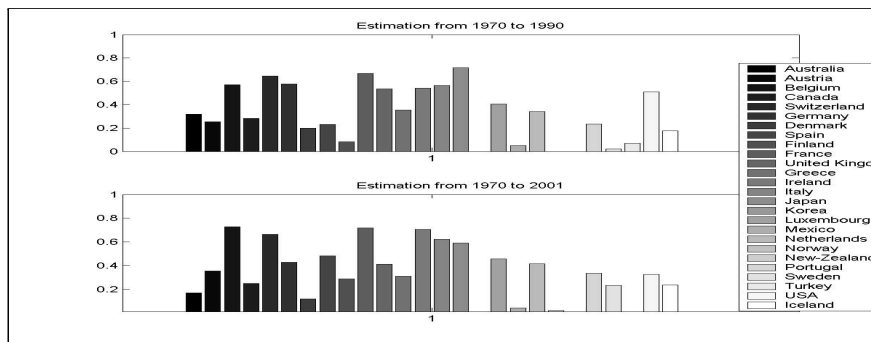
The importance of the first factor seems stable across periods, the variance decomposition ratios are more or less equal on both samples. However there are two countries for which this factor has varied in importance when comparing the sample until 1990 with the sample until 2001: for Spain it increased and for USA it decreased.

For the second factor the ratios are, also, stable. However five countries have experienced a reduction on the sensibility to this factor: Finland, Italy, Korea, Mexico and Turkey. However for Finland the second factor is still important, which does not happen with the other four countries. The reduction of the

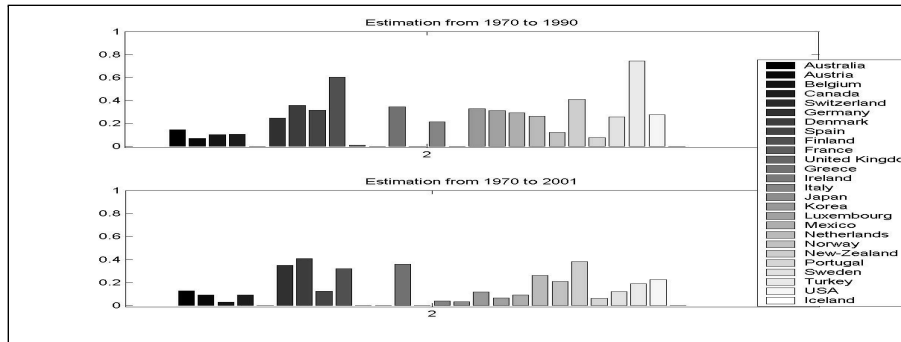Figure 12: Comparision of the variance decomposition for the second factor

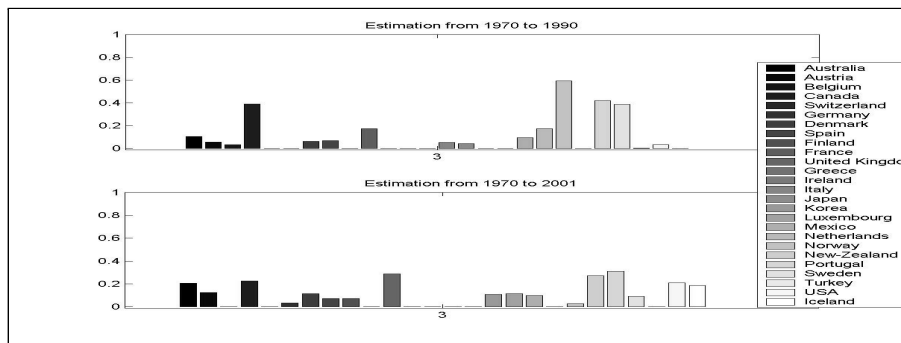Figure 13: Comparision of the variance decomposition for the third factor

Figure 14: Comparision of the variance decomposition for the fourth factor
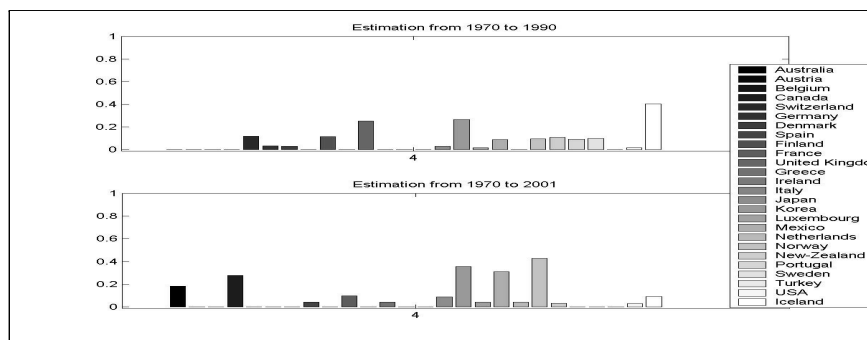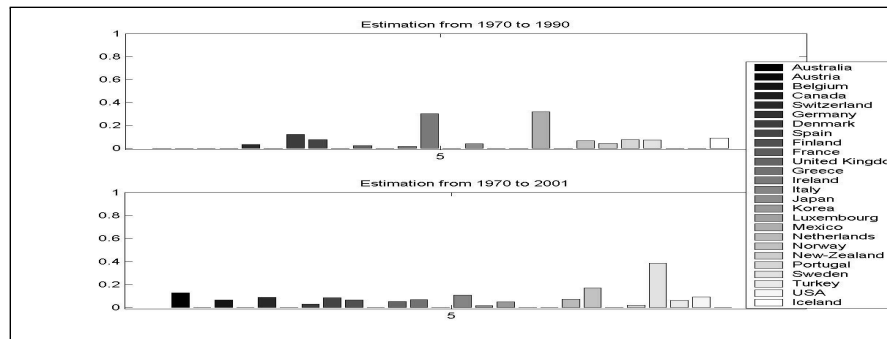
Figure 15: Comparision of the variance decomposition for the fifth factor

ratios for Korea, Mexico and Turkey are an indicator that these countries are less correlated with the world business cycle, as the importance of the first factor was still small.

As for the other three other factors it seems that the restrict sample captures completely different linkages across countries, either if we do direct or cross comparisons across the factors.

Therefore it seems that the regional linkages strength change when we consider different time samples.

3.2.4 Clustering analysis

From the previous results it seems that there is no stable regional common component, however it is not obvious if some countries cluster together or not, defining regions *in latus sensus* and, if those regions exist, which countries belong to them. That will be the issue of the present point.

From the previous point it seems that there are only two stable factors in this sample, therefore the clustering will be done using those stable factors. This study will be divided into two parts. The first presents the results for hard clustering and the second presents the results for fuzzy clustering[16]

Hard clustering. When considering how to cluster the countries I used two alternative methods: not considering the country idiosyncratic movement and considering it. In the first method the distance of two countries is measured

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[16]Appendix D shortly describes both methods, a more extensive description can be found in Kaufman and Rousseeuw(1990)

only by the importance of each factor on the volatility of each country business cycle:

$$d_{c1,c2} = \sqrt{\sum_{i=1}^{r} \left(\left(\lambda_i^{c1} \right)^2 - \left(\lambda_i^{c2} \right)^2 \right)^2} \tag{13}$$

where $\quad : \quad \left(\lambda_i^{cj} \right)^2$ is the importance of factor i to country c_j, j=1,2

By not considering the idiosyncratic movement we verify which countries are more similar in their structure of dependence relative to the common factors. This does not mean that countries that are similar have an high rate of com-movement between them, as their dependence form the common factors may be weak and the idiosyncratic component strong.

To check commovement we should consider the idiosyncratic factor of each country as two additional variables in defining the distance between countries:

$$d_{c1,c2} = \sqrt{\sum_{i=1}^{r} \left(\left(\lambda_i^{c1} \right)^2 - \left(\lambda_i^{c2} \right)^2 \right)^2 + (s^{c1})^2 + (s^{c2})^2} \tag{14}$$

where $\quad : \quad \left(\lambda_i^{cj} \right)^2$ is the importance of factor i to country c_j

$(s^{cj})^2$ is the importance of the idiosyncratic component of country c_j

and $j \quad = \quad 1,2$

in this way even if the structure dependence from the common factors is similar but weak, the countries will not appear in the same group but apart.

The next two figures show the cluster tree for both methods.

From figure (16) and making the divisions when a clustered group of countries joins with other group with more than two/three countries we can identify five/six groups: the first one is composed by France, Ireland, Belgium, Switzerland, Japan and Italy (call it the French-Japanese group); a second group comprises Australia, Canada, Sweden, Austria, Portugal, Iceland, Spain, Luxembourg and UK (this group can be divided into two subgroups: Spain, Luxembourg and UK in one and the remaining countries in other). A third group comprises Mexico, Turkey, Korea and Norway. A fourth one includes Germany, Netherlands, Finland, USA and Greece (a German-USA group). Finally Denmark and New Zealand appear as two countries apart from the others. However

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Figure 16: Hard Cluster of OECD countries without idiosyncratic component
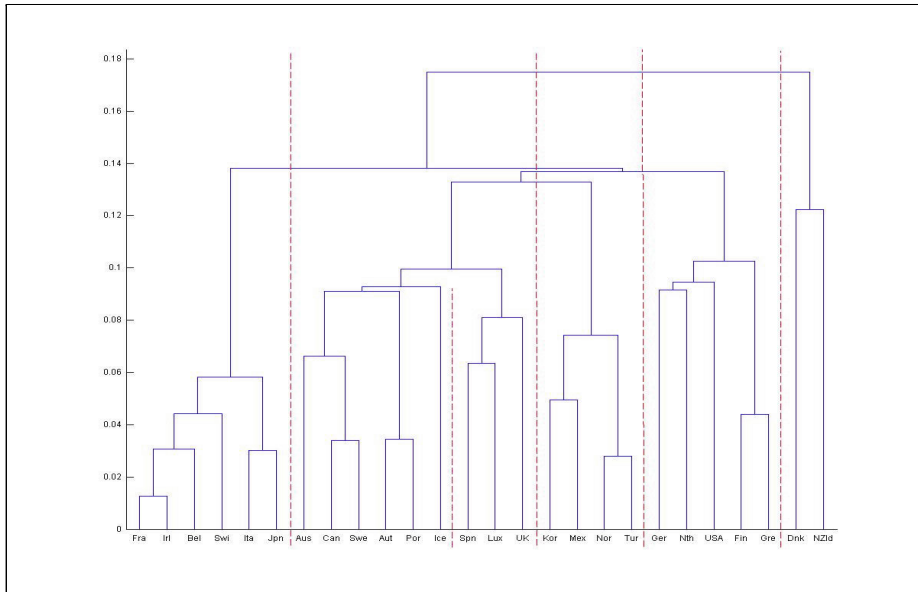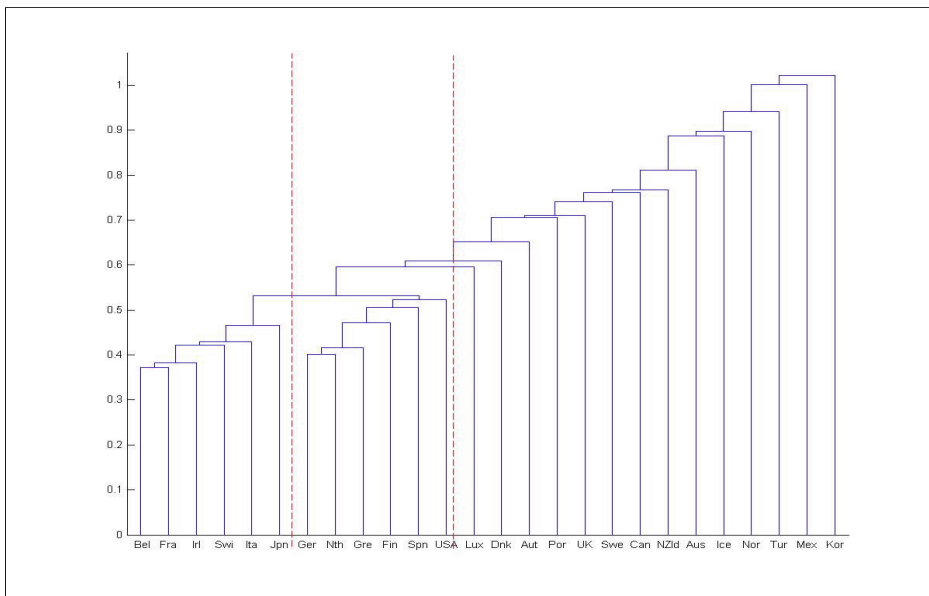

Figure 17: Hard Cluster of the OECD countries with idiosyncratic component

this just illustrates how the countries are similar in their dependence from the common components.

It is interesting to compare this division with the one obtained from figure(17). In that tree there are just two surviving groups: the French-Japanese one (composed by the same countries as before) and the German-American one (that adds Spain to the previous group). This two groups cluster between themselves before any other country. It seems therefore that the OECD commovements can be depicted by two centers: the French-Japanese and the German-American centers and all other countries are peripherical to those centers, being that Norway, Turkey, Mexico and Korea (the third group from the previous figure) appear as the most distant (and therefore commove less with the remaining). In fact those countries have a weak dependence from the two first common factors (see figures 3 and 4).

Fuzzy clustering   However the last approach has the limitation that allocates a country to a certain group, and sometimes the country position may be half way through two centers, in that case the method allocates it arbitrary to one of the groups. In order to correct that shortcoming this subsection presents the results for fuzzy clustering, where countries are not allocated certainly to a group but will be given a probability measure of belonging to the several groups. The study was done without the idiosyncratic component, hence, it is just checking for similar dependence on common factors.

The table (depicted in figure 18) reports the results for fuzzy clustering with 6 groups[17].

From those values seems that the groupings found in figure (16) are overall confirmed. Cluster IV comprises the French-Japanese group, however we can see that Italy and Japan association with this cluster is weaker when compared with the other members. Cluster VI comprises the USA-Germany group however it is not as strong defined as the other clusters. Cluster V comprises the Mexico, Norway, Korea and Turkey group, where appears also New Zealand but with a weaker association. Finally Clusters I, II and III comprises all the other countries divided into several sub-groups. When trying with four Clusters, this three groups appear as forming one single cluster.

As for the groups silhouettes, Clusters I to IV have quite high values, as the

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[17]The choice of the number of groups was based in the maximum value for the normalized Dunn coefficient, when the number of clusters range from 2 to 8. For six clusters the normalized Dunn coefficient is 0.3011.

Figure 18: Fuzzy cluster for the OECD countries

Clusters	I	II	III	IV	V	VI	Country Silhouettes
Australia	0.0852	**0.4779**	0.1436	0.0399	0.1520	0.1015	0.9999
Austria	0.1248	0.1019	**0.6606**	0.0310	0.0320	0.0497	0.8796
Belgium	0.0753	0.0368	0.0493	**0.7784**	0.0245	0.0357	0.8752
Canada	0.0719	**0.6187**	0.1663	0.0282	0.0557	0.0592	0.9999
Switzerland	0.1088	0.0468	0.0660	**0.7058**	0.0298	0.0428	0.8852
Germany	0.1676	0.1334	0.1507	0.0854	0.0865	**0.3764**	0.5917
Denmark	0.1147	0.1739	0.1357	0.0678	0.2213	**0.2865**	0.3583
Spain	**0.5969**	0.0767	0.1444	0.0732	0.0376	0.0712	0.7405
Finland	0.0529	0.0704	0.0620	0.0251	0.0462	**0.7434**	0.58
France	0.0435	0.0214	0.0287	**0.8721**	0.0142	0.0202	0.8882
UK	**0.3266**	0.1359	0.3038	0.0929	0.0606	0.0801	0.6475
Greece	0.0543	0.0636	0.0594	0.0274	0.0449	**0.7505**	0.6327
Ireland	0.0361	0.0173	0.0235	**0.8955**	0.0114	0.0162	0.8958
Italy	0.2313	0.0801	0.1192	**0.4470**	0.0485	0.0739	0.836
Japan	0.2951	0.0906	0.1404	**0.3399**	0.0531	0.0808	0.7778
Korea	0.0655	0.1388	0.0886	0.0387	**0.5872**	0.0812	0.5813
Luxembourg	**0.6342**	0.069	0.1539	0.0598	0.0319	0.0512	0.7991
Mexico	0.0843	0.2	0.1189	0.0479	**0.4502**	0.0987	0.3927
Netherland	0.2154	0.1465	0.1888	0.0807	0.0775	**0.2912**	0.4955
Norway	0.033	0.0691	0.0438	0.0191	**0.7858**	0.0493	0.6513
N. Zealand	0.1089	0.1724	0.1307	0.068	**0.3210**	0.199	0.5035
Portugal	0.1071	0.1168	**0.6645**	0.0309	0.0343	0.0464	0.8636
Sweden	0.0534	**0.7128**	0.1087	0.0216	0.0497	0.0538	0.9999
Turkey	0.0268	0.0547	0.0354	0.0158	**0.8293**	0.0381	0.6792
USA	0.159	0.2004	0.2098	0.0576	0.0837	**0.2896**	0.2924
Iceland	0.1412	**0.3245**	0.2652	0.0638	0.1101	0.0952	0.9999
Cluster Silhouettes	0.729	0.9999	0.8716	0.8597	0.5616	0.4918	

other two have silhouettes around 50% showing that those groups are not as well defined as the first four.

3.2.5   Conclusions for the OECD sample

First it seems that there are only two stable factors on this sample, and the world business cycle is a mixture of those two components. Only for Korea, Mexico and Turkey is the importance of the world business cycle small (it accounts for less than 20% of the national cycles variability). Moreover worldwide there is evidence of a core of countries that commove around two axis: a German-USA and a French-Japanese. The other countries seem to be peripherical to this core. That periphery can be decomposed into two groups with similar structures: one closer to the center (composed by Australia, Canada, Sweden, Austria, Portugal, Iceland, Spain, Luxembourg and UK) and other more distant (Mexico, Turkey,

Korea and Norway). Denmark and New Zealand seem to be half way between this two peripheries.

This leaves to question what are those factors depicting. From observing figure 2 and 5 both factors reflect the oil crisis of 73 and 81. They are different from mid-eighties onwards: the first factor depicts a long period of recession on the eighties, a growth period at the end of eighties and a recession on the early nineties and a period of recovering during the nineties. The second component depicts a growth period during the mid-eighties and a recession on the end of eighties. In the nineties it keeps around zero. We could think on the oil price, the USD exchange-rate volatility, periods of monetary and/or fiscal expansion, etc. Try to identify the shock source that those two components depict can be the issue of future research. However, as Kose et all.(2003) say: "...*it is easier to say what those components are not than what they are.*" In their study they could not identify any single source that could be responsible for the single world factor that they have estimated.

3.3   Results for the whole sample

In the previous point we have seen that the world business cycle is composed by two distinct components, that affect the variability of most national cycles. However that study was done for the OECD countries, and not taking into account developing countries. This section adds to the OECD countries more 33 developing countries (see appendix A) to try to see if we can identify the same components of the world business cycle and, if so, if those components are important for the volatility of national cycles of developing countries.

The structure of this subsection is equal to the previous one.

3.3.1   Estimation of the number of common factors

The estimation of the number of components for the 59 country sample was more difficult, due to the increased cross-heteroskedasticity of the idiosyncratic components found in the sample (see appendix B). The information criteria depicted in equation (2) give the following results (table 4) when $Rmax = 5$:

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Table 4 - Number of Common Factors

	Standardized Data	Non Standardized Data
IC1	5($Rmax$)	5($Rmax$)
IC2	4	5($Rmax$)
IC3	5($Rmax$)	5($Rmax$)

Table 5 shows the percentage of the common variance that each eigenvector is capturing.

Table 5

Eigenvalue	1	2	3	4	5
Ratio	0.2039	0.1383	0.1194	0.0939	0.0675
Eigenvalue	6	7	8	9	10
Ratio	0.0591	0.0558	0.0468	0.0346	0.0296

Analyzing both methods they give conflicting results: the IC2 points to four. If we fix at 5% the percentage from which we ignore the factors, table 5 points to seven. If we fix at 10% it points to three. The choice was to fix at 4 the number of common factors (following the indication of the IC2 for standardized data).

It might seem strange to estimate less factors for a bigger cross-country sample, however, as we saw before there was only two factors in the OECD sample that were stable, indicating that two should be the number of common components on that sample.

3.3.2 Estimation results

Figure 19[18] shows the evolution of the four factors estimated. From that we can realize that the first and second factor are similar to the ones estimated in the previous section. The third has no resemblance with any of the components estimated before and the fourth factor behavior during the eighties is similar to the behavior of the third component estimated in the OECD sample.

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[18] As before, all series of residuals, except three, accepted homoskedasticity at 10% significance level, and all accepted it at 5%.

As for AR(1), the picture is slightly different: 50 series accepted no AR(1) at 5% level and 56 accepted no AR(1) at 1% level. However, the problem of some series being AR(2), also, persists in this sample. Therefore we have to rely on the asymptotic distribution when $\sqrt{N}/T \to 0$. As $N = 59 \to \sqrt{N} \in (7; 8)$ which continues to be smaller than $T = 32$.

Figure 19: Factors estimated for the world sample
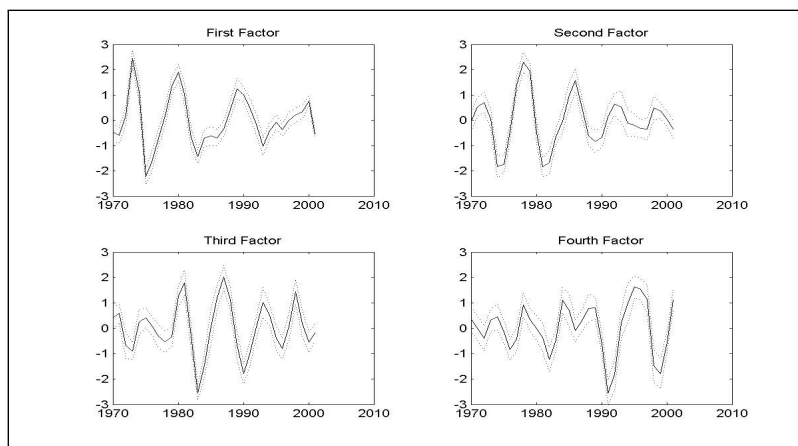
In Figures 20 to 23 we can see the variance decomposition for the different countries.

Taking 20% as benchmark the first two factors (that we considered as the two world business cycle components in the previous sample) are important for all European countries with the exception of Turkey and Sweden . In America they are important to USA, Canada, Chile, Costa Rica and Guatemala. In Asia to Japan, Hong Kong and Philippines. Finally, in Africa, Gambia and Ghana are affected by the first component,and Côte d'Ivoire, South Africa, Zambia and Zimbabwe are influenced by the second component.

The third component is important for Norway, Uruguay (more than 60%), Peru, Paraguay, Brazil, Korea, China, Malaysia, Philippines and Thailand. With the exception of Norway all countries are non-OECD ones.

As for the forth factor it seemed to have some resemblances with the third component estimated for the OECD (the Anglo-Saxon component). However, by analyzing the variance decomposition it is important only for a minority of countries and is not important for most Anglo-Saxon countries.

As conclusion we can realize that the first and second common component have a analogous behavior as in the OECD sample and its importance for the OECD countries is similar. As for the third and fourth they seem specific to non-OECD countries. However as we saw in the OECD sample only the first two components were robust when analyzing their stability through time. That

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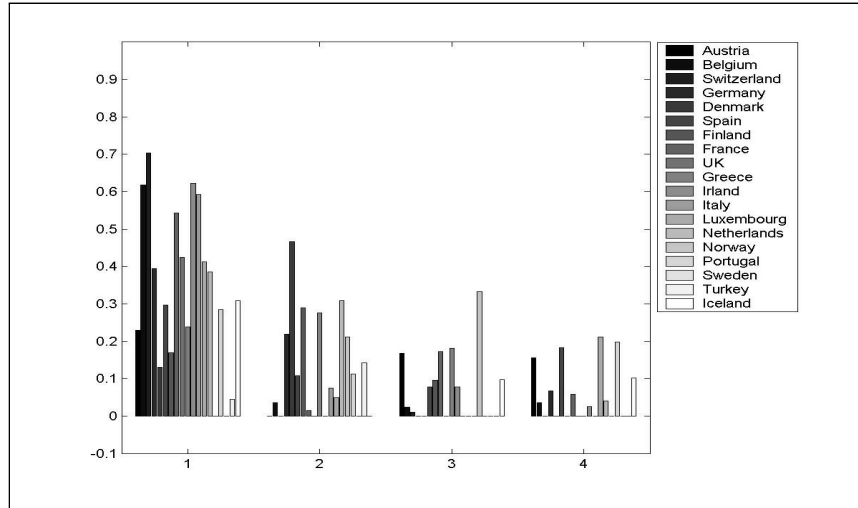
Figure 20: Variance decomposition for Europe

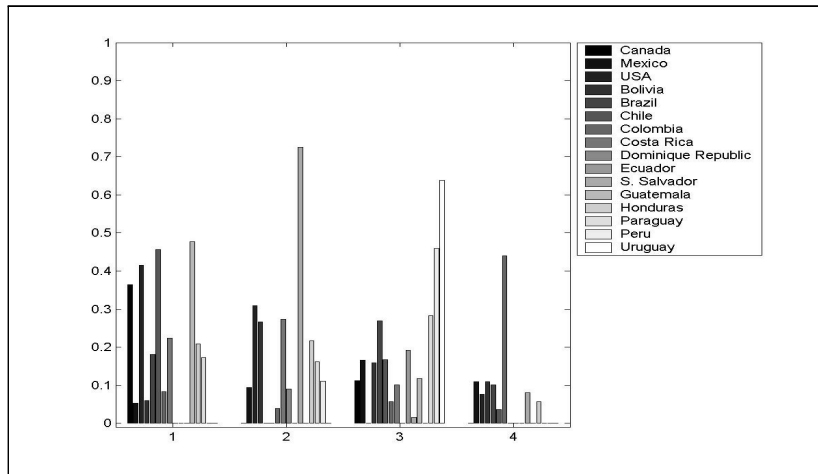Figure 21: Variance decomposition for North and South America

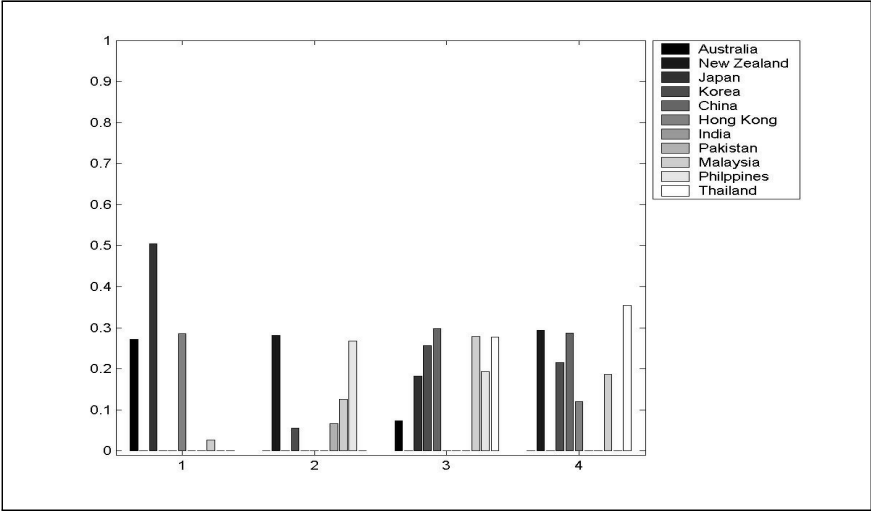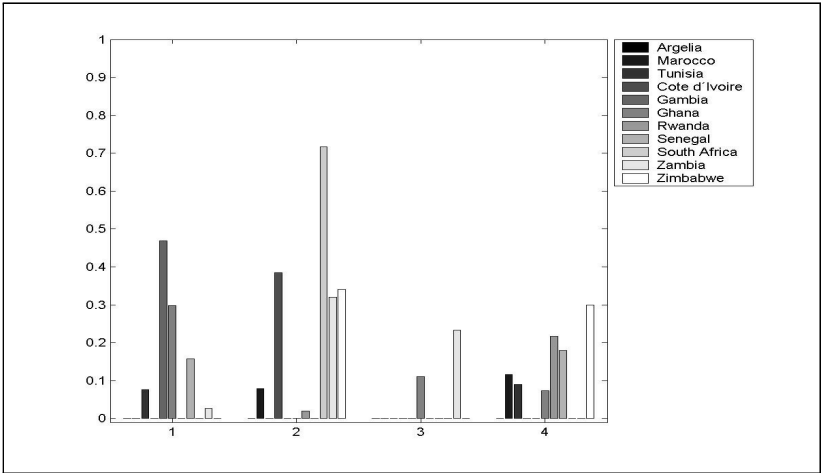Figure 22: Variance decomposition for Oceania and Asia

Figure 23: Variance decomposition for Africa

and a cluster analysis are the issues of the following sections.

3.3.3 Stability issues

As before, we are going to compare the results for the whole sample with the
results for a restricted time frame: 1970-1990.

Are the common factors the same? The first question is if the estimated
factors are the same. Figures 24 to 27 compare both estimations.
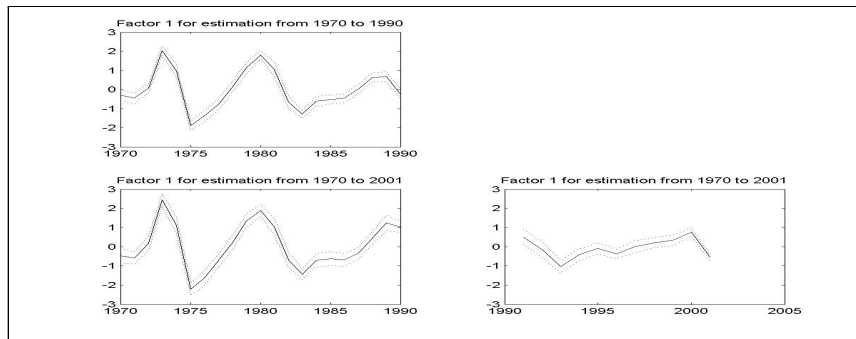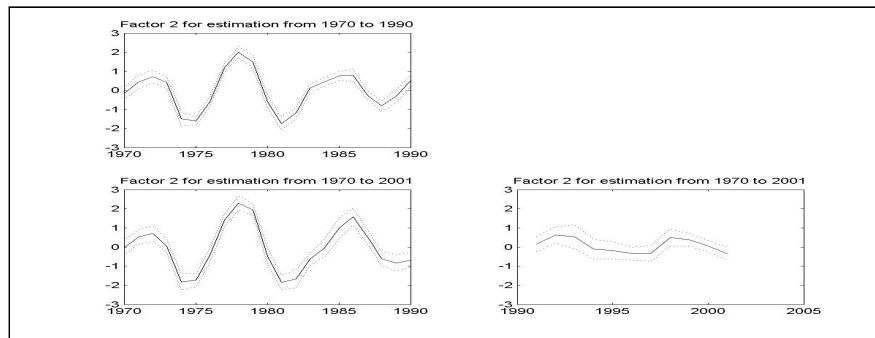
Figure 24: First factor comparison

Figure 25: Second factor comparison

From these figures we can realize that the first three factors estimations are
stable across time, although the third factor is slightly different in the second half
of the seventies. The fourth factor also has some resemblances across samples,
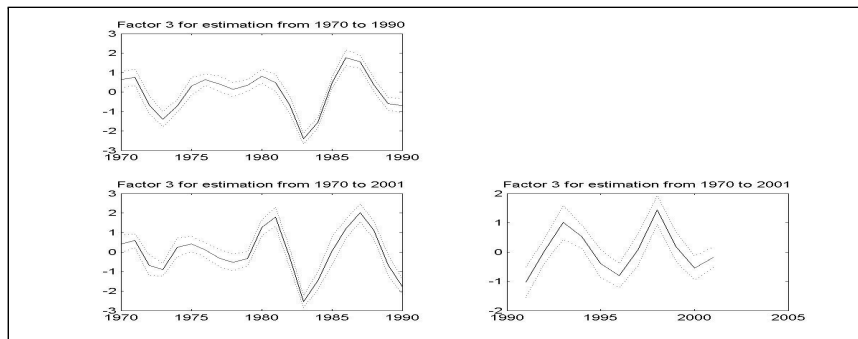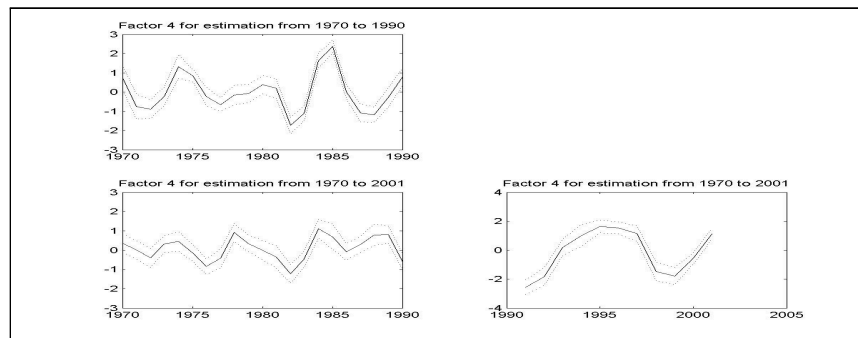
Figure 26: Third factor comparison

Figure 27: Fourth factor comparison

although the way to the trough on 1982 is quite different: on the sample 1970-2001 the factor peaks around 80 after being growing since 1976. In the sample 1970-1990 it peaks around 1978. However the confidence intervals are close enough to not dismiss that is the same factor[19].

Is the relative importance of the factors the same? If the factors estimated are the same, the next question is to know if their relative importance in explaining common variations change. Table 6 (on the next page) compares the ratios.

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[19]I also tried to estimate a model with more factors, but from the fifth factor onwards the estimate factors have little resemblance across samples. So I kept the model with only four factors.

Table 6

Eigenvalue	1	2	3	4	5
Ratio - Sample 1970-1990	0.2537	0.2059	0.1366	0.0873	0.0671
Ratio - Sample 1970-2001	0.2039	0.1383	0.1194	0.0939	0.0675
Eigenvalue	6	7	8	9	10
Ratio - Sample 1970-1990	0.0486	0.0428	0.0393	0.0310	0.0247
Ratio - Sample 1970-2001	0.0591	0.0558	0.0468	0.0346	0.0296

Contrary to the OECD sample where the importance of the first factor was similar, in this enlarged sample the importance of the first factor decreases from 25,4% to 20.1%. As in the OECD sample the second factor ratio decreases and the ratio for the third factor is slightly smaller.

The decrease of importance of the first factor can be an indicator that the business cycles of non-OECD countries are getting less similar to the cycles of OECD countries. As we saw before the 2nd factor is more or less constant at zero level after 1990, therefore it is not surprising that it's importance diminishes when we consider the whole sample compared with the time restricted sample.

Variance decomposition stability. Finally, if factors are the same in both samples, are they affecting the same countries in the same way? Figures 28 to 31 compares the variance decomposition for the two periods considered.

From those graphics we can see that despite the importance of factor 1 has decreased overall only Colombia experienced a huge drop (from more than 60% to less than 10%). There is no indication that the world got more integrated around factor 1.

As for the 2nd common component we see that a number of countries saw their ratios reduced: Zimbabwe, Zambia, Uruguay, Peru, Morocco, Turkey, Mexico and Korea. Only Philippines increased its ratio.

The third factor has seen a overall reduction on the ratios, however the countries that had the bigger ratios on the longer sample, continue to have the bigger ratios on the shorter sample.

As for factor four we can realize that for Algeria, Malaysia and Ghana its importance was reduced to almost zero. For Portugal the ratio decreased but continue to account for about 10% of the national cycle variability. By other side Thailand, Zimbabwe and Colombia have an increase on their ratios. This sharp variations can make us suspicious if the fourth factor is stable, or even if it is depicting the same factor.

Figure 28: Comparision of the variance decomposition ratio for factor 1
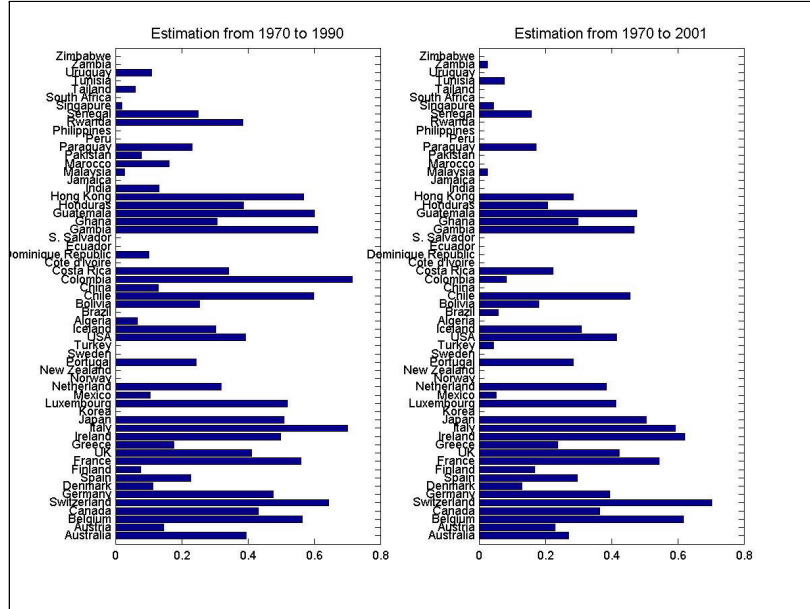

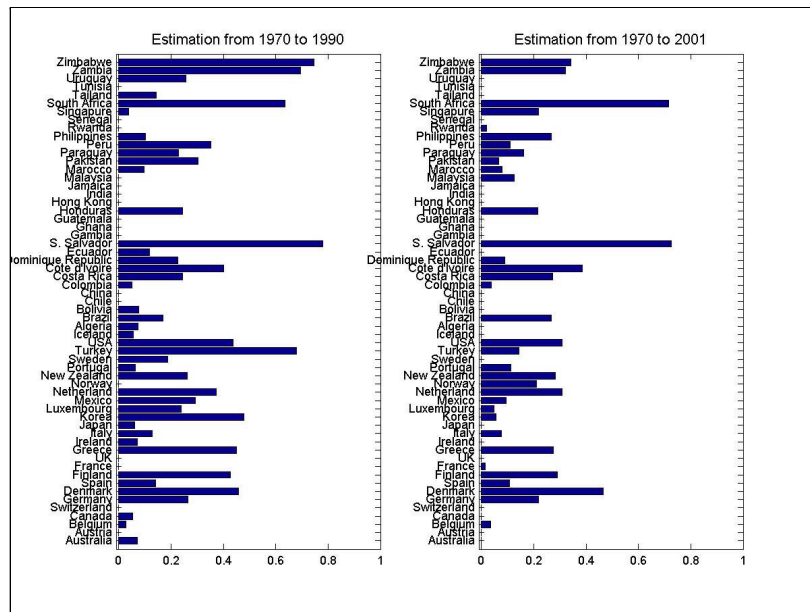Figure 29: Comparision of the variance decomposition ratio for factor 2

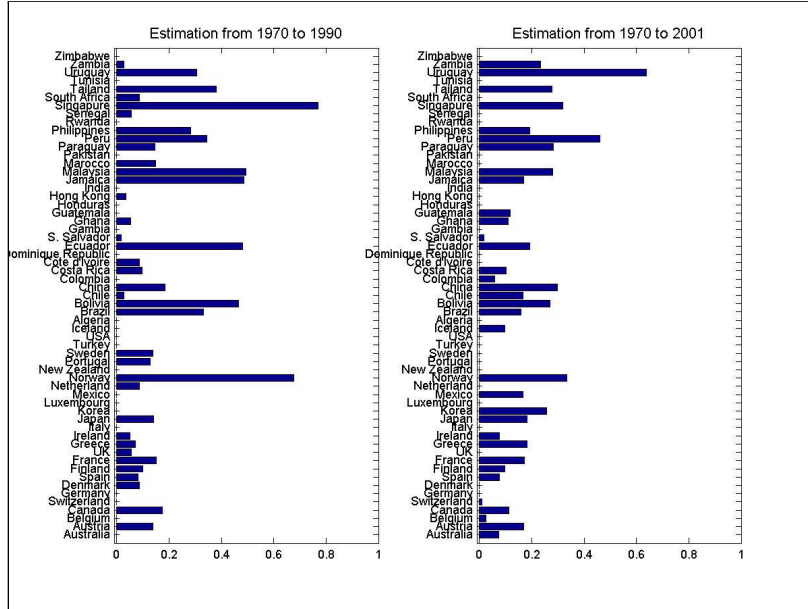Figure 30: Comparision of the variance decomposition ratio for factor 3
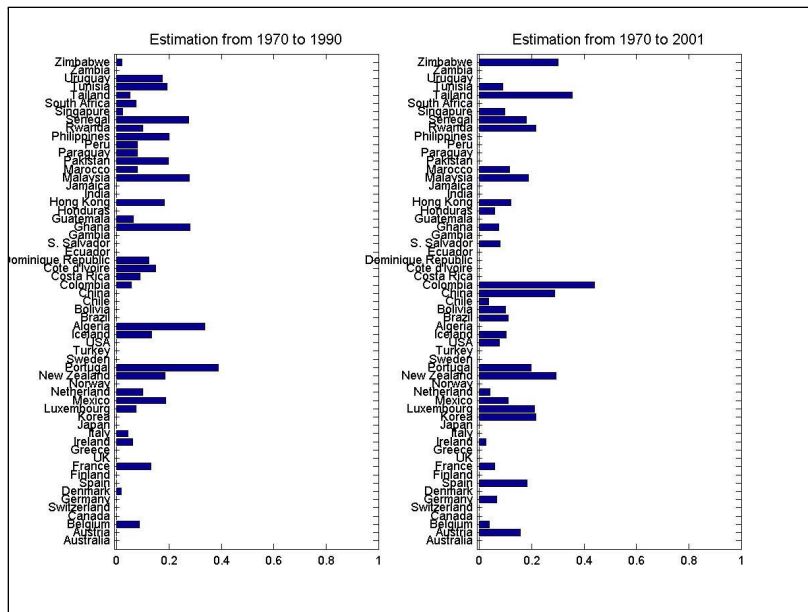

Figure 31: Comparision of the variance decomposition ratio for factor 4

3.3.4 Clustering analysis

As for the OECD sample, this subsection tries to see if we can identify countries belong to the same groups, and thus defining regions *in latus sensus*.

Hard clustering As for the OECD sample the next two figures show the hard clustering trees without the idiosyncratic element (checking similarity of structure) and with the idiosyncratic element (checking commovement). As the stability analysis has indicated some instability in the fourth factor the clustering presented in this and next subsection is made using only the first three estimated factors[20].

From figure 32 we get a rather complex image. However we can realize that group VI include USA, Germany and Netherlands and the majority of countries of group III are OECD ones. Is in subgroup IIIB and IIID that we can find the countries of French-Japanese group identified in the OECD pictures. The fact that they appear splited in two groups is due to the inclusion of Chile and Guatemala in subgroup IIIB that by averaging with France and Japan pushes the values away from the other countries, however, we should note that the hard-cluster done with the same data but only for the OECD countries gives a image identical to figure 13[21] .

The hard-clustering taking into account the idiosyncratic component gives a image similar to the one for the OECD sample. Two groups commoving: the German-USA (with Netherlands, Greece and Spain) and the French-Japanese (with Ireland, Belgium, Switzerland, Chile, Guatemala, Italy and Luxembourg). Those two groups form a center, as they cluster together and all the others cluster afterwards one by one, or in small groups.

From figures 32 and 33 we get the same picture as for the OECD sample. Two groups that have similar structures and commove between themselves (that we can label German-USA and French-Japanese), and all the other countries being a periphery to those centers. We should, also, note that in the central groups there are only two non-OECD countries: Chile and Guatemala and in the ten countries that commove less with the center, only one is part of the OECD: Turkey.

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[20]Countries are tagged from 1 to 59. The codes can be found in appendix A.

[21]In order to not overload this section with more figures I opted to not transcribe it as it does not add other information than the one reported in the previous figures.

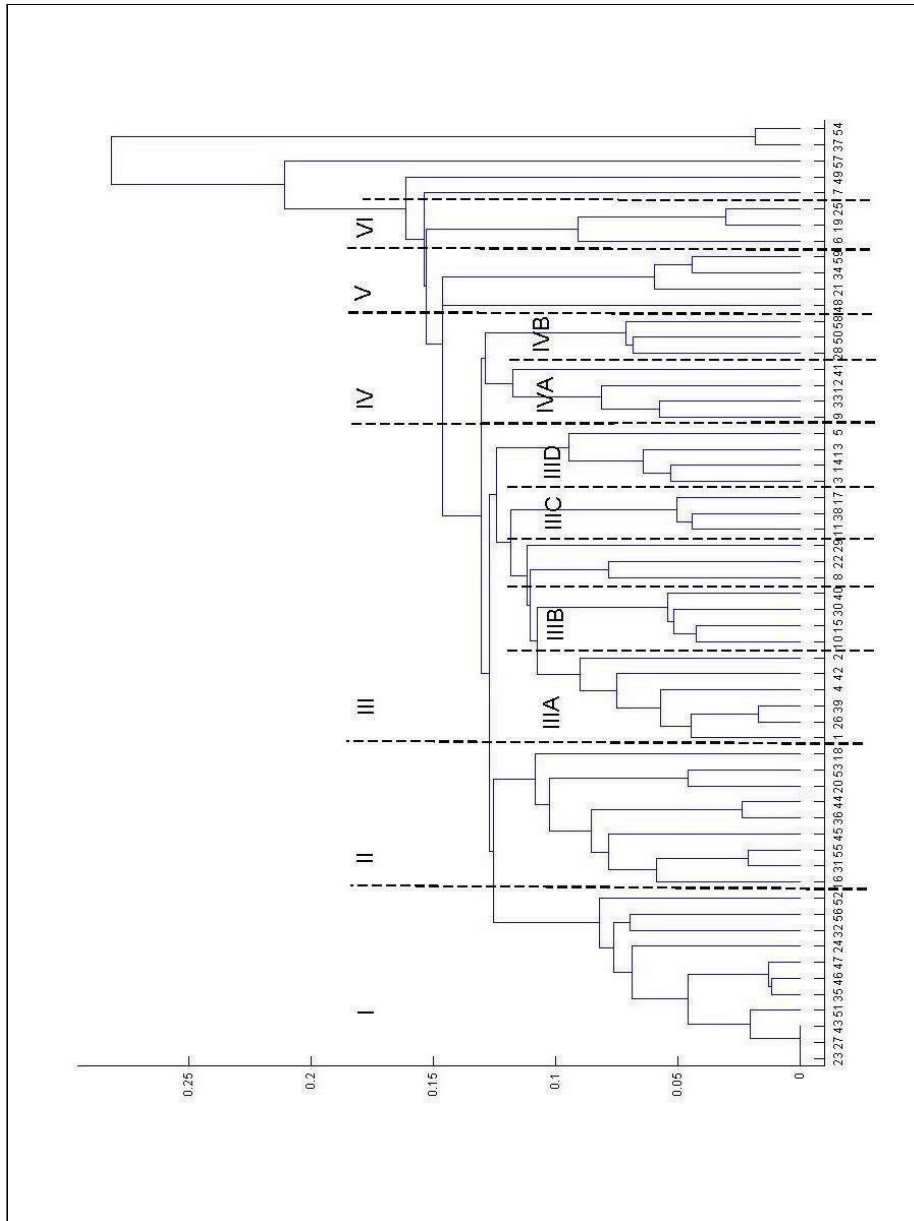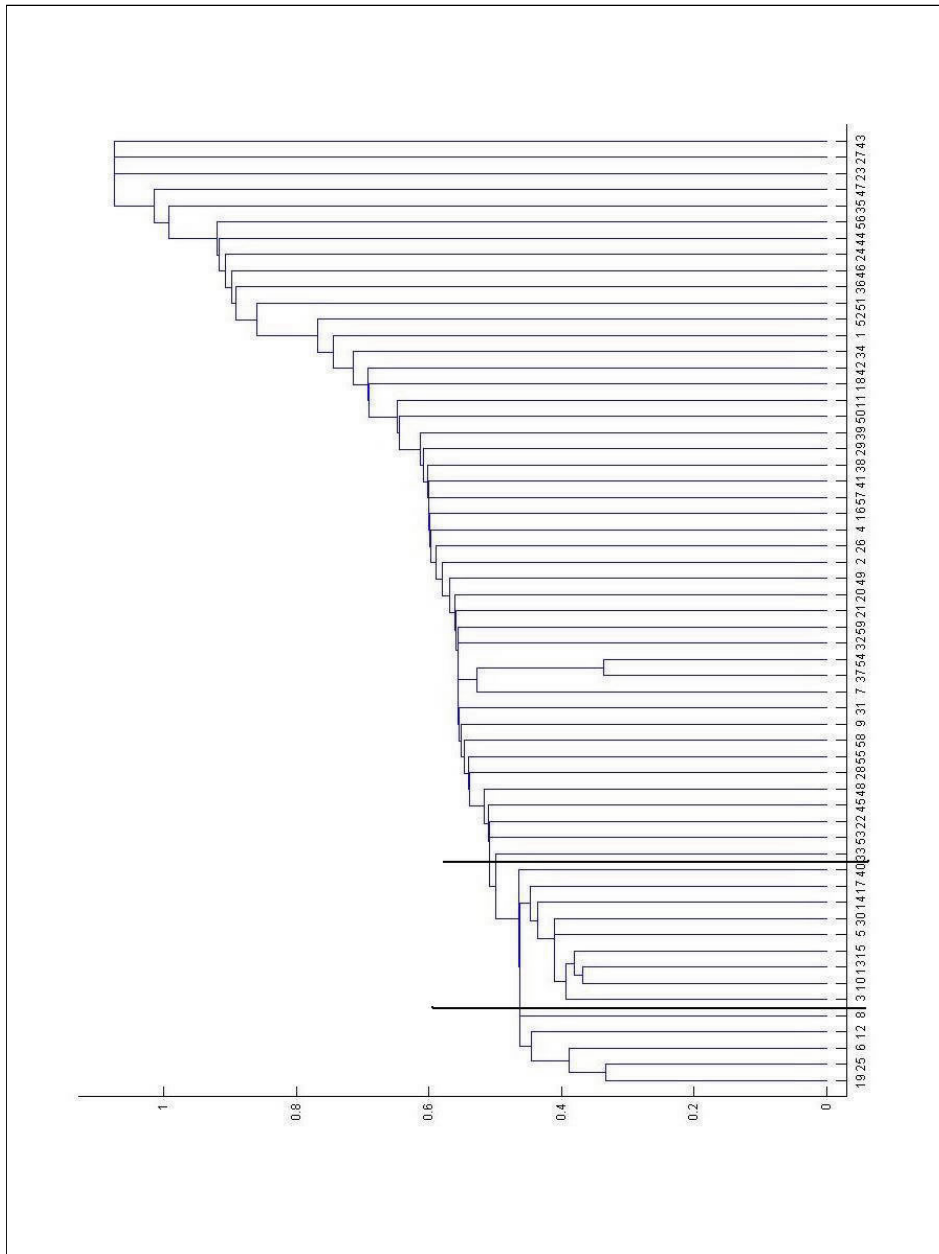Figure 32: Hard cluster without the idiosyncratic component

Figure 33: Hard Clustering with idiosyncratic componen

Fuzzy clustering   For the fuzzy cluster analysis, the use of 3 factors produced always low normalized Dunn-coeficents, the highest was 0.0899 for two clusters. Always taking into consideration that value, and therefore that the clustering is very weak, the results for two clusters are the ones in figure 34.

Figure 34: Fuzzy Cluster with three factors

	Cluster I	Cluster II	Country Silhouettes		Cluster I	Cluster II	Country Silhouettes
Australia	**0.6506**	0.3494	0.4181	Algeria	0.3483	**0.6517**	0.9997
Austria	**0.5602**	0.4398	0.2086	Brazil	0.3320	**0.6680**	0.9997
Belgium	**0.6763**	0.3237	0.6152	Bolivia	0.4750	**0.5250**	0.9997
Canada	**0.7175**	0.2825	0.5731	Chile	0.7036	**0.2964**	0.5979
Switzerland	**0.6436**	0.3564	0.5602	China	0.3642	**0.6358**	0.9997
Germany	**0.6536**	0.3464	0.4796	Colombia	0.3544	**0.6456**	0.9997
Denmark	**0.4498**	0.5502	0.9996	Costa Rica	0.4903	**0.5097**	0.9997
Spain	**0.6674**	0.3326	0.4272	Cote d'Ivoire	0.3907	**0.6093**	0.9997
Finland	0.4318	**0.5682**	0.9997	Dom. Republic	0.3163	**0.6837**	0.9997
France	**0.6855**	0.3145	0.6004	Ecuador	0.3300	**0.670**	0.9997
UK	**0.7174**	0.2826	0.6263	S. Salvador	0.4559	**0.5441**	0.9994
Greece	0.4915	**0.5085**	0.9997	Gambia	**0.7131**	0.2869	0.6393
Ireland	**0.6737**	0.3263	0.6092	Ghana	**0.6753**	0.3247	0.467
Italy	**0.6795**	0.3205	0.6142	Guatemala	**0.7191**	0.2809	0.6382
Japan	**0.6900**	0.3100	0.5953	Honduras	**0.5040**	0.4960	0.054
Korea	0.3257	**0.6743**	0.9997	Hong Kong	**0.6508**	0.3492	0.4451
Luxembourg	**0.7243**	0.2757	0.6226	India	0.3483	**0.6517**	0.9997
Mexico	0.2966	**0.7034**	0.9998	Jamaica	0.3262	**0.6738**	0.9997
Netherlands	**0.6015**	0.3985	0.3592	Malaysia	0.3275	**0.6725**	0.9997
Norway	0.3555	**0.6445**	0.9997	Morocco	0.3174	**0.6826**	0.9997
New Zealand	0.3558	**0.6442**	0.9997	Pakistan	0.3205	**0.6795**	0.9997
Portugal	**0.6431**	0.3569	0.4074	Paraguay	0.4304	**0.5696**	0.9997
Sweden	0.3483	**0.6517**	0.9997	Peru	0.4055	**0.5945**	0.9996
Turkey	0.3323	**0.6677**	0.9997	Philippines	0.3226	**0.6774**	0.9997
USA	**0.6095**	0.3905	0.3903	Rwanda	0.3382	**0.6618**	0.9997
Iceland	**0.6895**	0.3105	0.4982	Senegal	0.4874	**0.5126**	0.9997
				Singapore	0.3589	**0.6411**	0.9997
				South Africa	0.4557	**0.5443**	0.9994
				Thailand	0.3559	**0.6441**	0.9997
				Tunisia	0.3927	**0.6073**	0.9997
				Uruguay	0.4522	**0.5478**	0.9994
	Cluster I	Cluster II		Zambia	0.3577	**0.6423**	0.9997
Cluster silhouettes	0.4977	0.9977		Zimbabwe	0.3757	**0.6243**	0.9997

Although the clustering is very weak, as it can be seen for the number of countries where the probability of being in either cluster is almost 50%, it emerges the fact that most non-OECD countries belong to cluster II, and most of the OECD countries belong to cluster I. These facts emerge from the inclusion of the third factor.

If we compare with the fuzzy clustering with only two factors the first fact

Figure 35: Fuzzy cluster with two factors

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Country Silhouettes
Australia	**0.7127**	0.0586	0.0634	0.0806	0.0847	0.8514
Austria	**0.5542**	0.0971	0.1144	0.1288	0.1055	0.8143
Belgium	0.1562	0.0820	0.0730	0.1081	**0.5807**	0.8368
Canada	**0.4645**	0.0808	0.0788	0.1137	0.2623	0.7819
Switzerland	0.1896	0.1109	0.1011	0.1401	**0.4584**	0.7720
Germany	0.2467	0.1526	0.1017	**0.2670**	0.2320	0.5976
Denmark	0.1315	0.3088	0.1170	**0.3423**	0.1004	0.0345
Spain	**0.4297**	0.1207	0.0946	0.2039	0.1512	0.7284
Finland	0.1080	0.2585	0.0833	**0.4832**	0.0670	0.3825
France	0.1132	0.0503	0.0455	0.0677	**0.7233**	0.8669
UK	0.2538	0.0703	0.0663	0.0979	**0.5117**	0.7925
Greece	0.1410	0.1955	0.0858	**0.4876**	0.0900	0.6005
Ireland	0.1598	0.0830	0.0757	0.1078	**0.5736**	0.8364
Italy	0.1604	0.0837	0.0721	0.1131	**0.5706**	0.8237
Japan	0.1014	0.0400	0.0369	0.0542	**0.7675**	0.8669
Korea	0.0930	0.1494	**0.5869**	0.1222	0.0486	0.8227
Luxembourg	0.2993	0.0830	0.0732	0.1217	**0.4228**	0.7465
Mexico	0.1411	0.2487	**0.3320**	0.2105	0.0676	0.6599
Netherlands	0.2048	0.1813	0.1077	**0.3177**	0.1885	0.616
Norway	0.0851	**0.5224**	0.1326	0.2101	0.0498	0.9998
New Zealnd	0.0689	**0.6022**	0.0887	0.1968	0.0435	0.9999
Portugal	**0.4153**	0.1268	0.0979	0.2166	0.1433	0.7163
Sweden	0.0136	0.0165	**0.9480**	0.0148	0.0072	0.8777
Turkey	0.1226	**0.3503**	0.2211	0.2431	0.0628	0.9998
USA	0.2096	0.1766	0.1096	**0.2956**	0.2085	0.5970
Iceland	**0.6984**	0.0563	0.0577	0.0787	0.1088	0.8446
Algeria	0.0136	0.0165	**0.9480**	0.0148	0.0072	0.8777
Brazil	0.0724	0.5528	0.0820	**0.2491**	0.0437	0.9999
Bolivia	**0.3961**	0.1361	0.1872	0.1694	0.1111	0.7347
Chile	0.157	0.0511	0.0477	0.0705	**0.6736**	0.8389
China	0.0136	0.0165	**0.9480**	0.0148	0.0072	0.8777
Colombia	0.1783	0.1767	**0.3895**	0.1788	0.0766	0.7304
Costa Rica	0.1315	0.1992	0.0832	**0.5039**	0.0821	0.5782
Cote d'Ivoire	0.1020	**0.4375**	0.1137	0.2756	0.0712	0.9998
Dom. Republic	0.1144	0.2339	**0.4169**	0.1743	0.0604	0.7253
Ecuador	0.0136	0.0165	**0.9480**	0.0148	0.0072	0.8777
S. Salvador	0.1585	**0.2765**	0.1558	0.2752	0.1340	0.9996
Gambia	0.1268	0.0436	0.0406	0.0599	**0.7290**	0.8517
Ghana	**0.7334**	0.0512	0.0532	0.0714	0.0908	0.8521
Guatemala	0.1136	0.0405	0.0376	0.0555	**0.7529**	0.8578
Honduras	0.1563	0.2020	0.0934	0.4657	0.0826	0.5139
Hong Kong	**0.7423**	0.0511	0.0541	0.0708	0.0817	0.8552
India	0.0136	0.0165	**0.9480**	0.0148	0.0072	0.8777
Jamaica	0.0136	0.0165	**0.9480**	0.0148	0.0072	0.8777
Malaysia	0.1223	**0.3184**	0.2751	0.2208	0.0634	0.9998
Morocco	0.1097	0.2062	**0.4674**	0.159	0.0576	0.7661
Pakistan	0.1018	0.1751	**0.5301**	0.1397	0.0532	0.8011
Paraguay	0.1922	0.2255	0.1266	0.3707	0.0850	0.3409
Peru	0.1179	0.2811	**0.3421**	0.1959	0.0629	0.6327
Philippines	0.0683	**0.6064**	0.0907	0.1921	0.0425	0.9999
Rwanda	0.0475	0.0628	**0.8100**	0.0548	0.0249	0.8664
Senegal	**0.3356**	0.1494	0.2284	0.1787	0.1079	0.6793
Singapore	0.0809	**0.5340**	0.1073	0.2318	0.0460	0.9998
South Africa	0.1577	**0.2780**	0.1552	0.2762	0.1329	0.9996
Thailand	0.0136	0.0165	**0.9480**	0.0148	0.0072	0.8777
Tunisia	0.1723	0.1486	**0.4516**	0.1510	0.0764	0.7609
Uruguay	0.0136	0.0165	**0.9480**	0.0148	0.0072	0.8777
Zambia	0.0764	**0.5468**	0.0873	0.2398	0.0498	0.9999
Zimbabwe	0.0864	**0.5081**	0.1011	0.2465	0.0579	0.9999
Cluster Silhouettes	0.7858	0.9998	0.8110	0.4735	0.8264	

is that the number of clusters increase to 5 (Normalized Dunn coefficient equal to 0.2837). However most of the non-OECD countries cluster in groups II and III (see figure 35), as most OECD countries cluster in the other groups. These OECD groups have the by now familiar structure: the group V is the French-Japanese grouping, as the IV is the German-USA one.

3.3.5 Conclusions for the whole sample

As conclusion we can say that factor 1 is mostly important for the developed countries and some, few, developing countries. Factor 2 is also important for some developed countries and for a number of developing countries. The third factor affects more non-OECD countries than OECD countries.

Against this background is difficult to say that a true world business cycle exists, as it seems more a developed world business cycle (that can be said to be composed by the two first common components). Most developing countries are little or not affected by the first two factors. By other side a number of them seem to follow the third factor, although for the developing countries the idiosyncratic components seem to be the important factor of volatility of their national business cycles.

4 Conclusion

As main conclusion, we can say that it seems that exists a world business cycle that is itself composed by two components. This conclusion is similar to the one found in Bayoumi and Helbling(2003). In their study, using a different approach, they also found that the common variations across the G7 countries were due to two components. They interpreted the first component as reflecting the common global shocks, and the second reflecting country shocks that were transmitted to other countries. In the present study I do not go as far as to give a formal interpretation of those two components, however the first component has many similarities with the world business cycles estimated in other papers, as the second seems to be capturing the fluctuations prior to the 90's. In that sense seems that from the 90's onwards the world business cycle has only one component. To perform a closer study of what those components are and what they represent is left for future work.

A second conclusion is that most of the developing countries are very weakly linked to the world business cycle. This world cycle seems more a developed

world cycle, than a true world cycle. This results are in line with those found in Kose et all.(2003) and Mansour(2003). Also those studies showed that most of the developing countries cycles are idiosyncratic.

A third conclusion is the absence of regional cycles, contrary to previous works which tried to estimate world and regional business cycles by assuming the existence of regions and regional components. In this sense there was no evidence for a distinctive European business cycle. The conclusion is, also, not new as Artis(2003) found if there existed a European region also Japan and USA would be part of it, rendering it non-European. In terms of regions, the absence of regional cycles leads to the absence of regions *in strictu sensus*, other than the developed/developing countries division. However in the developed countries we can group them according to the dependence structure from the common components, forming regions *in latus sensus.*

Finally the limitations of the work should be pointed: in first place we should note that the statistical inference was done using the asymptotic distribution. That raises the question if this distribution is close enough to the finite sample distribution to be reliable. To try to answer that question a small Monte-Carlo is presented in appendix E, where the finite distribution of the common component and the asymptotic distribution are compared. Second, the factor model is static, and does not capture potential dynamics in the transmission process from the world business cycle to each country. Third, it assumes that the importance of the factors is constant through time. As we saw from the stability analysis it seems that for some countries the loadings vary. Therefore, to try to include some variation across time on the loadings as Stock and Watson(1999) suggest could help into getting a clear idea of the world synchronization and how it has evolved. Last, the stability study is not based in any statistical inference. This is a backdrop of all factor models, however in this case it should be possible to develop a stability test based on the asymptotic distributions of the estimated factors and loadings.

This last two issues (variability of loadings and a stability test) and try to identify what are the common components describing are left for future work.

Appendix A - List of countries

OECD countries:	
1-Australia	14-Italy
2-Austria	15-Japan
3-Belgium	16-South Korea
4-Canada	17-Luxembourg
5-Switzerland	18-Mexico
6-Germany	19-Netherlands
7-Denmark	20-Norway
8-Spain	21-New Zealand
9-Finland	22-Portugal
10-France	23-Sweden
11-United Kingdom	24-Turkey
12-Greece	25-USA
13-Ireland	26-Iceland

Non- OECD countries	
27-Algeria	44-Jamaica
28-Brazil	45-Malaysia
29-Bolivia	46-Marocco
30-Chile	47-Pakistan
31-China	48-Paraguay
32-Colombia	49-Peru
33-Costa Rica	50-Philippines
34-Côte d'Ivoire	51-Rwanda
35-Dominique Republic	52-Senegal
36-Ecuador	53-Singapure
37-S. Salvador	54-South Africa
38-Gambia	55-Tailand
39-Ghana	56-Tunisia
40-Guatemala	57-Uruguay
41-Honduras	58-Zambia
42-Hong Kong	59-Zimbabwe
43-India	

Appendix B - Are the idiosyncratic components cross heteroskedastic?

The next graphics show the variance of the estimated residuals for the two models without standardizing the data.

Figure 36:
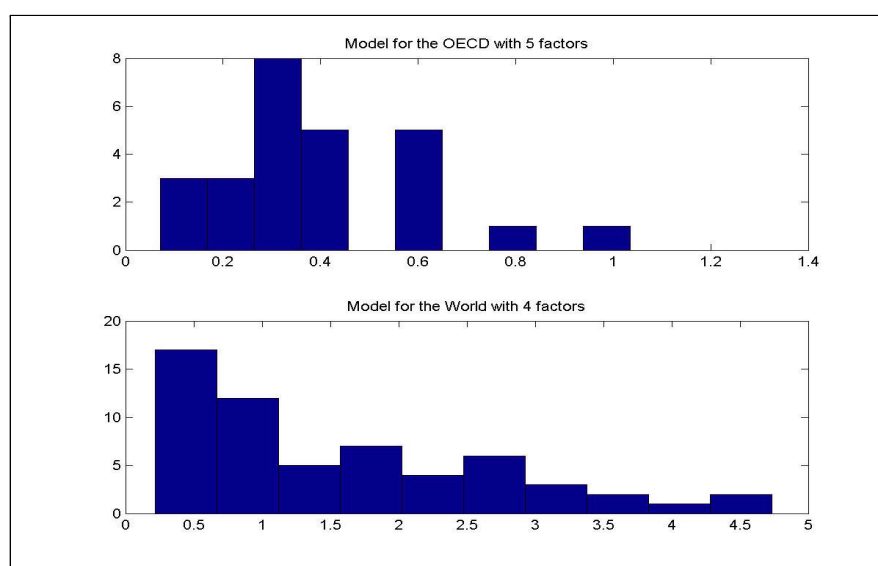
The world sample has more cross-section heteroskedasticity than the OECD sample. However, in the OECD case it does not seem too big to cause problems in the selection on the estimation of the number of factors (however a parameterized montecarlo simulation can help to answer that question). In the case the found cross-heterskodestacity do not cause problems, then them can be due to other sources: short sample, cross-correlation of the residuals (which would lead to problems on the inference of the loadings),etc..

Appendix C- Monte Carlo simulation for detecting the number of common factors

This simulation tries to see how many factors do the IC indicate for the factor model:

$$X_{it} = \lambda_i' F_t + e_{it} = C_{it} + e_{it}$$
$$i = 1, 2, 3, ..., N \text{ and } t = 1, 2, 3, ..., T$$

in which the number of factors was fixed at 2, 3 and 4. The factors are AR(1)processes described by:

$$F_t = 0.5 * F_{t-1} + \epsilon_t$$

ϵ_t are i.i.d.; randomly generated with variance equal to 1

The loadings λ_i' were generated randomly.

As for the idiosyncratic component e_{it} I considered two cases:

→ Cross-heteroskedastic: $\quad \frac{e_i' e_i}{T} = 0.1$ for $\frac{1}{4}$ of the series;

$\quad\quad\quad\quad\quad\quad\quad\quad \frac{e_i' e_i}{T} = 1$ for $\frac{1}{2}$ of the series

$\quad\quad\quad\quad\quad\quad\quad\quad \frac{e_i' e_i}{T} = 10$ for $\frac{1}{4}$ of the series

→ Cross-homoskedastic: $\frac{e_i' e_i}{T} = 1$ for all the N series

Being $T = 32$ and N equal to 26 or 59.

In both cases they are non-serial and non-cross correlated and homoskedastic on the time dimension.

The number of replications was 5000, and were done for standardized (Std) and non-Standardized (non-Std) data.

Table C1 - Cross-Heteroskedastic data

		2 factors		3 factors		4 factors	
		Std	non-Std	Std	non-Std	Std	non-Std
IC1	N=26	5.47 (1.177)	6 (0.0)	5.94 (0.346)	6 (0.0)	5.99 (0.133)	6 (0.0)
	N=59	2.1 (0.401)	5.76 (0.788)	3.70 (1.01)	5.87 (0.473)	5.15 (0.88)	5.91 (0.34)
IC2	N=26	2.65 (1.294)	6 (0.031)	4.55 (0.327)	5.99 (0.114)	5.50 (0.807)	5.97 (0.23)
	N=59	2 (0.045)	3.152 (1.492)	3.06 (0.281)	4.16 (1.24)	4.20 (0.525)	5.01 (0.88)
IC3	N=26	6 (0.0)	6 (0.0)	6 (0.0)	6 (0.0)	6 (0.0)	6 (0.0)
	N=59	5.95 (0.34)	6 (0.0)	6 (0.0)	6 (0.0)	6 (0.0)	6 (0.0)

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Table C2 - Cross-Homoskedastic data

		2 factors		3 factors		4 factors	
		Std	non-Std	Std	non-Std	Std	non-Std
IC1	N=26	4.11 (1.56)	2 (0.063)	4.92 (0.111)	3.02 (0.125)	5.4 (0.781)	4.05 (0.231)
	N=59	2.08 (0.331)	2 (0.0)	3.29 (0.061)	3 (0.0)	4.33 (0.572)	4 (0.0)
IC2	N=26	2.28 (0.712)	2 (0.0)	3.54 (0.779)	3 (0.0)	4.44 (0.644)	4 (0.032)
	N=59	2 (0.063)	2 (0.0)	3.04 (0.219)	3 (0.0)	4.09 (0.320)	4 (0.0)
IC3	N=26	6 (0.0)	6 (0.017)	6 (0.0)	6 (0.0)	6 (0.0)	6 (0.032)
	N=59	5.6 (0.949)	2.02 (0.318)	5.84 (0.499)	3.21 (0.572)	5.92 (0.313)	4.348 (0.628)

Appendix D - Short description of the clustering method

HARD CLUSTER TREES

The hard-cluster trees are built by applying the following steps:

1. Compute the following distances for all pair of countries:

1A Without the idiosyncratic component	1B With the idiosyncratic component
$d_{c1,c2} = \sqrt{\sum_{i=1}^{r} \left(\left(\lambda_i^{c1}\right)^2 - \left(\lambda_i^{c2}\right)^2 \right)^2}$	$d_{c1,c2} = \sqrt{\sum_{i=1}^{r} \left(\left(\lambda_i^{c1}\right)^2 - \left(\lambda_i^{c2}\right)^2 \right)^2 + (s^{c1})^2 + (s^{c2})^2}$

where $\left(\lambda_i^{cj}\right)^2$ is the importance of factor i to country cj;, $j = 1; 2$ and $(s^{cj})^2$ is the idiosyncratic component of country cj national cycle, $j = 1; 2$.

2. Find the minimum value,

If the minimum value is between two original countries go to 3A.

If the minimum value is between a clustered group and other country or clustered group go to 3B

3A Delete those two countries from the sample and add an artificial country where the loadings are equal to the average of the clustered countries.

3B Delete the clustered groups and add an artificial country where the loadings are equal to the average of all clustered original countries.

4 Go to step one.

FUZZY CLUSTER

For the fuzzy clustering we minimize the following objective function using the algorithm described in Kaufman and Rousseeuw (1990):

$$\sum_{v=1}^{K} \frac{\sum_{i,j=1}^{N} u_{iv}^2 u_{jv}^2 d(i,j)}{2 \sum_{j=1}^{N} u_{jv}^2}$$

where K is the number of clusters and N is the total number of countries; $d(i; j)$ is the distance between country i and j defined in 1A of the hard cluster tree algorithm and u_{iv} stands for the membership of country i in cluster v;

The normalized Dunn coefficient[22] is given by:

$$NDC = \frac{DC - (1/K)}{1 - (1/K)} \text{ where } DC = \sum_{i=1}^{N} \sum_{v=1}^{K} u_{iv}^2 / n$$

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[22] If NDC = 0 complete fuzziness, if NDC = 1 perfect hard-clustering

Appendix E - Monte Carlo simulation to compare the finite distribution with the asymptotic one

This simulation tries to see if the asymptotic distribution used in the estimation and inference of the model can approximate the finite distribution.

The model used is the same as in appendix C with 4 factors and N equal to 59. Only two changes were made: the ϵ_t series are generated with variance equal to 0.75 and the number of replications used was 1000.

As the number of factors is four and have equal variance, it makes it difficult to know which factor estimated (and respective loadings) corresponds to which true factor (and respective true loadings). Therefore the study was only made for the asymptotic distribution of the common factor, as is described in Bai(2003). He showed that:

$$c_{it} \quad = \quad \frac{\widehat{C}_{it} - C_{it}^0}{\sqrt{\frac{1}{N}V_{it} - \frac{1}{T}W_{it}}} \xrightarrow{d} N(0,1), \quad i = 1, 2, 3, ..., N \text{ and } t = 1, 2, ..., T$$

where : V_{it} and W_{it} are described in Bai(ibidem)

$\widehat{C}_{it}$ is the estimated common component ($\sum_{i=1}^{4} \widehat{\lambda}_{ri}\widehat{F}_{rt}$)

C_{it}^0 is the true common component ($\sum_{i=1}^{4} \lambda_{ri}F_{rt}$

In the following graphic the histograms depict the distribution of c_{it} using the estimated $\widehat{V}_{it}$ and $\widehat{W}_{it}$, and the plot of the N(0,1) density function.

Figure 37:
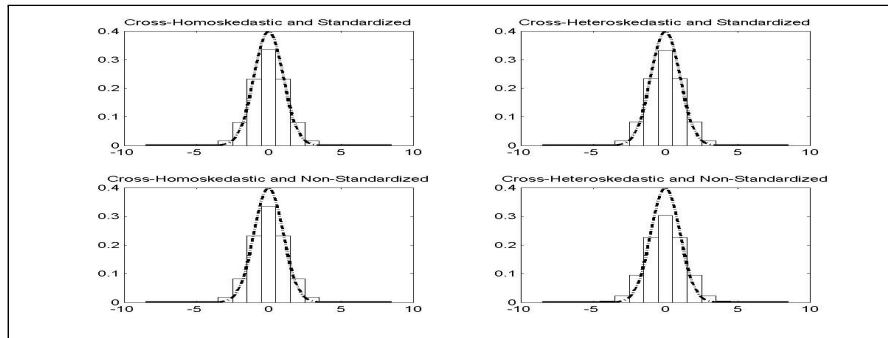
As we can see for this sample, the estimated distribution has fatter tails

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than the standard Gaussian distribution. Even if they are not that far from each other, rendering the use of the asymptotic distribution useful for inference, seems that a better distribution for a finite sample would be an improvement for this kind of studies. As final note, it does not seem that standardizing or not the data modifies the finite distribution.

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Determinants of Business Cycle Comovement: A Robust Analysis[*]

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ABSTRACT

This paper investigates the determinants of business cycle comovement between countries. Our dataset includes over 100 countries, both developed and developing. We search for variables that are "robust" in explaining comovement, using the approach of Leamer (1983). Variables considered are (i) bilateral trade between countries; (ii) total trade in each country; (iii) sectoral structure; (iv) similarity in export and import baskets; (v) factor endowments; and (vi) gravity variables. We find that bilateral trade is robust. However, two variables that the literature has argued are important for business cycles—industrial structure and currency unions—are found not to be robust. JEL codes: F33, F41. Keywords: international business cycles, comovement, international trade, currency unions.

1. Introduction

There is longstanding interest in the channels through which business fluctuations in one country are transmitted to other countries. It is often said that "When America sneezes, Europe catches a cold." But despite the theoretical and empirical analyses to date, it seems fair to say that there is no consensus on the important determinants of business-cycle comovement. The difficulty is that there are many potential candidate explanations.

One leading candidate is trade. Frankel and Rose (1998) present empirical evidence that higher bilateral trade between two countries is associated with more-correlated business cycles. Another explanation for business-cycle comovement is similarity in industrial structure. This linkage has been stressed in a series of papers by Jean Imbs (1998,1999, 2003). A third variable studied by Rose and Engel (2002) is currency unions. Other variables that may be important for business-cycle comovement are the following: (i) the extent of total trade in each country; (ii) factor endowments and (iii) gravity variables such as distance between countries, common language, adjacency, and so on.[1]

Our paper uses a dataset that includes over 100 countries, both developed and developing. We have collected data for each country on each of the variables described above. To say something definite about the important determinants of comovement, we use the "robustness" approach advocated by Leamer (1983), and used so effectively by Levine and Renelt (1992) in their analysis of growth regressions. With this approach, a variable is said to be a robust determinant of business-cycle comovement if the variable has a significant coefficient in a regression when all other potential explanatory variables have had a chance to "knock the variable out of the equation."

Our results are as follows. Nearly all of the variables considered are significant determinants of trade when considered in isolation. However, there are only a few robust variables. Bilateral trade is robust: countries that trade more with each other have more-correlated business cycles. Further, our results indicate that bilateral trade is robust to the

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[1] See also papers by Calderon, et al. (2002), Fidrmuc (2002), Kose, et al. (2003), Otto, et al. (2003) and Shin and Wang (2003). These authors study the determinants of business-cycle synchronization using a variety of country samples and economic variables. Recent contributions by Kose and Yi (2001,2004) explore the ability of dynamic, stochastic general equilibrium models to explore various theoretical explanations for the finding that stronger trade linkages are associated with more-correlated business cycles.

inclusion of gravity variables, suggesting an independent role for trade in transmitting business cycles.

Other variables that are robustly, positively related to business-cycle comovement are (i) an indicator variable that indicates that both countries are industrialized countries; (ii) an indicator variable that indicates that both countries are developing countries; (iii) a variable measuring the distance between the two countries. Variables that are not robust include (i) measures of industrial similarity; (ii) currency union; (iii) total trade undertaken by the two countries; (iv) measures of similarity in export and import baskets; and (v) measures of factor intensity.

Our finding that sectoral similarity is not robust stands in contrast to recent research by Imbs (1998,1998, 2003) in which he argues that sectoral similarity is strongly positively related to business-cycle correlations. Our finding on currency unions challenges much recent research, initiated by the contribution of Rose and Engel (2002), in which currency union is found to be related to business cycle comovement. Our results show that this relationship is not robust.

2. Econometric Methodology

This section describes the econometric methodology used in this paper. Briefly, the approach is Leamer's (1983) "Extreme Bounds Analysis" applied to band-pass-filtered data. The band-pass filter is designed to isolate business-cycle components of the data. We include country-specific indicator variables to remedy problems associated with using an estimated variable (the business-cycle correlation) as the dependent variable in our regressions. Readers may go directly to section 3 if they prefer to skip the econometric details.

2.1 Extreme-Bounds Analysis

Our analysis will involve regressions of a dependent variable, Y, on various sets of independent variables. Specifically, Y is a vector of business-cycle GDP correlations Y_{ij} between a pairs of countries i and j. We measure the business-cycle component of quarterly real GDP using the BP(6,32) filter described by Baxter and King (1999). Other researchers, such as Frankel and Rose (1998) and Rose and Engel (2002), have employed a variety of filters in their

related investigations. Frequently, the filter used does not matter importantly for the results. We confine our attention to just one filter because this filter was designed to measure business cycle correlations, which is the focus of this paper. The other filters, such as the first-difference filter, do not provide a good measure of the business-cycle frequencies. See Baxter and King (1999) for more detail.

The econometric approach that we use is the extreme-bounds analysis (EBA) suggested by Leamer (1983). The general form of the regression used for the EBA is as follows:

$$Y = I\beta_i + M\beta_m + Z\beta_z + u \tag{1}$$

The independent variables are of three types, as follows. I denotes a set of "always-included" variables. This set may be empty. The M-variable is the variable which is being tested for robustness. The Z-variables contain other variables that prior studies have suggested may be important for business-cycle correlations. The EBA is performed by varying the set of Z-variables included in the regression for a particular M-variable. From these regressions, the EBA determined the highest and lowest values of confidence intervals constructed from the estimated β_m. We will say that an M-variable is robust if these highest and lowest values are of the same sign (that is: this range does not include the value zero which would indicate that the variable is not significantly related to Y).

2.2 Econometric Issues

An important econometric problem results from the fact that the econometrician does not observe the true cross-country business cycle correlations Y_{ij}, but instead must use estimated correlations $\hat{Y}_{ij}$, which may contain measurement error. To make progress on this problem, it is necessary to make an assumption about the specific form of the measurement error.

We follow the approach taken by many cross-section analyses of large samples in specifying a fixed-effects model:

$$\hat{Y}_{ij} = Y_{ij} + V_i + V_j,$$
$$E(V_i) = \alpha_i,$$

where V_i is the fixed effect for country i.[2] Substituting this into the EBA model above yields the following regression model with a typical equation for correlation pair i and j:

$$\hat{Y}_{ij} = I_{ij}\beta_i + M_{ij}\beta_m + Z_{ij}\beta_z + V_i + V_j + U_{ij},$$
$$E(V_i) = \alpha_i,$$
$$E(V_iU_{ij}) = E(V_jU_{ij}) = 0,$$
$$E(U_{ij}U_{kl}) = \sigma^2 \text{ if } i = k \text{ and } j = l, \text{ 0 otherwise}$$

This model can be estimated by OLS where indicator variables are used to capture the country fixed effects.

3. Theory, Measurement and Results

The goal of this paper is to determine which economic and geographic variables are robustly correlated with business-cycle comovement. In order to interpret the results, it is useful to consider the findings in light of existing theory. At the heart of the issue lie two basic questions. First, why are there business cycles? Second, why are business cycles correlated across countries?

The generally accepted answer to the first question is that business cycles occur because something—random or deliberate--disturbs the steady evolution of an economy along its long-run path. The disturbances may be fiscal policies, monetary policies, changes in technological 'know-how,' or even the weather. Stockman (1988) found that sectoral shocks and national shocks were both important impulses to business cycles. Subsequently, a large literature developed seeking to determine the sources of shocks to national business cycles.[3] On the theoretical side, there is a large literature of open economy models which study the business-cycle effects of various shocks. Many of these are cited in the survey by Baxter (1995).

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[2] An alternative approach, utilized by Clark and van Wincoop (2001) and Imbs (2003), assumes a random effects model. There are two advantages to assuming a fixed effects model. First, unlike the random effects model the fixed effects model is robust to measurement error that is correlated with the dependent variables, which is likely to be the case in our EBA analysis. Second, given the large sample size of our EBA regressions random effects is computationally burdensome and from a time perspective not feasible given the large number of regressions we must run.

[3] Contributions include papers by Norrbin and Schlagenhauf (1996), Gregory, Head and Reynauld (1997), Gregory and Head (1999), Clark and Shin (2000), Lumsdaine and Prasad (2003), and Kose, Otrok and Whiteman (2003).

The second question—what causes cross-country correlation between business cycles—has also received substantial attention. The correlation and transmission of business cycles depends on the sources of the disturbances: are the shocks industry-specific or nation-specific? Further, the degree of interconnectedness of the two countries matters. Countries with open capital markets will respond similarly to disturbances which change the world interest rate. Countries that are willing and able to use monetary and fiscal policies may be able to insulate their countries against particular types of shocks, as originally suggested by Mundell (1961).

At present, however, there is no single model that can be said to successfully explain why some countries experience business-cycle comovement while others do not. Similarly, there is no consensus on the predominant sources of shocks to national and international business cycles. This is precisely why we are conducting the present, primarily empirical exercise. Our goal is to isolate those factors that appear to be robustly related to business-cycle correlation.

This section describes in detail the measurement of variables used in our investigation. We have grouped these variables into several sub-groups, according to the economic phenomenon that the variable is intended to measure. The details of the data sources and variable definitions are presented in Appendix A. We will consider measures of international trade, industrial structure, factor endowments, and currency union. We will also consider the so-called "gravity variables"—exogenous characteristics of country pairs that have been shown to explain a great deal of bilateral trade. The results reported in the text of the paper have all been estimated with country fixed effects. For the interested reader, we have reported complete results without country fixed effects in Appendix B. The results are quite insensitive to the removal of the country fixed effects.

Table 1 presents the correlation coefficients among all the variables used in our study. The first column of the table contains the correlations between the business-cycle correlation and the other variables. The variables are grouped according to the phenomenon they capture: bilateral trade intensity, total trade intensity, etc. The details of the construction of each variable are explained in the subsections below, and we will refer back to this table frequently. The within-group correlations are shaded for ease of reference. We turn now to a detailed consideration of each group of variables.

3.1 Gravity variables

In the existing literature, there is abundant evidence that the gravity variables can explain bilateral trade.[4] Further, several recent papers have shown that bilateral trade is trade is related to business-cycle comovement.[5] We begin the empirical analysis by studying the relationship between business-cycle comovement and the exogenous gravity variables: adjacency, distance, common language, population variables, total land, and indicator variables for two industrialized countries and two developing countries.

Table 2-A presents a regression of the business-cycle correlation on a typical set of gravity variables, ignoring country fixed effects. Variables significant at the 10% level include adjacency, distance, minimum population, the land variables and dummies indicating both industrial and both developing countries.

For comparison with our later results, Table 2-B presents results that combine the gravity variables with country fixed effects. Including the country fixed effects leads to collinearity between pairs of gravity variables that measure maximum and minimum values of a particular variable. Thus Table 2-B includes only one variable from each pair of this type—we choose the "minimum" value. We find that adjacency, common language, distance, minimum population and industrial country indicator are all significant.

In our analysis of the other variables, we use the gravity variables in two ways. First, we allow the gravity variables to act as Z-variables in the EBA regressions. Second, we use the set of gravity variables as I-variables (always-included variables) in the EBA regressions. The point of including gravity variables as I-variables is to control for that part of business-cycle comovement that is strictly exogenous to the country pair. Overall, our results are affected very little by whether the gravity variables are Z-variables or I-variables.

3.2 Bilateral trade

The relationship between trade and business cycles has received a great deal of attention, both in theoretical and empirical work. At the heart of this lies the question of why countries

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[4] See Frankel and Rose (1998).
[5] See Frankel and Rose (1998), Imbs (1998, 1999, 2003), and Clark and van Wincoop (2001).

trade in the first place. The secondary question, which cannot be addressed until the first question is answered, is "how does trade affect business cycles?"

Classical Ricardian theory explains trade as resulting from the fact that trade permits exploitation of gains from greater specialization. Modern theories that have a strongly Ricardian flavor include those by Baxter (1992), Eaton and Kortum (2002), and Alvarez and Lucas (2004). Models in which the gains from trade arise from increasing returns to scale are summarized in Helpman and Krugman (1985). In all these theories, increased trade results in increased sectoral specialization.

What are the implications of increases in trade and specialization for international business cycles? If the primary disturbances are sector-specific, then specialization should lead to decreased business-cycle correlation. On the other hand, trade may act as a conduit for the transmission of shocks that affect all industries. In this case, increased trade would lead to increased business cycle correlation.

The empirical relationship between trade and business cycles has been studied by several authors, beginning with work by Canova and Dellas (1993). Frankel and Rose (1998) found that bilateral trade was positively related to business-cycle comovement. Clark and van Wincoop (2001) also find that higher trade is related to more-highly-correlated business cycles. Gruben, et al. (2002) explore alternative econometric procedures and also include variables measuring the structure of trade. All these studies all conclude that trade is strongly, positively correlated with business cycle comovement.[6]

We construct four measures of bilateral trade intensity. The measures differ from one another in two ways: (i) the date at which the measure is calculated; we use both the beginning date and the ending date; and (ii) the scale variable used to normalize the bilateral trade measure: we use total trade and also aggregate GDP across the two countries.

The measure BT1 is defined as

$$BT1_{ij} = \frac{x_{ij} + m_{ij} + x_{ji} + m_{ji}}{x_i + m_i + x_j + m_j}$$

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[6] Frankel and Rose also study an instrumental-variables version of the regression in which gravity variables are used as instruments for bilateral trade. They find that the coefficient estimates are larger with instrumental-variables estimation.

where x_{ij} is the 1970 (beginning of sample) value of exports from country i to country j, m_{ij} is the 1970 value of imports from country i to country j, x_i is the 1970 value of country i's exports to all countries and m_i is the 1970 value of country i's imports from all countries. The measure BT3 uses the same formula as BT1, except that 1995 (end of sample) values are used. Measures BT1 and BT3 are very similar to the "preferred measure" used by Frankel and Rose (1998).

The measures BT2 and BT4 are constructed according to the following formula, where BT2 uses 1970 values and BT4 uses 1995 values, and where y_i is the value of country i's GDP:

$$BT2_{ij}, BT4_{ij} = \frac{x_{ij} + m_{ij} + x_{ji} + m_{ji}}{y_i + y_j} \ .$$

In summary, BT1 and BT3 express bilateral trade as a fraction of total trade, at the beginning and end of the sample period, respectively. The variables BT2 and BT4 express bilateral trade as a fraction of aggregate GDP in the two countries, at the beginning and end of the sample period.

3.2.1 A First Look

The measure BT1 is our preferred measure of bilateral trade, for two reasons. First, it measures trade at the beginning of the sample, which we will compare to business-cycle correlation over the subsequent sample period. Thus the direction of causality is clear. Second, we prefer the measure that uses total trade as the scale variable, rather than total GDP.

Figure 1 is a scatter plot showing the extent of bilateral trade at the beginning of the sample (measure BT1) on the horizontal axis, and the corresponding business-cycle correlation on the vertical axis. Each country-pair is a point on this plot. The univariate regression line of the business-cycle correlation, denoted y, on the BT1 measure of bilateral trade, denoted x, is indicated by the heavy solid line on the graph. The details of this univariate regression are also given. The slope is positive and significant, although the R-square is only 0.034. Some of the outliers are labeled.. For the most part, those country pairs that have both high bilateral trade and high business-cycle correlation are ones where this relationship might be expected. For example, the US and Canada have the highest bilateral trade measure, and also have highly correlated business cycles. Other country pairs of this type include Singapore/Malaysia, US/Japan and

France/Germany. One might worry that the outliers are responsible for the positive estimated slope coefficient. However, there are over 5000 observations plotted on this graph. If we remove the 20 observations for which BT1 exceeds 0.10, the slope coefficient actually rises and is still significant. Thus the positive relationship is not due to a few extreme observations.

3.2.2 Testing for Robustness

Table 3 presents the results of the base regressions for each of the four bilateral trade variables, together with the extreme bounds analysis for these variables. The top panel of the table conducts the analysis with no "always-included" variables. For each bilateral trade variable, we report the coefficients (β_m's) with the highest and lowest confidence intervals. We also present the standard error of β_m in each case, the t-statistic for the null hypothesis that $\beta_m = 0$, the number of observations, and the R-square of the regression. In the second-to-last column we report the other variables (the Z-variables) in the regression that yielded the high/low estimates. The final column reports on the robustness of the M-variable. The variable is said to be robustly correlated with cyclic comovement if the high and low values of all confidence intervals for the estimated β_m's are of the same sign.

The bottom panel of the table contains results for which the gravity variables are "always-included" I-variables. The gravity variables are: adjacency, distance, common language, population variables, total land, and indicator variables for two industrialized countries and two developing countries. The purpose of having the gravity variables always-included is to control for that part of business-cycle correlation which can be viewed as exogenous.

The reason for including the gravity variables is as follows. In the existing literature, there is abundant evidence that the gravity variables can explain bilateral trade, and that trade is related to business-cycle comovement. This raises a natural question of whether there is anything left for variables such as bilateral trade, industrial structure, or monetary union to explain, once the exogenous gravity variables are included in the regression.

Looking first at the base regressions with no always-included variables, we find that all four measures of bilateral trade intensity have positive coefficients which are

statistically significant.[7] These variables continue to be significant in the base regressions even when the gravity variables are included (bottom panel of Table 3). This is somewhat surprising, as the gravity variables have long been known to be very good at explaining the extent of bilateral trade. We expected that including the gravity variables might eliminate the statistical significance of the bilateral trade variables, but this is not the case.

We turn now to the "robustness" tests—the extreme bounds analysis (EBA). Throughout, we use a 10% critical value. All four measures of bilateral trade intensity are robust when there are no always-included variables. When the gravity variables are included, only one of the four measures continues to be robust. The robust measure is BT1, which is our preferred measure for reasons given above. In all cases, the sign of the coefficient on bilateral trade is positive, indicating that higher levels of bilateral trade are associated with higher business-cycle correlation. Comparing the coefficients on the trade variables with and without the gravity variables included, we find that including the gravity variables reduces the size of the estimated coefficient in all cases, by approximately 30-50%.

3.3 Extent of Total Trade

The next variable we consider is the extent of total trade carried out by the pair of countries. In contrast to the bilateral trade measure, the total trade measure is intended to capture the general "openness" of the two countries.[8] Just "openness" may matter; it may not be important how much bilateral trade there is, rather, the total amount of trade may be important. This variable may capture the flow of technological transmission that occurs through trade in general, not with a specific trading partner. Another possibility is that the extent of total trade is a good measure of the extent to which the country is exposed to global shocks. Thus it is possible that higher trade, in the aggregate, leads to more-highly-correlated business cycles.

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[7] The base regressions include country fixed effects, while the regressions in the scatter plots do not. Thus the coefficient estimates differ between the two specifications.
[8] Many empirical investigations that wish to measure the openness of an economy use the amount of total trade as a proxy for openness.

3.3.1 A first look

Figure 2 presents a scatter plot of total trade against business-cycle correlation. The specific measure of total trade plotted here is TT1, defined as

$$TT1_{ij} = \frac{x_i + m_i + x_j + m_j}{y_i + y_j}$$

where x_i and m_i denote total exports and imports, respectively, for country i, measured at the beginning of the sample in 1970. We also construct an end-of-sample measure, TT2, using 1995 data.

Figure 2 shows that there is a positive, significant relationship between total trade and business-cycle correlation. For most countries, total trade is a very small fraction of GDP, and this is reflected in the "cloud" of observations clustered between 0.00 and 0.25 on the TT1 axis. Further, the R-square of 0.0042 is extremely small.

3.3.2 Testing for robustness

Table 4 presents the detailed results for the two measures of total trade. In the base regressions, the coefficient is always negative, and also significant. Considered in isolation, higher total trade is associated with lower business-cycle correlation. It is difficult to think of a good economic reason why this ought to be the case. However, the EBA shows that the total trade variables are fragile, whether or not the gravity variables are included. Once other variables are considered, there is no independent role for total trade in explaining business-cycle correlation.

3.4 Similarity of Industrial Structure

If the primary business-cycle shocks are sector-specific, then countries with greater similarity in sectoral structure would tend to have more-correlated business cycles, other things equal. Stockman (1988) showed that sectoral shocks were one important impulse to business cycles. In a sequence of empirical papers, Imbs (1998,

1999, 2003) has presented results showing that similarity of industrial structure is significantly, positively related to business-cycle correlations. In his 1998 paper, using quarterly data for 21 OECD countries, Imbs finds that bilateral trade is not important for business cycles once country fixed effects are included.

We will study six measures of industrial similarity. These measures have been chosen for comparability with existing research. We have also tried to include several alternative, reasonable methods for defining industrial similarity. Our first measure of industrial similarity, suggested by Shea (1996) and used by Imbs (1998, 1999), is the correlation of sectoral shares:

$$ISC1_{ij} = \frac{\sum_{n=1}^{N} s_{in} s_{jn}}{\sqrt{\sum_{n=1}^{N} s_{in}^2} \sqrt{\sum_{n=1}^{N} s_{jn}^2}}.$$

where 'sectors' are defined as one of seven sub-sectors of aggregate GDP

The variable ISC1 takes on values in the interval [0,1]. Greater similarity in sectoral structure leads to larger values of ISC1. If $s_{in} = s_{jn}$ so that sectoral shares of each industry are the same across countries, ISC1 is equal to 1.

Some studies look only at the structure of manufacturing, so we define a comparable measure for manufacturing alone. Our manufacturing index ISC2 uses 3-digit-level manufacturing data for 30 industries, defined as:

$$ISC2_{ij} = \frac{\sum_{n=1}^{N} s_{in} s_{jn}}{\sqrt{\sum_{n=1}^{N} s_{in}^2} \sqrt{\sum_{n=1}^{N} s_{jn}^2}}.$$

where the industry subscripts, *n,* now refer to manufacturing industries.

The next measure of industrial similarity is:

$$ISS1_{ij} = 1 - \sum_{n=1}^{N} \left(s_{in} - s_{jn} \right)^2$$

where s_{in} is the sector-n fraction of GDP of country i. If $s_{in} = s_{jn}$ so that sectoral shares of each industry are the same across countries, ISS1 is equal to one. More generally, higher levels of sectoral similarity result in higher values of ISS1. We also construct ISS2, which is the corresponding measure using manufacturing data.

Finally, we construct a third pair of measures similar to those used by Clark and van Wincoop (2001) and Imbs (2003). This measure of sectoral similarity uses absolute values of differences in sectoral shares:

$$ISA1_{ij} = 1 - \sum_{n=1}^{N} \left| s_{in} - s_{jn} \right|$$

If $s_{in} = s_{jn}$ so that sectoral shares of each industry are the same across countries, ISA1 is equal to one. ISA2 uses the same definition applied to manufacturing data. As with all our measures, higher values of ISA1 and ISA2 indicate greater similarity in industrial structure.

We refer back to Table 1 to look at the correlations among these variables. This table shows that there is low correlation between a particular measure constructed from GDP data and the same measure constructed from manufacturing data. Specifically, the correlation between ISS1 and ISS2 is 0.29; the correlation between ISA1 and ISA2 is 0.30, and the correlation between ISC1 and ISC2 is 0.23. Since these correlations are low, we will allow the manufacturing measures as Z-variables in regressions where a corresponding GDP measure is the M-variable, and vice-versa (e.g., ISS1 and ISS2; ISA1 and ISA2; and ISC1 and ISC2). However, the correlations among all the GDP measures is high (in absolute value), as are the correlations among the manufacturing measures. Thus, if one GDP measure, (e.g., ISC1) is an M-variable, then other GDP measures (e.g., ISS1 or ISA1) will not be included as Z-variables.

3.4.1 A first look

Figure 3 presents a scatter plot of ISC1 and business-cycle correlation. There is considerable dispersion in the scatter plot. A glance at the points themselves does not obviously imply any relationship between these variables. The solid line is the estimated regression line from a regression of the business-cycle correlation on ISC1. The details of the estimate are shown on the graph. The estimate of the slope coefficient is 0.17, with a standard error of 0.03.

The R-square of the regression is 0.013. Thus, industrial structure is indeed significantly, positively related to business-cycle correlation when considered in isolation.

3.4.2 Testing for robustness

Table 5 presents the results of the EBA for the industrial similarity variables. The "base" regressions show that each of the six measures of industrial similarity has a positive and significant coefficient when considered alone. This is true whether the gravity variables are included or not. The coefficient estimates in these base regressions range from 0.11 to 0.36. Thus, taking the high estimate of 0.36, an increase in sectoral correlation from, say, 0.30 to 0.50 would be accompanied by an increase in the business-cycle correlation of 0.20*0.36=0.072. This is not a large increase, but still of economic interest if it is robust.

However, the EBA finds that all the industrial structure variables are fragile, independent of whether the gravity variables are included as I-variables. Although most of the point estimates of the coefficients are always positive, the confidence intervals for the "low" estimates include negative numbers.

To try to understand what may be leading to the fragility, we look at the "other variables"—the Z-variables—included in the "low" regressions. In the top panel, with no always-included variables, we find that bilateral trade variables appear in 5 of the 6 "low" regressions in which the industrial structure variable is not statistically significant. Trade similarity variables appear in 3 regressions, while a factor endowment variable (one or more of MAXK, MINK, MINED, MAXED, described in detail in the next section) appears in all 6. The indicator for developing countries appears twice, while the indicator for the developed countries appears once.

When we look at the regressions with the gravity variables always-included, we find that the bilateral trade variables do not appear in any of the extreme-value regressions (neither "high" nor "low"). Factor endowment variables measuring labor and capital again appear in all six regressions, as do trade similarity measures. Total trade variables appear in two regressions. The developing/industrialized indicators are included in the I-variables and therefore were not considered as Z-variables.

What can we infer from this pattern of Z-variables in the regressions that lead to the result of fragility? Broadly, it appears that inclusion of factor-endowment variables, especially

endowments of labor and capital, reduce the influence of industrial structure to insignificant levels. Traditional Heckscher-Ohlin theory predicts a strong relationship between factor endowments and the sectoral structure of production. Other trade theories, notably modern Ricardian theories in which factor accumulation is endogenous, predict a strong relationship between the production structure and the relative supplies of factors in the economy.[9] Thus it may not be surprising that including factor endowments leads to fragility of the industrial structure variables. Bilateral trade and the structure of trade also appear frequently in regressions with insignificant coefficient estimates for industrial structure. Again, all trade theories predict a tight relationship between factor endowments, production, and the extent and type of trade. Nevertheless, we found (in Section 3.2 above) that bilateral trade was robustly related to business-cycle correlation, even when the Z-variables included industrial structure, factor endowments, trade structure, etc. The results of this section are that industrial structure is not similarly robust.

3.5   Similarity in Baskets of Traded Goods

We considered similarity in baskets of traded goods as one possible economic variable that could be related to business-cycle comovement across countries. For example, if countries export and/or import similar baskets of goods, then they would be affected similarly by shocks to the world prices of their import and export goods. In addition, countries with similar baskets of traded goods would be affected similarly in the event of sector-specific shocks hitting their export and/or import sectors.

For completeness, we define nine measures of trade similarity: three groups of three measures each. The three groups parallel the three groups used for the industrial similarity measures. The first group uses a correlation coefficient, identified by the mnemonic TSC. The second group uses square of differences in sectoral shares, identified by the mnemonic TSS. The third group uses the absolute values of differences in sectoral shares, identified by the mnemonic TSA. Within each group, we construct a measure comparing (i) total export shares using 2-digit SITC data for all country pairs , denoted by "1" as the last digit of the variable name; (ii) total import shares using 2-digit SITC data for all country pairs, denoted by "2" as the last digit of the variable name; and (iii) bilateral export shares using 2 digit SITC data for all country pairs,

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[9] See Baxter (1992).

denoted by "3" as the last digit. Thus, TSC3 refers to the correlation coefficient measure of trade similarity (TSC), using data bilateral export shares ("3").

The correlation matrix reported in Table 1 shows that there is high correlation between (i) TSS1, TSA1 and TSC1; (ii) TSS2, TSA2 and TSC2; and (iii) TSS3, TSA3 and TSC3. Correlation (in absolute value) is small among other pairs of the trade similarity variables. To avoid multicollinearity we select variables for the regressions as follows. When the M-variable is TSS1 trade similarity variables from the same group are permitted as Z-variables (i.e, TSS2 and TSS3), while the highly-collinear variables TSA1, TSC1 are excluded from the set of Z-variables. A similar rule is used for the other variable groups.

3.5.1 A first look

Figure 4 presents a scatter plot of TSC3 and the business-cycle correlation. A glance at the highly dispersed scatter gives a general impression that there is no relationship between these variables. However, there is a weak, but significant, negative relationship between the similarity of the structure of bilateral trade (TSC3) and the business-cycle correlation.

3.5.2 Robustness analysis

As described above, we constructed nine measures of similarity in traded goods, comprising three sets of three different measures. The three sets are distinguished by the basket of goods considered. The first uses total exports, the second uses total imports, and the third uses bilateral exports. Within each set, there are three measures which are constructed in a manner analogous to the three measures of industrial similarity.

Table 6 presents the robustness analysis for the trade-similarity variables. Looking first at the "base" regressions, we find that most of the trade-similarity variables are not significant, even without the addition of Z-variables. All the coefficients but one are positive, but very small. Less than half are significant.

The EBA analysis finds that none of the trade-similarity variables is robust. This finding is independent of whether the gravity variables are included as Z-variables. The Z-variables that appear in the "low" regressions include industrial similarity variables and bilateral trade variables. Apparently, given observations on industrial similarity and bilateral trade, there is

nothing to be added by including trade similarity as an explanatory variable for business cycle correlation. Given the tight link between these three variables that is implied by trade theory, this finding is perhaps not very surprising.

3.6 Factor Endowments

Most theories of interacting economies predict a significant relationship among factor endowments, trade, and business-cycle comovement. This would be true of standard Heckscher-Ohlin theory, and would also be true of Ricardian theories. Hybrid models that combine elements of monopolistic competition in manufacturing with competitive markets in other goods would also imply a relationship among these variables. We consider three factors of production: human capital (measured as log of years of education); log of physical capital per worker, and log of arable land per worker. In each case, we consider variables measuring the minimum value of the variable between the two countries, as well as the maximum value of the variable.[10]

3.6.1 A first look

We begin by taking a closer look at one particular measure of factor endowments: a variable measuring the log of the minimum education level between the two countries, MINED. Figure 5 presents a scatter plot of this variable against the business-cycle correlation. The scatter plot reflects the fact that MINED takes on several discrete values. The estimated univariate regression line shows a positive and significant relationship. The higher is the minimum education level between the two countries, the higher is the business-cycle correlation between the two countries. However, the scatter is highly dispersed, and the R-square of the regression is only about 0.04. Clearly,

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[10] As noted earlier, the inclusion of country fixed effects leads to collinearity between maximum and minimum measures of a given economic variable. For completeness we report the results for all variables. However, it will be apparent that the coefficients on the minimum M-variables have equal and opposite signs from the corresponding maximum variables.

MINED does not explain a great deal of the cross-sectional variance in the business-cycle correlation.

3.6.2 Robustness analysis

Table 7 presents the complete results for the factor endowment variables. We begin by looking at the top panel which summarizes results with no Z-variables. Education and capital variables are all significant in the base regressions

The minimum-education variable (MINED) has a positive and significant coefficient, while the maximum-education variable (MAXED) has a negative and significant coefficient. Similarly, the minimum-capital variable (MINK) is positive and significant, while the maximum-capital variable (MAXK) is negative and significant. By contrast, the land variables are not significant, although they show the same pattern in the signs of the coefficients: positive for minimum-land (MINL) and negative for maximum land (MAXL).

In the bottom panel, showing results for which the gravity variables are Z-variables, we find the same pattern of signs of the coefficients. However, the magnitudes of the coefficients are reduced by half or more, and the variables are no longer significant, except for the two capital variables.

The EBA reveals that none of the factor-endowment variables is robust, independently of the inclusion of Z-variables. Variables that appear in the "high" and "low" regressions include total trade, industrial similarity, other factor intensity variables (notably capital and education), bilateral trade, and trade similarity. There is thus no clear pattern that can explain why the factor endowment variables fail to be robust.

3.7 Currency Union

Since Mundell (1961), economists and policymakers have been interested in the economic requirements for, and effects of, currency union. More recently, the formation of the European Monetary Union in 1999 has led to abundant research on the effects that currency

unions have on trade and business-cycle characteristics of member countries. Frankel and Rose (1998) point out that countries with more-similar business cycles are more natural candidates for membership in a common-currency area. Further, the currency union itself might change the nature of bilateral business cycles. Theories of the way in which this might happen are summarized in more detail in papers by Frankel and Rose (1998, 2002). Most theories predict that a common currency will reduce intra-union barriers to trade and will thereby lead to greater intra-union trade in goods and capital. However, the theories differ in their predictions for the effect of this increased trade on business-cycle comovement. Increased trade will lead to reduced comovement if the result of increased trade is greater specialization in a setting with shocks that are predominantly industry-specific. Increased trade will lead to *increased* comovement if the main source of shocks are demand shocks that are common across countries. One source of shocks might be the common monetary policy.

Most recent empirical evidence suggests that currency union leads to increased business-cycle correlation among member countries. Kim (1995) shows that the industrial structure of the 50 U.S. states has become much more alike in the 90 years following the formation of the U.S. common currency area (U.S. Federal Reserve System), which suggests regions do not specialize in the production of goods under a currency union. Rose and Engel (2002) estimate the effect of currency unions on between business cycle comovement. They find that the coefficient on the currency unions is positive. However, significance of this coefficient is not robust to the changes in the set of additional explanatory variables.

Table 8 presents the robustness analysis for the currency union variable. Because the currency union variable is a binary (dummy) variable, we do not present a scatter plot of this variable against the business-cycle correlation (as we did for all other variables). Table 8 shows that the currency union variable carries a significant coefficient in the base regression when the gravity variables are not included. The estimated coefficient in the base coefficient is 0.08, implying that membership in a currency union increases the business-cycle correlation by 0.08. The coefficient on the currency union variable is not significant in the base regression that includes the gravity variables as Z-variables. The point estimate has dropped to 0.03, and the standard error is also 0.03.

Currency union is found to be fragile in the extreme-bounds analysis. The "high" and "low" values of the confidence intervals are similar whether or not the gravity variables are included as Z-variables. The Z-variables that lead to the "high" estimates are industrial similarity (ISC1, ISC2); and trade similarity, TSC3. The Z-variables found in the "low" regressions are total trade (TT1), industrial similarity (ISA1), and the minimum-education variables (MINED).

In summary, we find that currency union is not a robust predictor of business-cycle correlation. Currency union is only a significant predictor of business cycle correlation if other variables are not included in the regression.

3.8 A Return to the Gravity Variables

It is well-known that a large fraction of bilateral trade can be explained, in a statistical sense, by a set of "gravity variables" which include distance between countries, indicator variables for common language and adjacency, and variables which measure the difference the countries levels of GDP. To this point, the gravity variables have been included in the analysis as a set of "always-included" variables, the results of which are shown in the bottom panel of Tables 3-8. It is notable that the robustness results obtained for the other variables have been largely invariant to whether the gravity variables were included or not. In this section, we investigate whether the any of the gravity variables is a robust explanatory variable for business-cycle correlation.

3.8.1 A first look

The distance between two countries is one variable that is routinely included in "gravity regressions" for which bilateral trade is the dependent variable. Many of our gravity variables are binary (dummy) variables, but distance is not. Thus it is a good candidate for graphing in a scatter plot. Figure 6 plots the log of distance against the business-cycle correlation. As in all of our graphs, the scatter is very diffuse. The estimated regression equation shows that there is a significant negative relationship between distance and business-cycle correlation. Countries that are located closer to each other have, other things equal, more-highly-correlated business cycles.

There are many reasons to expect that this would be the case. For example, regional shocks to weather would affect countries similarly if they are located near each other. Countries trade more if they are located closer together (this is why the gravity equations work so well in the first place), and if shocks are transmitted through trade, then we would expect distance to be related to business-cycle comovement. However, we might also wonder whether there is anything left for distance to explain, once bilateral trade is taken into account. The EBA allows us to answer precisely these types of questions.

3.8.2 Robustness analysis

Table 9 presents the EBA of the gravity variables. We have included maximum-GDP and minimum-GDP variables as potential Z-variables, since these are frequently used in gravity regressions. We have not included them previously as I-variables since they cannot be viewed as exogenous with respect to the various M-variables.

Our findings are as follows. The log of distance is found to be robustly, negatively related to business-cycle correlation. Since the coefficient on distance is negative, it is the "high" regression for which the confidence interval comes closest to including the value of zero. In this regression, we find bilateral trade (BT3) as one of the Z-variables. This is in line with our intuition that distance may affect business-cycle correlation through its effect on bilateral trade. But, we also find that distance is significant even after bilateral trade is taken into account.

There are only two other robust gravity variables: these are the indicator variables for (i) two industrialized countries; and (ii) two developing countries. The coefficient is positive in each case. This means that the business-cycle correlation is higher if the countries are of similar "types"—both developing or both industrialized. The business-cycle correlation is lower if one country is developing and one is developed. To the extent that intra-industry trade drives trade between industrialized countries, and to the extent that sectoral shocks predominate, we might expect the finding for industrialized countries. However, we view the finding for developing countries as surprising and worth further thought and analysis.

The other gravity variables are all fragile. These include adjacency; common language; minimum and maximum log population variables, and minimum and maximum log total land variables. Adjacency and common-language were both significant in the base regressions, but

were found to be fragile once Z-variables were considered. The population and total-land variables were not significant even in the base regressions.

4. Conclusion

This paper has investigated the robustness of correlations between business-cycle comovement and a host of economics variables. Our key findings are as follows.

(i) Higher bilateral trade between two countries is robustly correlated with a higher business-cycle correlation between the countries. The finding that trade is robust emerges both with and without the gravity variables playing the role of "always-included" I- variables. The fact that bilateral trade is robust even when the gravity variables are included indicates that bilateral trade matters for business-cycle comovement separately from the effects on trade occurring through the gravity variables.

(ii) Greater similarity in industrial structure is not robustly correlated with business-cycle correlations. Although industrial structure variables are significant in the base regressions (with no other explanatory variables), the significance disappears when the full set of Z-variables is considered. This finding occurs with and without the gravity variables as I-variables. This finding indicates that the findings of Imbs (1998, 1999, 2003) which stress the importance of industrial structure, are fragile.

(iii) Countries belonging to a currency union do not have significantly more highly correlated business cycles than countries that do not share a common currency. This finding calls into question the prior empirical findings of Rose and Engel (2002).

(iv) Two indicator variables were found to be robust. The first indicates that both countries in the pair are industrialized countries; the second indicates that both are developing countries. In both cases, the variables are positively related to business-cycle correlation.

(v) Only one "gravity" variable was found to be robust: this variable is the distance between the two countries. Distance is negatively related to business-cycle correlation, as one would expect.

Our other findings are negative, in the sense that we found many variables not to be robust. Specifically, total trade measures are fragile, as are the measures of the similarity of total and bilateral trade. Factor endowment variables, including measures of education, capital, and arable land, were all found to be fragile. All gravity variables except for distance were found to be fragile.

In conclusion, our goal in writing this paper was to clarify the relationship between business-cycle comovement and other economic variables. In doing so, we hope to provide guidance for future theoretical and empirical investigations into the sources and propagation mechanisms of international business cycles.

APPENDIX A: Data Sources and Definitions

Variable	Definition and Source
Bilateral Trade	
BT1	Ratio of bilateral trade to total trade in 1970 (Source: Feenstra, Lipsey and Bowen, 1997, World Trade Flows CD-ROM, 1970-1992)
BT2	Ratio of bilateral trade to GDP in 1970 (Sources: Feenstra, Lipsey and Bowen, 1997, World Trade Flows CD-ROM, 1970-1992, and Penn World Tables version 5.6)
BT3	Ratio of bilateral trade to total trade in 1995 (Source: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
BT4	Ratio of bilateral trade to GDP in 1995 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997, and Penn World Tables version 5.6)
Total Trade	
TT1	Ratio of total trade to GDP in 1970 (Sources: Feenstra, Lipsey and Bowen, 1997, World Trade Flows CD-ROM, 1970-1992, and Penn World Tables version 5.6)
TT2	Ratio of total trade to GDP in 1995 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997, and Penn World Tables version 5.6)
Similarity of Industrial Structure	
ISS1	Broad industry similarity, squared difference in 1980 (Source: United Nations Statistical Yearbook 46th Issue on CD-ROM)
ISS2	Manufacturing sector similarity, squared difference in 1980 (Source: United Nations Industrial Development Organization, 2000, Industrial Statistics Database on CD-ROM)
ISA1	Broad industry similarity, absolute difference in 1980 (Source: United Nations Statistical Yearbook 46th Issue on CD-ROM)
ISA2	Manufacturing sector similarity, absolute difference in 1980 (Source: United Nations Industrial Development Organization, 2000, Industrial Statistics Database on CD-ROM)
ISC1	Broad industry similarity, sector share correlation in 1980 (Source: United Nations Statistical Yearbook 46th Issue on CD-ROM)
ISC2	Manufacturing sector similarity, sector share

	correlation in 1980 (Source: United Nations Industrial Development Organization, 2000, Industrial Statistics Database on CD-ROM)
Trade Similarity	
TSS1	Export similarity, squared difference in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
TSS2	Import similarity, squared difference in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
TSS3	Similarity of bilateral trade flows, squared difference in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
TSA1	Export similarity, absolute difference in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
TSA2	Import similarity, absolute difference in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
TSA3	Similarity of bilateral trade flows, absolute difference in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
TSC1	Export similarity, goods share correlation in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
TSC2	Import similarity, goods share correlation in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
TSC3	Similarity of bilateral trade flows, goods share correlation in 1980 (Sources: Feenstra, 2000, World Trade Flows CD-ROM, 1980-1997)
Factor Endowments	
MINED	Log of minimum bilateral average years of schooling for total population 15 years and older (Source: Barro and Lee, 199?)
MAXED	Log of maximum bilateral average years of schooling for total population 15 years and older (Source: Barro and Lee, 199?)
MINK	Log of minimum bilateral capital per worker using aggregate investment in 1980 (Source: Easterly and Levine, 2002)
MAXK	Log of maximum bilateral capital per worker using aggregate investment in 1980 (Source: Easterly and Levine, 2002)
MINL	Log of minimum bilateral arable land (1000s of hectares) per worker in 1980 (Source: World Bank

	Development Indicators on CD-ROM)
MAXL	Log of maximum bilateral arable land (1000s of hectares) per worker in 1980 (Source: World Bank Development Indicators on CD-ROM)
Currency Unions	
CU	Dummy variable indicating country pair is in currency union (Source: Frankel and Rose, 2002)
CB	Dummy variable indicating one country maintains a currency board with other currency (Source: Frankel and Rose, 2002)
CUB	Dummy variable indicating country pair is part of a currency union or currency board (Source: Frankel and Rose, 2002)
Gravity variables	
ADJ(1)	Dummy variable indicating common border (Source: Macalester University, International Trade Database)
LANG (2)	Dummy variable indicating common language (Source: Macalester University, International Trade Database)
DIST (3)	Log of distance in kilometers (Source: Macalester University, International Trade Database)
MINPOP(4)	Log of minimum bilateral population (Source: Penn World Tables version 5.6)
MAXPOP(5)	Log of maximum bilateral population (Source: Penn World Tables version 5.6)
MINTL(6)	Log of minimum bilateral total land area (1000s of hectares) (Source: United Nations Statistical Yearbook 46th Issue on CR-ROM)
MAXTL(7)	Log of maximum bilateral total land area (1000s of hectares) (Source: United Nations Statistical Yearbook 46th Issue on CR-ROM)
MINGDP (8)	Log of minimum bilateral GDP (Source: Penn World Tables version 5.6)
MAXGDP (9)	Log of maximum bilateral GDP (Source: Penn World Tables version 5.6)
IND(10)	Dummy variable indicating both countries are developed/industrial (Source: IMF World Economic Outlook 2002)
DEV(11)	Dummy variable indicating both countries are developing (Source: IMF World Economic Outlook 2002)

Notes:

1. Bilateral trade intensity: $TB1, TB3 = \dfrac{x_{ij} + m_{ij} + x_{ji} + m_{ji}}{x_i + m_i + x_j + m_j}$, where x_{ij} is the value of exports

   from country i to country j, m_{ij} is the value of imports from country i to country j, x_i is the value of country i's exports to all countries and m_i is the value of country i's imports from all countries; and $TB2, TB4 = \dfrac{x_{ij} + m_{ij} + x_{ji} + m_{ji}}{y_i + y_j}$, where y_i is the value of country i's GDP.

2. Total trade intensity: $TT1, TT2 = \dfrac{x_i + m_i + x_j + m_j}{y_i + y_j}$, where y_i is the value of country i's GDP.

3. Broad industry similarity: $ISS1 = \dfrac{1}{N} \sum\limits_{n=1}^{N} \left(s_{in} - s_{jn} \right)^2$, where s_{in} is the fraction of GDP

   devoted to sector n; $ISA2 = \dfrac{1}{N} \sum\limits_{n=1}^{N} \left| s_{in} - s_{jn} \right|$; and $ISC1 = \dfrac{\sum\limits_{n=1}^{N} s_{in} s_{jn}}{\sqrt{\sum\limits_{n=1}^{N} s_{in}^2} \sqrt{\sum\limits_{n=1}^{N} s_{jn}^2}}$.

4. Manufacturing industry similarity: $ISS2 = \dfrac{1}{N} \sum\limits_{n=1}^{N} \left(s_{in} - s_{jn} \right)^2$, where s_{in} is the fraction of

   manufacturing devoted to sub-sector n; $ISA2 = \dfrac{1}{N} \sum\limits_{n=1}^{N} \left| s_{in} - s_{jn} \right|$; and

   $ISC2 = \dfrac{\sum\limits_{n=1}^{N} s_{in} s_{jn}}{\sqrt{\sum\limits_{n=1}^{N} s_{in}^2} \sqrt{\sum\limits_{n=1}^{N} s_{jn}^2}}$.

5. Export similarity: $TSS2 = \dfrac{1}{N} \sum\limits_{n=1}^{N} \left(s_{in} - s_{jn} \right)^2$, where s_{in} is good n's share of country i's total

   exports, $s_{in} = x_{in} / x_i$; $TSA2 = \dfrac{1}{N} \sum\limits_{n=1}^{N} \left| s_{in} - s_{jn} \right|$; and $TSC2 = \dfrac{\sum\limits_{n=1}^{N} s_{in} s_{jn}}{\sqrt{\sum\limits_{n=1}^{N} s_{in}^2} \sqrt{\sum\limits_{n=1}^{N} s_{jn}^2}}$.

6. Import similarity: $TSS2 = \dfrac{1}{N}\sum_{n=1}^{N}\left(s_{in} - s_{jn}\right)^{2}$, where s_{in} is good n's share of country i's total

imports, $s_{in} = m_{in}/m_{i}$; $TSA2 = \dfrac{1}{N}\sum_{n=1}^{N}\left|s_{in} - s_{jn}\right|$; and $TSC2 = \dfrac{\sum_{n=1}^{N} s_{in} s_{jn}}{\sqrt{\sum_{n=1}^{N} s_{in}^{2}}\sqrt{\sum_{n=1}^{N} s_{jn}^{2}}}$.

7. Bilateral trade similarity: $TSS3 = \dfrac{1}{N}\sum_{n=1}^{N}\left(s_{ijn} - s_{jin}\right)^{2}$, where s_{ijn} is good n's share of

country i's exports to country j, $s_{ijn} = x_{ijn}/x_{ij} = m_{jin}/m_{ji}$; $TSA3 = \dfrac{1}{N}\sum_{n=1}^{N}\left|s_{ijn} - s_{jin}\right|$; and

$TSC2 = \dfrac{\sum_{n=1}^{N} s_{ijn} s_{jin}}{\sqrt{\sum_{n=1}^{N} s_{ijn}^{2}}\sqrt{\sum_{n=1}^{N} s_{jin}^{2}}}$.

Appendix B: Estimation without Country Fixed Effects

Tables A-1 and A-2 present results of the EBA without country fixed effects. The main findings of the paper are not changed by removal of the country fixed effects.

Table A-1: EBA Without Country Fixed Effects
Gravity Variables Not Included as I-variables

Variable	Bound	β	Std. Error	t	# Obs.	R-sq	Z-Variables			Robust/ Fragile
Bilateral Trade										
BT1	High	3.94	0.29	13.77	4748	0.04	CU	LANG	MINTL	robust
BT1	Base	3.50	0.27	13.20	4948	0.03				
BT1	Low	1.69	0.38	4.43	1107	0.14	ISA2	TSA3	IND	
BT2	High	16.79	2.01	8.35	2623	0.04	ISC1	MAXL	ADJ	robust
BT2	Base	13.49	1.07	12.57	4948	0.03				
BT2	Low	5.41	1.25	4.33	3736	0.11	MINED	ADJ	IND	
BT3	High	4.13	0.40	10.30	3155	0.05	ISC1	ADJ	MINPOP	robust
BT3	Base	4.30	0.28	15.37	5884	0.04				
BT3	Low	1.76	0.33	5.31	2696	0.14	ISA2	MINED	IND	
BT4	High	7.78	0.82	9.54	3076	0.04	ISC1	MAXL	MINPOP	robust
BT4	Base	7.09	0.47	15.05	5884	0.04				
BT4	Low	3.71	0.71	5.21	2551	0.11	ISA2	MINED	IND	
Total Trade										
TT1	High	0.18	0.05	3.52	1107	0.08	ISA2	TSA3	MAXGDP	fragile
TT1	Base	0.11	0.02	4.58	4948	0.00				
TT1	Low	-0.06	0.05	-1.07	1687	0.02	TSS3	MAXED	MINL	
TT2	High	0.13	0.02	7.55	1516	0.10	ISC2	TSC3	MAXGDP	fragile
TT2	Base	0.05	0.01	5.68	5884	0.01				
TT2	Low	-0.03	0.02	-1.40	1989	0.11	TSS3	MINL	IND	
Industrial Similarity										
ISC1	High	0.47	0.05	9.18	1060	0.10	TSC3	MAXED	MAXGDP	fragile
ISC1	Base	0.17	0.03	6.52	3238	0.01				
ISC1	Low	-0.01	0.06	-0.24	957	0.16	ISC2	TSC3	MINK	
ISC2	High	0.47	0.04	11.77	1516	0.10	TT2	TSC3	MAXGDP	fragile
ISC2	Base	0.23	0.02	9.16	3401	0.02				
ISC2	Low	0.05	0.05	1.05	1296	0.17	TSC3	MINED	IND	
ISS1	High	0.06	0.04	1.36	2011	0.11	BT1	ISS2	MINK	fragile
ISS1	Base	-0.24	0.03	-7.43	3238	0.02				
ISS1	Low	-0.61	0.06	-9.43	992	0.10	TSS3	MAXED	MAXL	
ISS2	High	-0.05	0.06	-0.96	1296	0.17	TSS3	MINED	IND	fragile
ISS2	Base	-0.30	0.03	-10.47	3401	0.03				
ISS2	Low	-0.53	0.05	-11.28	1516	0.10	TT2	TSS3	MAXGDP	

Table A-1: EBA Without Country Fixed Effects
Gravity Variables Not Included as I-variables

Variable	Bound	β	Std. Error	t	# Obs.	R-sq	Z-Variables			Robust/ Fragile
ISA1	High	0.03	0.02	1.13	2011	0.11	BT1	ISA2	MINK	fragile
ISA1	Base	-0.14	0.02	-7.63	3238	0.02				
ISA1	Low	-0.34	0.03	-10.20	1060	0.11	TSA2	TSA3	MAXED	
ISA2	High	-0.05	0.03	-1.55	1296	0.17	TSA3	MINED	IND	fragile
ISA2	Base	-0.18	0.02	-11.35	3401	0.04				
ISA2	Low	-0.30	0.03	-11.65	1518	0.09	TSA3	MAXGDP	MINPOP	
Trade Similarity										
TSC1	High	0.20	0.02	7.85	1828	0.05	TSC3	MAXED	MAXK	fragile
TSC1	Base	-0.02	0.01	-1.54	3817	0.00				
TSC1	Low	-0.09	0.02	-4.57	1641	0.06	ISC1	ISC2	MINPOP	
TSC2	High	0.17	0.05	3.35	1828	0.03	TSC3	MAXED	MAXGDP	fragile
TSC2	Base	-0.06	0.03	-2.08	3895	0.00				
TSC2	Low	-0.18	0.05	-3.95	1678	0.05	ISC1	ISC2	MINPOP	
TSC3	High	0.04	0.02	1.81	1296	0.12	ISC2	MINED	MAXGDP	fragile
TSC3	Base	-0.06	0.02	-3.55	2174	0.01				
TSC3	Low	-0.08	0.02	-3.86	1107	0.05	TT1	ISC1	TSC1	
TSS1	High	0.13	0.03	4.58	1641	0.07	ISS1	ISS2	MINTL	fragile
TSS1	Base	0.00	0.02	0.06	3817	0.00				
TSS1	Low	-0.20	0.03	-6.00	1828	0.04	TSS3	MAXED	MAXGDP	
TSS2	High	0.51	0.08	6.48	1678	0.07	ISS1	ISS2	MINPOP	fragile
TSS2	Base	0.19	0.05	3.87	3895	0.00				
TSS2	Low	-0.31	0.09	-3.49	1828	0.03	TSS3	MAXED	MAXGDP	
TSS3	High	0.07	0.03	2.19	891	0.11	BT2	ISS1	ISS2	fragile
TSS3	Base	-0.03	0.02	-1.51	2174	0.00				
TSS3	Low	-0.06	0.02	-2.61	1769	0.03	TT1	MAXED	MAXGDP	
TSA1	High	0.09	0.01	6.90	1641	0.09	ISA1	ISA2	MINPOP	fragile
TSA1	Base	0.04	0.01	4.66	3817	0.01				
TSA1	Low	-0.09	0.02	-5.29	1828	0.04	TSA3	MAXED	MAXGDP	
TSA2	High	0.23	0.03	8.35	1678	0.09	ISA1	ISA2	MINPOP	fragile
TSA2	Base	0.14	0.02	7.35	3895	0.01				
TSA2	Low	-0.10	0.04	-2.63	1828	0.03	TSA3	MAXED	MAXGDP	
TSA3	High	0.07	0.02	4.08	1038	0.06	TT1	ISA1	MAXL	fragile
TSA3	Base	0.06	0.01	4.69	2174	0.01				
TSA3	Low	-0.02	0.02	-1.06	1296	0.12	ISA2	MINED	MAXGDP	

Table A-1: EBA Without Country Fixed Effects
Gravity Variables Not Included as I-variables

Variable	Bound	β	Std. Error	t	# Obs.	R-sq	Z-Variables			Robust/ Fragile
Factor Endowments										
MINED	High	0.17	0.02	7.96	1013	0.12	TT1	ISC1	TSC3	fragile
MINED	Base	0.09	0.01	13.02	4093	0.04				
MINED	Low	-0.03	0.02	-1.68	1769	0.13	BT2	TSA3	MINK	
MAXED	High	0.20	0.03	6.96	1227	0.09	ISA2	TSA3	MAXL	fragile
MAXED	Base	0.08	0.01	7.55	4093	0.01				
MAXED	Low	-0.02	0.02	-0.96	2551	0.07	ISC1	MINED	DEV	
MINK	High	0.08	0.01	11.62	1296	0.16	ISC2	TSC3	MAXED	fragile
MINK	Base	0.04	0.00	16.81	5776	0.05				
MINK	Low	0.01	0.01	1.79	2551	0.10	ISS1	MINED	IND	
MAXK	High	0.05	0.01	3.91	1518	0.08	ISC2	TSC3	DEV	fragile
MAXK	Base	0.03	0.00	9.76	5776	0.02				
MAXK	Low	-0.01	0.01	-1.32	2163	0.08	TSA3	MINK	DEV	
MINL	High	0.00	0.00	1.08	3155	0.03	TT2	ISC2	MAXL	fragile
MINL	Base	-0.01	0.00	-1.90	5563	0.00				
MINL	Low	-0.02	0.01	-3.01	1985	0.01	TSS3	DIST	MINTL	
MAXL	High	0.00	0.01	0.45	1985	0.01	TSC3	MINL	DIST	fragile
MAXL	Base	0.00	0.00	-0.81	5563	0.00				
MAXL	Low	-0.03	0.01	-4.28	1991	0.12	TSS3	MAXTL	IND	
Currency Union										
CU	High	0.15	0.07	2.29	1192	0.11	ISC1	TSC3	MINK	fragile
CU	Base	-0.02	0.03	-0.95	5993	0.00				
CU	Low	-0.28	0.12	-2.37	2273	0.08	TT1	ISA1	MINED	
Gravity Variables										
ADJ	High	0.25	0.04	6.71	1828	0.04	TSA3	MAXED	DEV	fragile
	Base	0.19	0.03	6.98	5776	0.01				
	Low	-0.03	0.05	-0.50	2011	0.06	BT2	ISA1	ISA2	
LANG	High	0.02	0.02	1.31	1192	0.07	ISS1	TSS3	DEV	fragile
	Base	0.01	0.01	1.35	5776	0.00				
	Low	-0.05	0.02	-2.90	1439	0.08	BT1	ISC2	TSC3	
DIST	High	0.00	0.00	0.98	1516	0.10	BT3	ISC2	TSC3	fragile
	Base	0.00	0.00	-4.41	5776	0.00				
	Low	0.00	0.00	-4.48	1060	0.12	ISS1	TSS3	MAXED	

Table A-1: EBA Without Country Fixed Effects
Gravity Variables Not Included as I-variables

Variable	Bound	β	Std. Error	t	# Obs.	R-sq	Z-Variables			Robust/ Fragile
MINPOP	High	0.02	0.01	3.32	2036	0.08	TT1	TSC3	MINK	fragile
	Base	0.01	0.00	2.71	5993	0.00				
	Low	-0.06	0.01	-7.26	1828	0.05	TSA3	MAXED	MINGDP	
MAXPOP	High	0.03	0.01	3.07	1107	0.06	TT1	ISS1	TSS3	fragile
	Base	0.00	0.00	1.50	5993	0.00				
	Low	-0.07	0.01	-9.55	1518	0.12	ISC2	TSC3	MAXGDP	
MINTL	High	0.00	0.01	0.89	1991	0.01	TSA3	MINL	MINPOP	fragile
	Base	0.00	0.00	0.23	5776	0.00				
	Low	-0.02	0.00	-5.98	1464	0.09	ISS2	TSS3	MAXGDP	
MAXTL	High	0.02	0.01	2.48	1991	0.01	TSA3	MAXL	MAXPOP	fragile
	Base	0.00	0.00	1.54	5776	0.00				
	Low	-0.03	0.00	-7.35	2441	0.07	ISS2	TSS2	MAXGDP	
IND	High	0.32	0.02	20.13	5773	0.07	MAXPOP	MINTL	MAXTL	robust
	Base	0.32	0.02	19.69	5993	0.06				
	Low	0.19	0.03	6.82	1192	0.15	ISA2	TSA3	MINK	
DEV	High	0.03	0.02	1.54	2171	0.03	TSC3	MAXGDP	MAXPOP	fragile
	Base	-0.07	0.01	-10.83	5993	0.02				
	Low	-0.09	0.02	-5.43	1389	0.07	ISC2	TSC3	MINL	
MINGDP	High	0.07	0.01	10.76	2163	0.05	TSS3	DIST	MINPOP	fragile
	Base	0.02	0.00	9.43	5993	0.01				
	Low	-0.01	0.01	-1.45	3398	0.10	ISA2	MINK	MINPOP	
MAXGDP	High	0.08	0.01	10.77	1518	0.12	ISC2	TSC3	MAXPOP	fragile
	Base	0.02	0.00	8.43	5993	0.01				
	Low	0.00	0.00	-0.18	2192	0.09	ISA1	TSA2	IND	

Table A-2: EBA Without Country Fixed Effects
Gravity Variables Included as I-variables

Variable	Bound	β	Std. Error	t	R-sq		Z-Variables		Robust/ Fragile
Bilateral Trade									
BT1	High	1.62	0.40	4.04	0.09	TT1	ISC1	CU	robust
	Base	1.70	0.33	5.20	0.09				
	Low	1.09	0.45	2.40	0.15	ISA1	TSA3	MINL	
BT2	High	6.15	2.27	2.71	0.07	ISC1	MINL	CU	fragile
	Base	5.87	1.23	4.77	0.09				
	Low	3.99	2.32	1.72	0.11	ISA1	MINED	MAXL	
BT3	High	2.32	0.45	5.11	0.10	TT2	ISC1	MAXED	robust
	Base	2.00	0.34	5.96	0.08				
	Low	1.35	0.40	3.35	0.19	ISC2	TSC3	MINK	
BT4	High	3.88	0.95	4.10	0.07	ISC1	MINL	CU	robust
	Base	3.33	0.54	6.17	0.09				
	Low	2.72	1.01	2.70	0.11	ISA1	ISA2	MAXL	
Total Trade									
TT1	High	-0.02	0.08	-0.28	0.17	ISA1	ISA2	TSA3	fragile
	Base	0.03	0.03	1.08	0.09				
	Low	-0.18	0.07	-2.60	0.15	TSA3	MAXED	MINL	
TT2	High	0.05	0.02	2.71	0.12	ISC1	ISC2	MAXED	fragile
	Base	0.01	0.01	1.31	0.08				
	Low	-0.06	0.03	-2.31	0.15	TSA3	MAXED	MINL	
Industrial Similarity									
ISC1	High	0.34	0.06	6.11	0.17	TSC3	MAXED	MAXL	fragile
	Base	0.11	0.03	4.34	0.07				
	Low	-0.06	0.03	-1.60	0.13	BT1	ISC2	MINK	
ISC2	High	0.27	0.06	4.73	0.16	TT2	ISC1	TSC3	fragile
	Base	0.18	0.03	6.65	0.11				
	Low	-0.03	0.05	-0.52	0.20	TSC3	MINED	MINK	
ISS1	High	0.07	0.05	1.55	0.13	BT1	ISS2	MINK	fragile
	Base	-0.16	0.03	-4.91	0.08				
	Low	-0.31	0.05	-6.33	0.12	TSS2	MAXED	MAXL	
ISS2	High	0.01	0.06	0.14	0.20	TSS3	MINED	MINK	fragile
	Base	-0.22	0.03	-6.98	0.11				
	Low	-0.35	0.07	-5.04	0.17	ISS1	TSS1	TSS3	
ISA1	High	0.04	0.02	1.43	0.13	BT1	ISA2	MINK	fragile

Variable	Bound	β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
	Base	-0.09	0.02	-4.86	0.08				
	Low	-0.25	0.04	-6.47	0.17	TSA3	MAXED	MAXL	
ISA2	High	-0.01	0.04	-0.28	0.20	TSA3	MINED	MINK	fragile
	Base	-0.14	0.02	-7.93	0.12				
	Low	-0.21	0.04	-5.44	0.17	ISA1	TSA1	TSA3	

Trade Similarity

Variable	Bound	β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
TSC1	High	0.10	0.03	4.18	0.16	TSC3	MAXED	MAXL	fragile
	Base	-0.01	0.01	-0.59	0.10				
	Low	-0.04	0.02	-2.06	0.14	BT3	ISC1	ISC2	
TSC2	High	0.13	0.05	2.60	0.15	TSC3	MAXED	MINL	fragile
	Base	-0.01	0.03	-0.44	0.10				
	Low	-0.10	0.07	-1.47	0.17	ISC1	ISC2	TSC3	
TSC3	High	0.03	0.02	1.32	0.20	ISC2	MINED	MINK	fragile
	Base	-0.02	0.02	-1.52	0.13				
	Low	-0.02	0.02	-0.86	0.18	BT3	TSC1	MAXED	
TSS1	High	0.12	0.04	2.65	0.17	ISS1	ISS2	TSS3	fragile
	Base	0.00	0.02	-0.25	0.10				
	Low	-0.11	0.03	-3.17	0.15	TSS3	MAXED	MAXL	
TSS2	High	0.23	0.11	2.07	0.17	ISS1	ISS2	TSS3	fragile
	Base	0.05	0.05	0.90	0.10				
	Low	-0.22	0.08	-2.64	0.18	TSS3	MINED	MINK	
TSS3	High	0.08	0.03	2.55	0.17	BT2	ISS1	ISS2	fragile
	Base	0.02	0.02	1.09	0.13				
	Low	0.01	0.03	0.37	0.18	TT2	ISS2	MINED	
TSA1	High	0.04	0.02	1.50	0.17	ISA1	ISA2	TSA3	fragile
	Base	0.01	0.01	1.08	0.10				
	Low	-0.04	0.02	-2.50	0.15	TSA3	MAXED	MINL	
TSA2	High	0.08	0.05	1.77	0.17	ISA1	ISA2	MAXK	fragile
	Base	0.05	0.02	2.30	0.10				
	Low	-0.09	0.04	-2.54	0.15	TSA3	MAXED	MINL	
TSA3	High	0.03	0.02	1.75	0.16	ISA1	ISA2	MINL	fragile
	Base	0.02	0.01	1.82	0.14				
	Low	-0.01	0.02	-0.83	0.20	ISA2	MINED	MINK	

Table A-2: EBA Without Country Fixed Effects
Gravity Variables Included as I-variables

Variable	Bound	β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
Factor Endowments									
MINED	High	0.13	0.02	5.17	0.20	ISC1	ISC2	TSC3	fragile
	Base	0.05	0.01	6.50	0.11				
	Low	-0.05	0.02	-2.42	0.18	BT2	TSA3	MINK	
MAXED	High	0.13	0.04	3.17	0.17	ISS1	TSS3	MAXL	fragile
	Base	0.02	0.01	1.19	0.10				
	Low	-0.01	0.03	-0.22	0.16	TSA3	MINED	MAXK	
MINK	High	0.06	0.01	7.09	0.20	ISC2	TSC3	MAXED	fragile
	Base	0.02	0.00	7.95	0.09				
	Low	0.01	0.01	0.95	0.10	ISA1	MINED	MINL	
MAXK	High	0.01	0.02	0.59	0.18	ISS2	TSS3	MAXED	fragile
	Base	0.01	0.00	2.74	0.08				
	Low	-0.04	0.02	-2.10	0.16	ISC1	TSC3	MINK	
MINL	High	-0.01	0.01	-0.99	0.16	BT4	ISC2	TSC3	fragile
	Base	-0.01	0.00	-3.07	0.07				
	Low	-0.03	0.01	-3.91	0.15	TT2	TSS3	MAXED	
MAXL	High	-0.02	0.01	-2.23	0.10	ISA1	TSA2	MINL	robust
	Base	-0.03	0.01	-4.41	0.07				
	Low	-0.05	0.01	-4.13	0.17	ISA2	TSA3	MAXED	
Currency Union									
CU	High	-0.10	0.10	-1.01	0.17	ISC1	TSC3	MINK	fragile
	Base	-0.03	0.03	-0.97	0.08				
	Low	-0.30	0.12	-2.54	0.10	TT1	ISS1	MAXED	

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Table 1: Variable Correlation Matrix

Variable	Business Cycle	BT1	BT2	BT3	BT4	TT1	TT2	ISS1	ISA1	ISC1	ISS2	ISA2	ISC2	TSS1	TSA1	TSC1	TSS2	TSA2	TSC2	TSS3	TSA3	TSC3
Bilateral Trade Intensity																						
BT1	0.18	1	0.81	0.76	0.64	0.00	0.03	0.12	0.14	0.11	0.18	0.19	0.16	-0.02	-0.10	0.01	-0.14	-0.19	-0.08	0.12	-0.07	-0.04
BT2	0.18	0.81	1	0.64	0.87	0.12	0.12	0.11	0.12	0.09	0.14	0.15	0.13	-0.01	-0.08	0.00	-0.09	-0.13	-0.05	0.12	-0.04	-0.02
BT3	0.20	0.76	0.64	1	0.76	-0.01	0.03	0.15	0.16	0.13	0.22	0.23	0.19	0.01	-0.09	0.01	-0.16	-0.23	-0.10	0.13	-0.11	-0.07
BT4	0.19	0.64	0.87	0.76	1	0.12	0.14	0.14	0.15	0.12	0.15	0.16	0.14	0.03	-0.07	0.01	-0.09	-0.15	-0.05	0.12	-0.07	-0.04
Total Trade Intensity																						
TT1	0.06	0.00	0.12	-0.01	0.12	1	0.86	-0.11	-0.11	-0.11	-0.24	-0.23	-0.25	-0.11	-0.15	-0.20	-0.02	-0.05	0.01	-0.04	0.00	0.07
TT2	0.07	0.03	0.12	0.03	0.14	0.86	1	-0.10	-0.10	-0.10	-0.24	-0.24	-0.28	-0.12	-0.21	-0.23	-0.08	-0.14	-0.05	-0.04	-0.01	0.05
Similarity of Industrial Structure																						
ISS1	0.13	0.12	0.11	0.15	0.14	-0.11	-0.10	1	0.98	0.97	0.29	0.29	0.26	0.23	0.14	0.21	0.04	0.03	0.05	0.08	-0.06	-0.03
ISA1	0.13	0.14	0.12	0.16	0.15	-0.11	-0.10	0.98	1	0.96	0.29	0.30	0.27	0.22	0.13	0.22	0.05	0.03	0.06	0.08	-0.07	-0.03
ISC1	0.11	0.11	0.09	0.13	0.12	-0.11	-0.10	0.97	0.96	1	0.24	0.25	0.23	0.22	0.13	0.21	0.03	0.02	0.05	0.07	-0.07	-0.04
ISS2	0.18	0.18	0.14	0.22	0.15	-0.24	-0.24	0.29	0.29	0.24	1	0.97	0.95	0.23	0.15	0.25	0.07	0.01	0.08	0.24	-0.04	-0.09
ISA2	0.19	0.19	0.15	0.23	0.16	-0.23	-0.24	0.29	0.30	0.25	0.97	1	0.94	0.21	0.14	0.26	0.06	0.01	0.08	0.23	-0.06	-0.10
ISC2	0.16	0.16	0.13	0.19	0.14	-0.25	-0.28	0.26	0.27	0.23	0.95	0.94	1	0.24	0.20	0.31	0.11	0.07	0.11	0.24	-0.04	-0.08
Similarity of Trade Structure																						
TSS1	0.00	-0.02	-0.01	0.01	0.03	-0.11	-0.12	0.23	0.22	0.22	0.23	0.21	0.24	1	0.85	0.61	0.43	0.46	0.37	0.11	0.01	0.11
TSA1	-0.08	-0.10	-0.08	-0.09	-0.07	-0.15	-0.21	0.14	0.13	0.13	0.15	0.14	0.20	0.85	1	0.71	0.57	0.71	0.43	0.12	0.23	0.38
TSC1	-0.02	0.01	0.00	0.01	0.01	-0.20	-0.23	0.21	0.22	0.21	0.25	0.26	0.31	0.61	0.71	1	0.47	0.53	0.42	0.14	0.07	0.20
TSS2	-0.06	-0.14	-0.09	-0.16	-0.09	-0.02	-0.08	0.04	0.05	0.03	0.07	0.06	0.11	0.43	0.57	0.47	1	0.92	0.79	0.03	0.11	0.20
TSA2	-0.12	-0.19	-0.13	-0.23	-0.15	-0.05	-0.14	0.03	0.03	0.02	0.01	0.01	0.07	0.46	0.71	0.53	0.92	1	0.71	0.05	0.27	0.36
TSC2	-0.03	-0.08	-0.05	-0.10	-0.05	0.01	-0.05	0.05	0.06	0.05	0.08	0.08	0.11	0.37	0.43	0.42	0.79	0.71	1	0.03	0.07	0.12
TSS3	0.03	0.12	0.12	0.13	0.12	-0.04	-0.04	0.08	0.08	0.07	0.24	0.23	0.24	0.11	0.12	0.14	0.03	0.05	0.03	1	0.71	0.29
TSA3	-0.10	-0.07	-0.04	-0.11	-0.07	0.00	-0.01	-0.06	-0.07	-0.07	-0.04	-0.06	-0.04	0.01	0.23	0.07	0.11	0.27	0.07	0.71	1	0.66
TSC3	-0.08	-0.04	-0.02	-0.07	-0.04	0.07	0.05	-0.03	-0.03	-0.04	-0.09	-0.10	-0.08	0.11	0.38	0.20	0.20	0.36	0.12	0.29	0.66	1

Table 1: Variable Correlation Matrix, cont'd.

Variable		BT1	BT2	BT3	BT4	TT1	TT2	ISS1	ISA1	ISC1	ISS2	ISA2	ISC2	TSS1	TSA1	TSC1	TSS2	TSA2	TSC2	TSS3	TSA3	TSC3
Factor Endowments																						
MINED	0.20	0.19	0.17	0.22	0.21	0.12	0.19	0.35	0.37	0.32	0.25	0.28	0.21	0.01	-0.17	-0.05	-0.09	-0.21	-0.05	0.06	-0.22	-0.21
MAXED	0.12	0.12	0.10	0.13	0.12	0.28	0.35	-0.04	-0.03	-0.05	-0.04	-0.05	-0.12	-0.15	-0.33	-0.26	-0.19	-0.31	-0.13	-0.02	-0.18	-0.15
MINK	0.22	0.20	0.19	0.26	0.24	0.17	0.20	0.40	0.39	0.34	0.33	0.32	0.24	0.05	-0.17	-0.08	-0.17	-0.27	-0.12	0.09	-0.21	-0.24
MAXK	0.13	0.11	0.11	0.14	0.13	0.34	0.40	-0.11	-0.12	-0.15	-0.05	-0.07	-0.17	-0.22	-0.41	-0.35	-0.26	-0.36	-0.16	0.00	-0.20	-0.22
MINL	-0.03	-0.02	-0.07	-0.06	-0.13	-0.42	-0.56	0.05	0.06	0.04	0.20	0.21	0.18	0.02	0.10	0.11	0.11	0.16	0.13	0.03	0.06	0.01
MAXL	-0.01	0.01	-0.03	-0.02	-0.09	-0.11	-0.14	0.08	0.08	0.06	0.10	0.08	0.07	0.01	0.03	0.04	0.01	0.03	0.06	0.03	0.00	0.00
Gravity variables																						
ADJ	0.09	0.34	0.31	0.38	0.30	-0.03	-0.03	0.07	0.07	0.06	0.09	0.10	0.08	0.00	-0.01	0.02	-0.07	-0.08	-0.04	0.09	0.02	0.01
LANG	0.02	0.12	0.10	0.08	0.05	-0.04	-0.08	0.02	0.02	0.02	0.03	0.04	0.05	-0.05	-0.02	0.00	-0.06	-0.06	-0.02	0.02	0.00	0.01
DIST	-0.06	-0.19	-0.18	-0.20	-0.17	-0.02	0.06	0.04	0.03	0.03	-0.11	-0.11	-0.10	0.12	0.10	0.04	0.08	0.10	0.06	-0.12	-0.01	0.02
MINPOP	0.04	0.17	0.10	0.20	0.11	-0.17	-0.06	0.02	0.04	0.02	0.31	0.33	0.23	-0.11	-0.21	-0.10	-0.17	-0.24	-0.07	0.01	-0.19	-0.24
MAXPOP	0.02	0.11	0.02	0.16	0.05	-0.48	-0.29	0.00	0.00	-0.01	0.09	0.08	0.00	-0.10	-0.21	-0.10	-0.28	-0.35	-0.23	-0.05	-0.19	-0.23
MINTL	0.00	0.06	-0.01	0.05	-0.04	-0.39	-0.38	0.05	0.06	0.04	0.30	0.28	0.22	-0.05	-0.03	-0.02	-0.04	-0.03	0.02	0.02	-0.03	-0.11
MAXTL	0.02	0.06	-0.03	0.07	-0.04	-0.42	-0.35	0.00	0.00	-0.03	0.16	0.13	0.09	-0.03	-0.06	-0.03	-0.21	-0.21	-0.13	-0.02	-0.10	-0.14
IND	0.25	0.34	0.32	0.37	0.35	0.07	0.09	0.23	0.26	0.20	0.28	0.29	0.24	0.05	-0.07	0.04	-0.06	-0.14	-0.02	0.14	-0.13	-0.09
DEV	-0.14	-0.13	-0.11	-0.14	-0.13	-0.23	-0.31	0.01	0.01	0.01	0.00	0.02	0.10	0.27	0.45	0.33	0.25	0.37	0.14	-0.01	0.18	0.21
Currency Union																						
CU	-0.01	0.04	0.03	0.00	-0.01	0.00	-0.06	0.00	0.01	0.00	0.05	0.05	0.07	0.01	0.04	-0.01	-0.02	0.01	0.01	0.02	0.05	0.03

Variable	MINED	MAXED	MINK	MAXK	MINL	MAXL	ADJ	LANG	DIST	MINPOP	MAXPOP	MINTL	MINTL	IND	DEV	CU
Bilateral Trade Intensity																
BT1	0.19	0.12	0.20	0.11	-0.02	0.01	0.34	0.12	-0.19	0.17	0.11	0.06	0.06	0.34	-0.13	0.04
BT2	0.17	0.10	0.19	0.11	-0.07	-0.03	0.31	0.10	-0.18	0.10	0.02	-0.01	-0.03	0.32	-0.11	0.03
BT3	0.22	0.13	0.26	0.14	-0.06	-0.02	0.38	0.08	-0.20	0.20	0.16	0.05	0.07	0.37	-0.14	0.00
BT4	0.21	0.12	0.24	0.13	-0.13	-0.09	0.30	0.05	-0.17	0.11	0.05	-0.04	-0.04	0.35	-0.13	-0.01
Total Trade Intensity																
TT1	0.12	0.28	0.17	0.34	-0.42	-0.11	-0.03	-0.04	-0.02	-0.17	-0.48	-0.39	-0.42	0.07	-0.23	0.00
TT2	0.19	0.35	0.20	0.40	-0.56	-0.14	-0.03	-0.08	0.06	-0.06	-0.29	-0.38	-0.35	0.09	-0.31	-0.06
Similarity of Industrial Structure																
ISS1	0.35	-0.04	0.40	-0.11	0.05	0.08	0.07	0.02	0.04	0.02	0.00	0.05	0.00	0.23	0.01	0.00
ISA1	0.37	-0.03	0.39	-0.12	0.06	0.08	0.07	0.02	0.03	0.04	0.00	0.06	0.00	0.26	0.01	0.01
ISC1	0.32	-0.05	0.34	-0.15	0.04	0.06	0.06	0.02	0.03	0.02	-0.01	0.04	-0.03	0.20	0.01	0.00
ISS2	0.25	-0.04	0.33	-0.05	0.20	0.10	0.09	0.03	-0.11	0.31	0.09	0.30	0.16	0.28	0.00	0.05
ISA2	0.28	-0.05	0.32	-0.07	0.21	0.08	0.10	0.04	-0.11	0.33	0.08	0.28	0.13	0.29	0.02	0.05
ISC2	0.21	-0.12	0.24	-0.17	0.18	0.07	0.08	0.05	-0.10	0.23	0.00	0.22	0.09	0.24	0.10	0.07
Similarity of Trade Structure																
TSS1	0.01	-0.15	0.05	-0.22	0.02	0.01	0.00	-0.05	0.12	-0.11	-0.10	-0.05	-0.03	0.05	0.27	0.01
TSA1	-0.17	-0.33	-0.17	-0.41	0.10	0.03	-0.01	-0.02	0.10	-0.21	-0.21	-0.03	-0.06	-0.07	0.45	0.04
TSC1	-0.05	-0.26	-0.08	-0.35	0.11	0.04	0.02	0.00	0.04	-0.10	-0.10	-0.02	-0.03	0.04	0.33	-0.01
TSS2	-0.09	-0.19	-0.17	-0.26	0.11	0.01	-0.07	-0.06	0.08	-0.17	-0.28	-0.04	-0.21	-0.06	0.25	-0.02
TSA2	-0.21	-0.31	-0.27	-0.36	0.16	0.03	-0.08	-0.06	0.10	-0.24	-0.35	-0.03	-0.21	-0.14	0.37	0.01
TSC2	-0.05	-0.13	-0.12	-0.16	0.13	0.06	-0.04	-0.02	0.06	-0.07	-0.23	0.02	-0.13	-0.02	0.14	0.01
TSS3	0.06	-0.02	0.09	0.00	0.03	0.03	0.09	0.02	-0.12	0.01	-0.05	0.02	-0.02	0.14	-0.01	0.02
TSA3	-0.22	-0.18	-0.21	-0.20	0.06	0.00	0.02	0.00	-0.01	-0.19	-0.19	-0.03	-0.10	-0.13	0.18	0.05
TSC3	-0.21	-0.15	-0.24	-0.22	0.01	0.00	0.01	0.01	0.02	-0.24	-0.23	-0.11	-0.14	-0.09	0.21	0.03

Table 1: Variable Correlation Matrix, cont'd.

Variable	MINED	MAXED	MINK	MAXK	MINL	MAXL	ADJ	LANG	DIST	MINPOP	MAXPOP	MINTL	MAXTL	IND	DEV	CU
Factor Endowments																
MINED	1	0.48	0.78	0.45	-0.11	0.00	0.04	0.03	0.05	0.02	0.12	-0.11	-0.02	0.33	-0.33	-0.11
MAXED	0.48	1	0.45	0.76	-0.09	0.14	-0.02	-0.03	0.07	0.01	0.05	-0.10	0.02	0.23	-0.59	-0.16
MINK	0.78	0.45	1	0.49	-0.11	0.06	0.07	0.00	0.08	0.00	0.07	-0.08	0.01	0.39	-0.35	-0.10
MAXK	0.45	0.76	0.49	1	-0.06	0.11	-0.03	-0.11	0.12	0.05	0.07	-0.03	0.03	0.22	-0.71	-0.21
MINL	-0.11	-0.09	-0.11	-0.06	1	0.39	0.04	0.01	-0.21	0.18	0.07	0.54	0.24	0.03	-0.05	0.09
MAXL	0.00	0.14	0.06	0.11	0.39	1	0.00	0.04	0.01	0.11	-0.02	0.31	0.41	0.09	-0.14	0.07
Gravity variables																
ADJ	0.04	-0.02	0.07	-0.03	0.04	0.00	1	0.07	-0.19	0.06	0.03	0.06	0.03	0.13	0.02	0.09
LANG	0.03	-0.03	0.00	-0.11	0.01	0.04	0.07	1	-0.16	-0.03	-0.04	-0.02	0.00	-0.01	0.05	0.21
DIST	0.05	0.07	0.08	0.12	-0.21	0.01	-0.19	-0.16	1	-0.02	0.08	-0.05	0.08	-0.12	0.04	-0.17
MINPOP	0.02	0.01	0.00	0.05	0.18	0.11	0.06	-0.03	-0.02	1	0.44	0.63	0.37	0.09	-0.13	-0.06
MAXPOP	0.12	0.05	0.07	0.07	0.07	-0.02	0.03	-0.04	0.08	0.44	1	0.36	0.60	0.07	-0.12	-0.12
MINTL	-0.11	-0.10	-0.08	-0.03	0.54	0.31	0.06	-0.02	-0.05	0.63	0.36	1	0.44	0.06	-0.09	0.02
MAXTL	-0.02	0.02	0.01	0.03	0.24	0.41	0.03	0.00	0.08	0.37	0.60	0.44	1	0.02	-0.04	-0.01
IND	0.33	0.23	0.39	0.22	0.03	0.09	0.13	-0.01	-0.12	0.09	0.07	0.06	0.02	1	-0.27	-0.02
DEV	-0.33	-0.59	-0.35	-0.71	-0.05	-0.14	0.02	0.05	0.04	-0.13	-0.12	-0.09	-0.04	-0.27	1	0.09
Currency Union																
CU	-0.11	-0.16	-0.10	-0.21	0.09	0.07	0.09	0.21	-0.17	-0.06	-0.12	0.02	-0.01	-0.02	0.09	1

Table 2: Regression of business-cycle correlation on gravity variables
A. Without country fixed effects

Independent variables	β	Std. Error	t	pr > |t|
constant	0.045	0.042	2.07	0.2853
Adjacency	0.131	0.027	4.77	<.0001
Common Language	0.014	0.009	1.52	0.1289
Distance	-1.2E-6	7.5E-07	-1.59	0.1111
Minimum log(Population)	0.005	0.003	1.66	0.0967
Maximum log(Population)	-0.003	0.003	-1.12	0.2622
Minimum log(Total land area)	-0.006	0.002	-2.82	0.0049
Maximum log(Total land area)	0.006	0.003	2.07	0.0383
Two industrialized countries	0.284	0.017	16.85	<.0001
Two developing countries	-0.040	0.007	-5.86	<.0001

Adjusted R-Square: 0.076
Number of observations: 5670 country pairs

B. With country fixed effects

Independent variables	β	Std. Error	t	pr > |t|
Adjacency	0.121	0.026	4.59	0.00
Common Language	0.017	0.009	1.79	0.07
Distance	-3.3E-06	9.2E-07	-3.61	0.00
Minimum log(Population)	-0.011	0.007	-1.63	0.10
Minimum log(Total land area)	-0.002	0.005	-0.42	0.68
Two industrialized countries	0.240	0.019	12.85	0.00

Adjusted R-Square: 0.2113

Table 3
Extreme Bounds Analysis of Bilateral Trade
Dependent Variable: Bilateral Correlation of Cyclic Output

M-Var.		β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
Robustness Tests with No "Always-Included" Variables									
BT1	High	2.82	0.28	10.00	0.19 CU	MAXPOP	MINTL		robust
	Base	2.42	0.26	9.34	0.20				
	Low	1.42	0.38	3.70	0.21 ISA1	ADJ	DEV		
BT2	High	11.89	1.93	6.16	0.18 ISC1	MAXL	MINPOP		robust
	Base	9.27	1.04	8.90	0.20				
	Low	5.64	1.62	3.48	0.20 ISA1	ADJ	DEV		
BT3	High	2.85	0.31	9.17	0.19 CB	ADJ	MINPOP		robust
	Base	3.13	0.28	11.14	0.19				
	Low	1.31	0.32	4.13	0.41 TSA3	DIST	IND		
BT4	High	5.47	0.86	6.39	0.16 ISC1	MAXL	MINPOP		robust
	Base	5.07	0.47	10.76	0.19				
	Low	2.67	0.75	3.56	0.38 ISA1	TSA3	DIST		
Robustness Tests with Gravity Variables Always Included									
BT1	High	1.21	0.39	3.10	0.21 ISC1	MAXK	CU		robust
	Base	1.34	0.32	4.24	0.22				
	Low	0.67	0.40	1.67	0.31 ISA1	TSA1	MAXED		
BT2	High	4.84	2.23	2.17	0.20 ISC1	MAXL	CU		fragile
	Base	4.57	1.19	3.84	0.22				
	Low	2.69	2.25	1.20	0.27 ISA1	TSA1	MAXL		
BT3	High	1.65	0.44	3.77	0.20 ISC1	MAXK	CU		fragile
	Base	1.48	0.33	4.45	0.20				
	Low	0.57	0.48	1.18	0.40 TT2	ISA1	TSA3		
BT4	High	2.65	0.95	2.79	0.18 ISC1	MAXK	MINL		fragile
	Base	2.46	0.53	4.62	0.20				
	Low	0.94	1.04	0.91	0.38 ISA1	TSA3	MINL		

Table 4
Extreme Bounds Analysis of Total Trade
Dependent Variable: Bilateral Correlation of Cyclic Output

M-Var.		β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
Robustness Tests with No "Always-Included" Variables									
TT1	High	0.02	0.08	0.28	0.24	ISC1	ISC2	MAXPOP	fragile
	Base	-0.26	0.05	-5.48	0.19				
	Low	-0.46	0.09	-5.22	0.37	TSA3	MINPOP	MAXTL	
TT2	High	-0.01	0.03	-0.44	0.42	ISC1	ISC2	TSC3	fragile
	Base	-0.14	0.02	-8.07	0.18				
	Low	-0.16	0.03	-5.54	0.36	TSA3	MINPOP	MINTL	
Robustness Tests with Gravity Variables Always Included									
TT1	High	0.06	0.08	0.79	0.27	BT2	ISC1	ISC2	fragile
	Base	-0.14	0.05	-2.61	0.22				
	Low	-0.32	0.12	-2.68	0.40	ISC1	TSC3	MINL	
TT2	High	-0.03	0.04	-0.64	0.44	ISS1	ISS2	TSS3	fragile
	Base	-0.08	0.02	-4.32	0.20				
	Low	-0.11	0.04	-2.70	0.39	ISS1	TSS3	MINL	

Table 5
Extreme Bounds Analysis of Industrial Structure
Dependent Variable: Bilateral Correlation of Cyclic Output

M-Var.		β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
Robustness Tests with No "Always-Included" Variables									
ISC1	High	0.47	0.07	6.58	0.35	TSC1	TSC3	MINTL	fragile
	Base	0.25	0.03	7.59	0.16				
	Low	0.04	0.10	0.36	0.39	BT2	TSC3	MAXK	
ISC2	High	0.28	0.05	5.47	0.42	ISC2	TSC1	TSC3	fragile
	Base	0.22	0.03	7.92	0.25				
	Low	0.03	0.04	0.87	0.30	BT1	MAXED	DEV	
ISS1	High	0.68	0.08	8.23	0.35	TSS1	TSS3	MAXTL	fragile
	Base	0.36	0.04	8.55	0.17				
	Low	0.11	0.12	0.92	0.39	BT2	TSS3	MAXK	
ISS2	High	0.51	0.09	5.95	0.42	ISS1	TSS1	TSS3	fragile
	Base	0.27	0.03	7.75	0.25				
	Low	0.04	0.05	0.78	0.30	BT3	MINED	IND	
ISA1	High	0.36	0.04	8.54	0.35	TSA2	TSA3	MAXTL	fragile
	Base	0.19	0.02	8.17	0.16				
	Low	0.05	0.07	0.72	0.43	ISA2	TSA3	MINK	
ISA2	High	0.27	0.04	6.13	0.42	ISA1	TSA1	TSA3	fragile
	Base	0.15	0.02	8.40	0.26				
	Low	0.03	0.02	1.09	0.30	BT1	MAXED	DEV	
Robustness Tests with Gravity Variables Always Included									
ISC1	High	0.26	0.10	2.70	0.40	TSC3	MAXED	MINL	fragile
	Base	0.15	0.03	4.31	0.19				
	Low	0.04	0.11	0.42	0.41	TT1	TSC3	MINK	
ISC2	High	0.22	0.07	3.16	0.43	ISC1	TSC3	MAXL	fragile
	Base	0.11	0.03	3.46	0.27				
	Low	-0.02	0.07	-0.36	0.48	TSC1	TSC3	MINED	
ISS1	High	0.36	0.09	3.78	0.38	TSS1	TSS3	MINL	fragile
	Base	0.22	0.04	4.84	0.19				
	Low	0.09	0.12	0.73	0.41	TT1	TSS3	MINK	
ISS2	High	0.33	0.09	3.51	0.44	ISS1	TSS1	TSS3	fragile
	Base	0.13	0.04	3.38	0.27				
	Low	-0.01	0.08	-0.06	0.48	TSS1	TSS3	MINED	
ISA1	High	0.16	0.05	3.21	0.38	TSA1	TSA3	MINL	fragile
	Base	0.11	0.02	4.36	0.19				
	Low	0.03	0.06	0.45	0.41	TT1	TSA3	MINK	
ISA2	High	0.18	0.05	3.54	0.44	ISA1	TSA1	TSA3	fragile
	Base	0.08	0.02	3.89	0.27				
	Low	-2.8E-03	0.04	-0.06	0.48	TSA1	TSA3	MINED	

M-Var.		β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
						Robustness Tests with No "Always-Included" Variables			
TSC1	High	0.16	0.03	6.31	0.38	TSC3	MAXED	MINPOP	fragile
	Base	0.06	0.01	4.72	0.26				
	Low	0.00	0.04	0.02	0.42	ISC1	ISC2	TSC3	
TSC2	High	0.16	0.06	2.71	0.39	TSC3	MAXED	DIST	fragile
	Base	0.03	0.03	0.96	0.26				
	Low	-0.06	0.08	-0.81	0.42	ISC1	ISC2	TSC3	
TSC3	High	0.06	0.02	3.48	0.39	MAXED	LANG	DIST	fragile
	Base	0.02	0.02	1.58	0.35				
	Low	-0.04	0.02	-1.83	0.38	BT2	ISC1	TSC1	
	Base	0.08	0.02	4.54	0.26				
	Low	-0.07	0.05	-1.37	0.42	ISS1	ISS2	TSS3	
TSS2	High	0.32	0.10	3.31	0.39	TSS3	MAXED	DIST	fragile
	Base	0.07	0.06	1.16	0.26				
	Low	-0.26	0.13	-2.02	0.43	ISS1	ISS2	TSS3	
TSS3	High	0.04	0.02	2.11	0.36	MAXED	MAXPOP	MAXTL	fragile
	Base	0.04	0.02	2.10	0.35				
	Low	-0.06	0.03	-1.96	0.44	BT2	ISS1	ISS2	
TSA1	High	0.12	0.02	5.80	0.38	TSA2	TSA3	MAXED	fragile
	Base	0.05	0.01	5.36	0.26				
	Low	-0.02	0.02	-1.02	0.42	ISA1	ISA2	TSA3	
TSA2	High	0.15	0.04	3.76	0.39	TSA3	MF1	DIST	fragile
	Base	0.02	0.02	0.79	0.26				
	Low	-0.10	0.05	-1.78	0.42	ISA1	ISA2	TSA3	
TSA3	High	0.05	0.01	3.65	0.39	MAXED	LANG	DIST	fragile
	Base	0.02	0.01	1.26	0.35				
	Low	-0.02	0.02	-1.37	0.43	BT4	ISA1	MISA3	

Table 6, cont'd.
Extreme Bounds Analysis of Structure of Bilateral Trade
Dependent Variable: Bilateral Correlation of Cyclic Output

	M-Var.	β	Std. Error	t	R-sq		Z-Variables		Robust/ Fragile
			Robustness Tests with Gravity Variables Always Included						
TSC1	High	0.11	0.03	3.54	0.48	ISC2	TSC3	MAXED	fragile
	Base	0.02	0.01	1.16	0.29				
	Low	-3.1E-03	0.04	-0.09	0.44	ISC1	ISC2	TSC3	
TSC2	High	0.13	0.06	2.35	0.43	TSC3	MAXED	CB	fragile
	Base	0.02	0.03	0.76	0.29				
	Low	-0.06	0.08	-0.73	0.44	ISC1	ISC2	TSC3	
TSC3	High	0.02	0.02	1.19	0.48	ISC2	MAXED	MINK	fragile
	Base	0.02	0.01	1.12	0.41				
	Low	-0.03	0.02	-1.18	0.45	BT2	ISC1	ISC2	
TSS1	High	0.13	0.05	2.76	0.48	ISS2	TSS3	MAXED	fragile
	Base	0.04	0.02	2.07	0.29				
	Low	-0.05	0.05	-1.00	0.44	ISS1	ISS2	TSS3	
TSS2	High	0.25	0.10	2.58	0.41	TSS3	MINED	MINL	fragile
	Base	0.05	0.06	0.80	0.29				
	Low	-0.20	0.13	-1.58	0.44	ISS1	ISS2	TSS3	
TSS3	High	0.01	0.02	0.29	0.47	ISS2	MINED	MAXK	fragile
	Base	-0.01	0.02	-0.29	0.41				
	Low	-0.06	0.03	-2.04	0.45	BT2	ISS1	ISS2	
TSA1	High	0.06	0.02	2.94	0.48	ISA2	TSA3	MAXED	fragile
	Base	0.03	0.01	2.90	0.29				
	Low	-0.02	0.02	-0.63	0.44	ISA1	ISA2	TSA3	
TSA2	High	0.12	0.04	2.98	0.41	TSA3	MAXED	MINL	fragile
	Base	0.03	0.03	1.25	0.29				
	Low	-0.05	0.05	-0.97	0.44	ISA1	ISA2	TSA3	
TSA3	High	0.04	0.02	2.50	0.48	ISA2	MINED	MINK	fragile
	Base	0.02	0.01	1.61	0.41				
	Low	-0.01	0.02	-0.74	0.44	BT4	ISA1	ISA2	

Table 7
Extreme Bounds Analysis of Factor EndowmentVariables
Dependent Variable: Bilateral Correlation of Cyclic Output

M-Var.		β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
Robustness Tests with No "Always-Included" Variables									
MINED	High	0.21	0.06	3.30	0.38	TT1	ISC1	TSC3	fragile
	Base	0.12	0.02	6.27	0.20				
	Low	-0.14	0.06	-2.56	0.45	ISC2	TSC3	MAXK	
MAXED	High	0.14	0.06	2.56	0.45	ISC2	TSC3	MINK	fragile
	Base	-0.12	0.02	-6.27	0.20				
	Low	-0.21	0.06	-3.30	0.38	TT1	ISC1	TSC3	
MINK	High	0.14	0.01	9.38	0.39	TSA3	MAXED	CU	fragile
	Base	0.05	0.01	10.00	0.18				
	Low	0.02	0.01	1.33	0.21	ISS1	MINED	DEV	
MAXK	High	-0.02	0.01	-1.33	0.21	ISS1	MAXED	DEV	fragile
	Base	-0.05	0.01	-10.00	0.18				
	Low	-0.14	0.01	-9.38	0.39	TSA3	MINED	CU	
MINL	High	0.05	0.02	3.33	0.41	TT1	ISC2	TSC3	fragile
	Base	0.02	0.01	1.73	0.15				
	Low	0.00	0.02	0.17	0.37	BT4	TSS3	MINED	
MAXL	High	0.00	0.02	-0.17	0.37	BT4	TSS3	MAXED	fragile
	Base	-0.02	0.01	-1.73	0.15				
	Low	-0.05	0.02	-3.33	0.41	TT1	ISC2	TSC3	
Robustness Tests with Gravity Variables Always Included									
MINED	High	0.05	0.07	0.73	0.42	BT2	ISA1	TSA3	fragile
	Base	0.03	0.02	1.64	0.24				
	Low	-0.13	0.06	-2.39	0.48	ISC2	TSC3	MAXK	
MAXED	High	0.13	0.06	2.39	0.48	ISC2	TSC3	MAXK	fragile
	Base	-0.03	0.02	-1.64	0.24				
	Low	-0.05	0.07	-0.73	0.42	BT2	ISA1	TSA3	
MINK	High	0.06	0.03	2.05	0.44	ISC1	ISC2	TSC3	fragile
	Base	0.02	0.01	2.91	0.20				
	Low	-1.2E-03	0.02	-0.08	0.23	TT1	ISA1	MINED	
MAXK	High	0.00	0.02	0.08	0.23	TT1	ISA1	MAXED	fragile
	Base	-0.02	0.01	-2.91	0.20				
	Low	-0.06	0.03	-2.05	0.44	ISC1	ISC2	TSC3	
MINL	High	0.04	0.02	1.92	0.43	ISC1	ISC2	TSC3	fragile
	Base	0.01	0.01	1.24	0.19				
	Low	2.8E-03	0.02	0.18	0.41	BT4	TSS3	MAXED	
MAXL	High	-2.8E-03	0.02	-0.18	0.41	BT4	TSS3	MAXED	fragile
	Base	-0.01	0.01	-1.24	0.19				
	Low	-0.04	0.02	-1.92	0.43	ISC1	ISC2	TSC3	

Table 8
Extreme Bounds Analysis of Currency Union/Currency Board
Dependent Variable: Bilateral Correlation of Cyclic Output

M-Var.		b	Std. Error	t	R-sq		Z-Variables		Robust/ Fragile
Robustness Tests with No "Always-Included" Variables
CU	High	0.32	0.07	4.45	0.37	ISC1	TSC3	ADJ	fragile
	Base	0.08	0.03	2.90	0.17				
	Low	-0.20	0.12	-1.77	0.20	TT1	ISA1	MINED	
Robustness Tests with Gravity Variables Always Included
CU	High	0.32	0.08	4.17	0.45	ISC1	ISC2	TSC3	fragile
	Base	0.03	0.03	1.13	0.20				
	Low	-0.21	0.11	-1.82	0.23	TT1	ISA1	MINED	

Table 9
Extreme Bounds Analysis of Structure of Gravity Variables
Dependent Variable: Bilateral Correlation of Cyclic Output

M-Var.		β	Std. Error	t	R-sq	Z-Variables			Robust/ Fragile
Robustness Tests with No "Always-Included" Variables									
DIST	High	-2.3E-06	1.1E-06	-2.03	0.28	BT3	ISC2	MAXK	robust
	Base	-5.9E-06	8.6E-07	-6.87	0.17				
	Low	-1.3E-05	1.4E-06	-9.24	0.37	TSA2	TSA3	MINTL	
ADJ	High	0.23	0.03	7.58	0.37	TSA1	TSA3	MAXPOP	fragile
	Base	0.19	0.03	7.36	0.17				
	Low	0.05	0.05	1.02	0.26	BT2	ISA1	ISA2	
LANG	High	0.07	0.02	4.15	0.36	ISC1	TSC3	MAXTL	fragile
	Base	0.03	0.01	3.58	0.17				
	Low	-0.01	0.01	-0.58	0.29	BT2	ISA2	DIST	
MINPOP	High	0.05	0.02	2.94	0.37	TT1	ISC1	TSC3	fragile
	Base	-0.01	0.01	-1.15	0.17				
	Low	-0.04	0.01	-2.79	0.35	TSC3	MINGDP	MINTL	
MAXPOP	High	0.04	0.01	2.79	0.35	TSC3	MAXGDP	MAXTL	fragile
	Base	0.01	0.01	1.15	0.17				
	Low	-0.05	0.02	-2.94	0.37	TT1	ISC1	TSC3	
MINTL	High	0.02	0.01	1.87	0.36	TT1	ISC1	TSC3	fragile
	Base	-3.5E-03	0.01	-0.68	0.16				
	Low	-0.02	0.01	-1.70	0.40	ISA2	TSA3	MINL	
MAXTL	High	0.02	0.01	1.70	0.40	ISA2	TSA3	MAXL	fragile
	Base	3.5E-03	0.01	0.68	0.16				
	Low	-0.02	0.01	-1.87	0.36	TT1	ISC1	TSC3	
IND	High	0.29	0.03	11.56	0.41	TSS3	MINED	MINGDP	robust
	Base	0.25	0.02	13.65	0.20				
	Low	0.10	0.04	2.75	0.43	ISA1	ISA2	TSA3	
DEV	High	0.29	0.03	11.56	0.41	TSS3	MINED	MAXGDP	robust
	Base	0.25	0.02	13.65	0.20				
	Low	0.10	0.04	2.75	0.43	ISA1	ISA2	TSA3	

Figure 1: Bilateral Trade and Business Cycle Correlation

$y = 3.4991x + 0.0515$
$(0.2651) \quad (0.0036)$

$R^2 = 0.034$
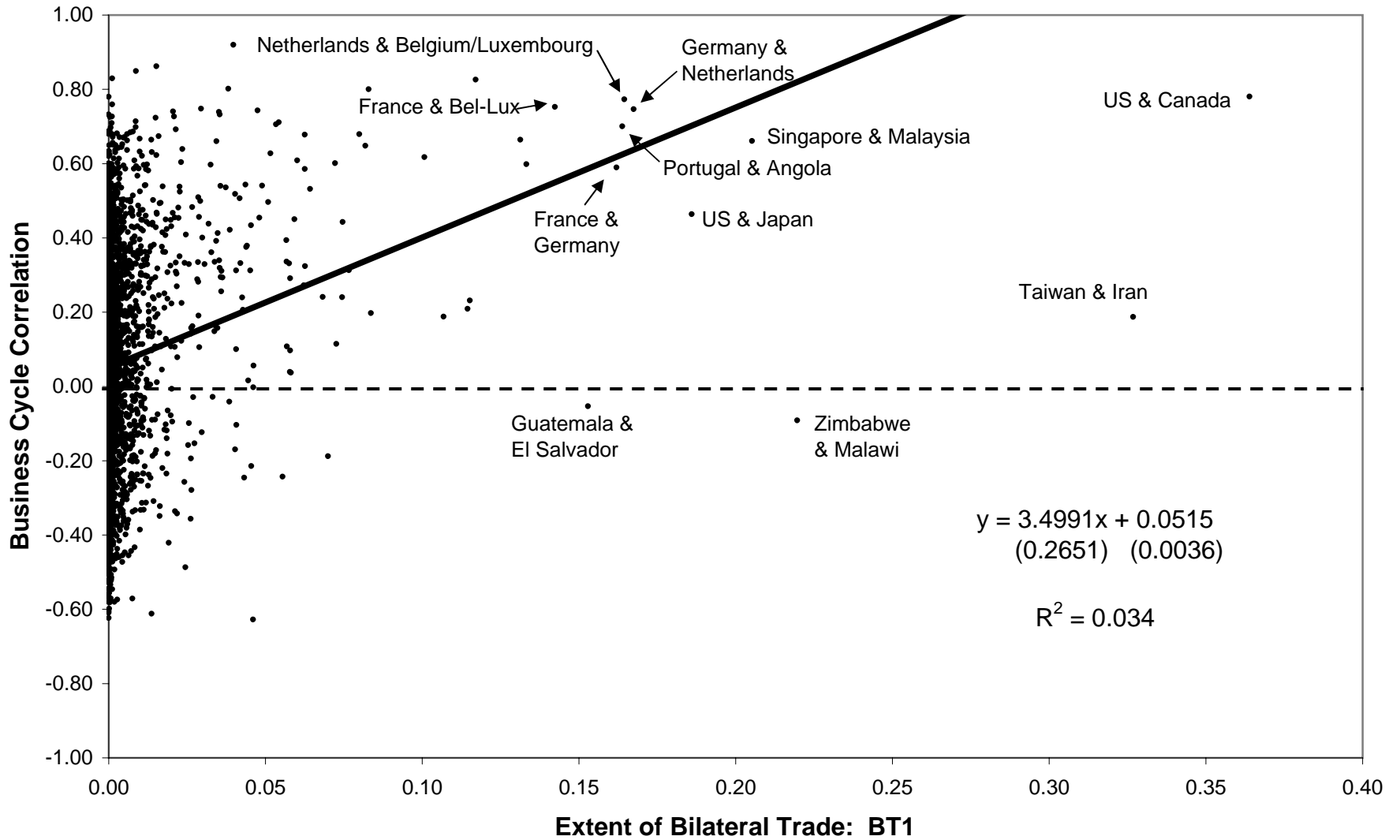
Figure 2: Total Trade and Business Cycle Correlation

$y = 0.1136x + 0.0395$
(0.0248) (0.0060)

$R^2 = 0.0042$

Business Cycle Correlation

Total Trade: TT1
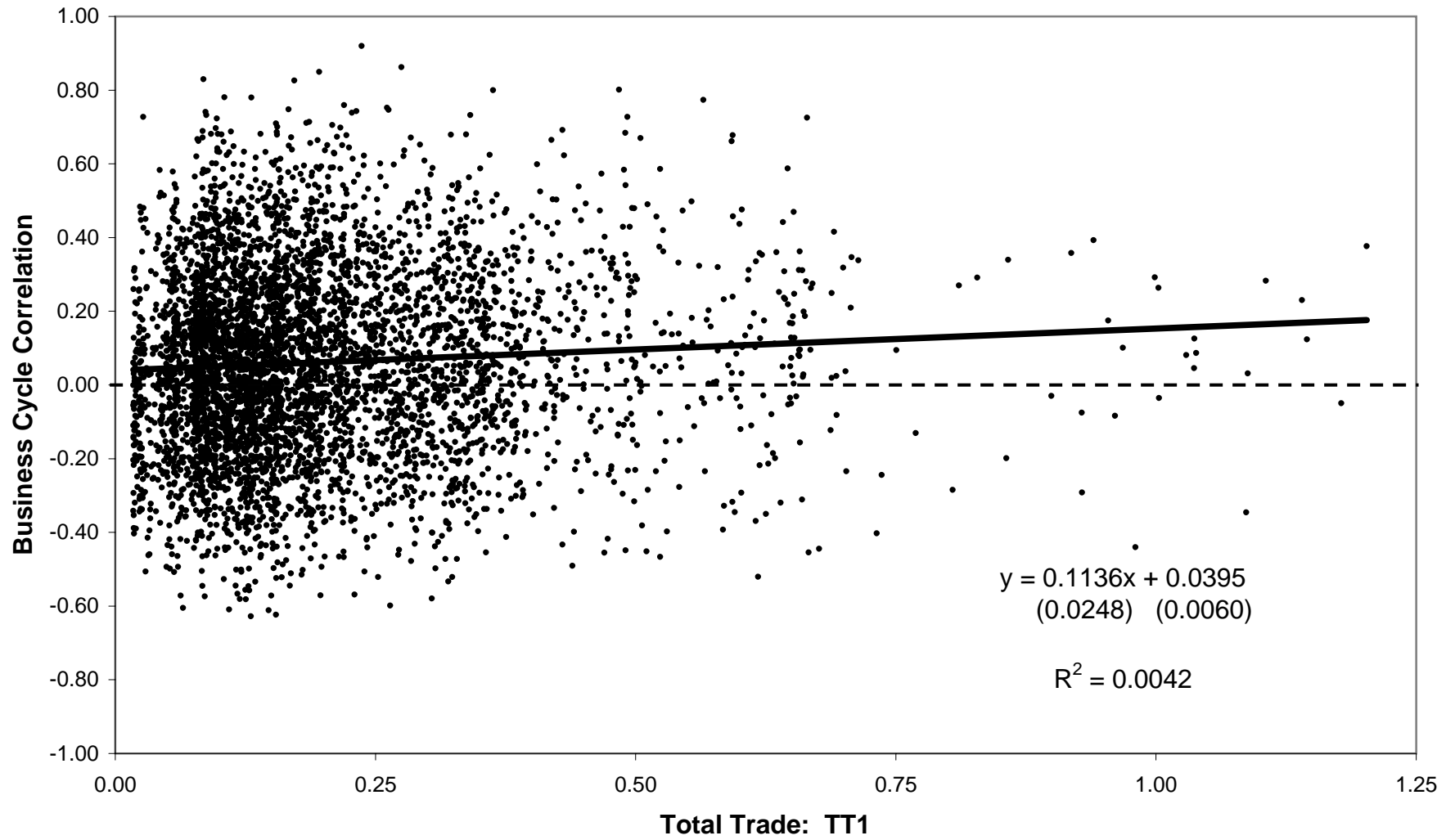
Figure 3: Industrial Similarity and Business Cycle Correlation

y = 0.1683x - 0.0841
(0.0258) (0.0210)

r2=0.0129

Business Cycle Correlation

Industrial Similarity: ISC1
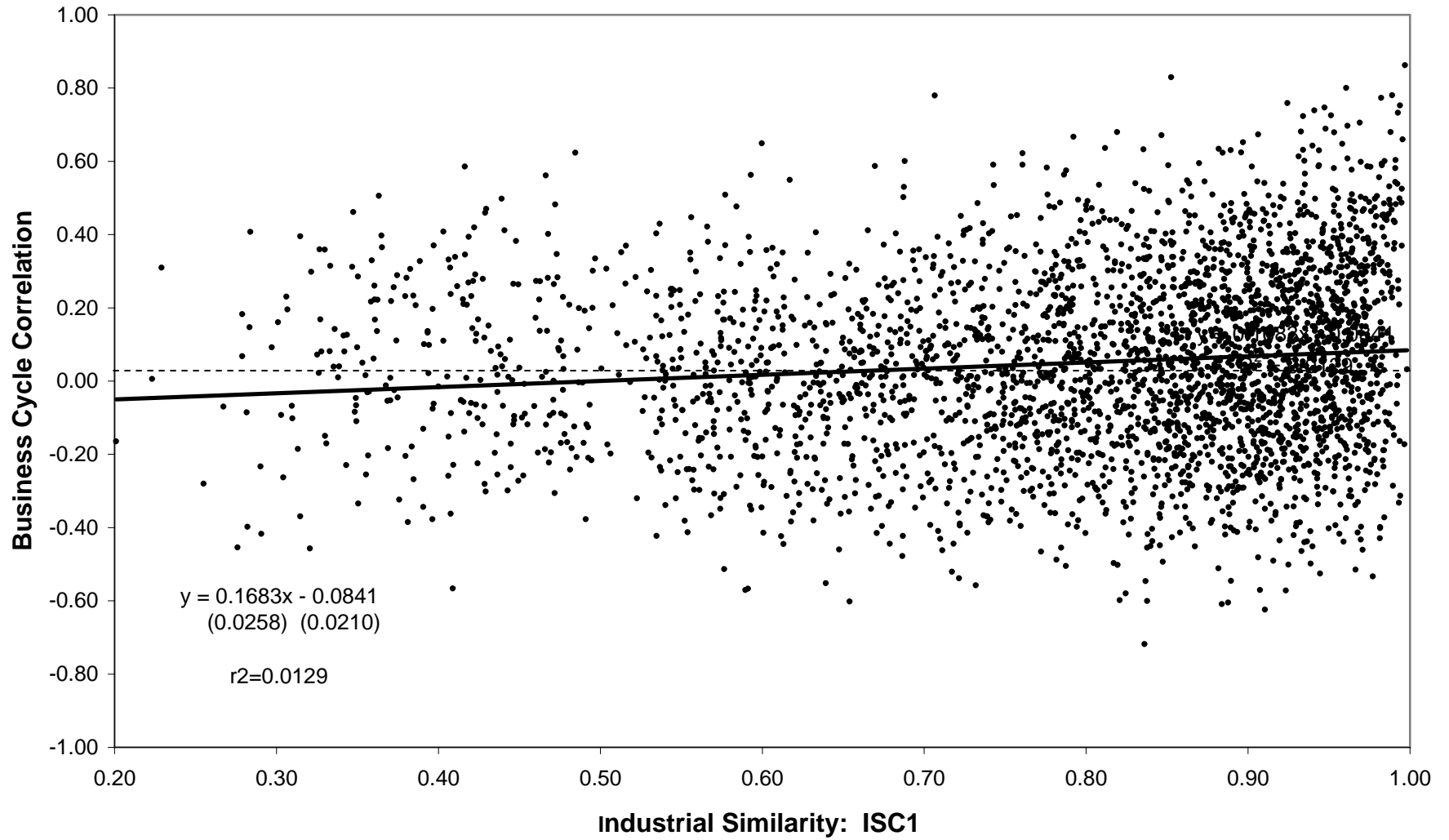
Figure 4: Similarity of Bilateral Trade and Business Cycle Correlation

$y = -0.0557x + 0.1290$
(0.0157) (0.0104)

$R^2 = 0.0058$
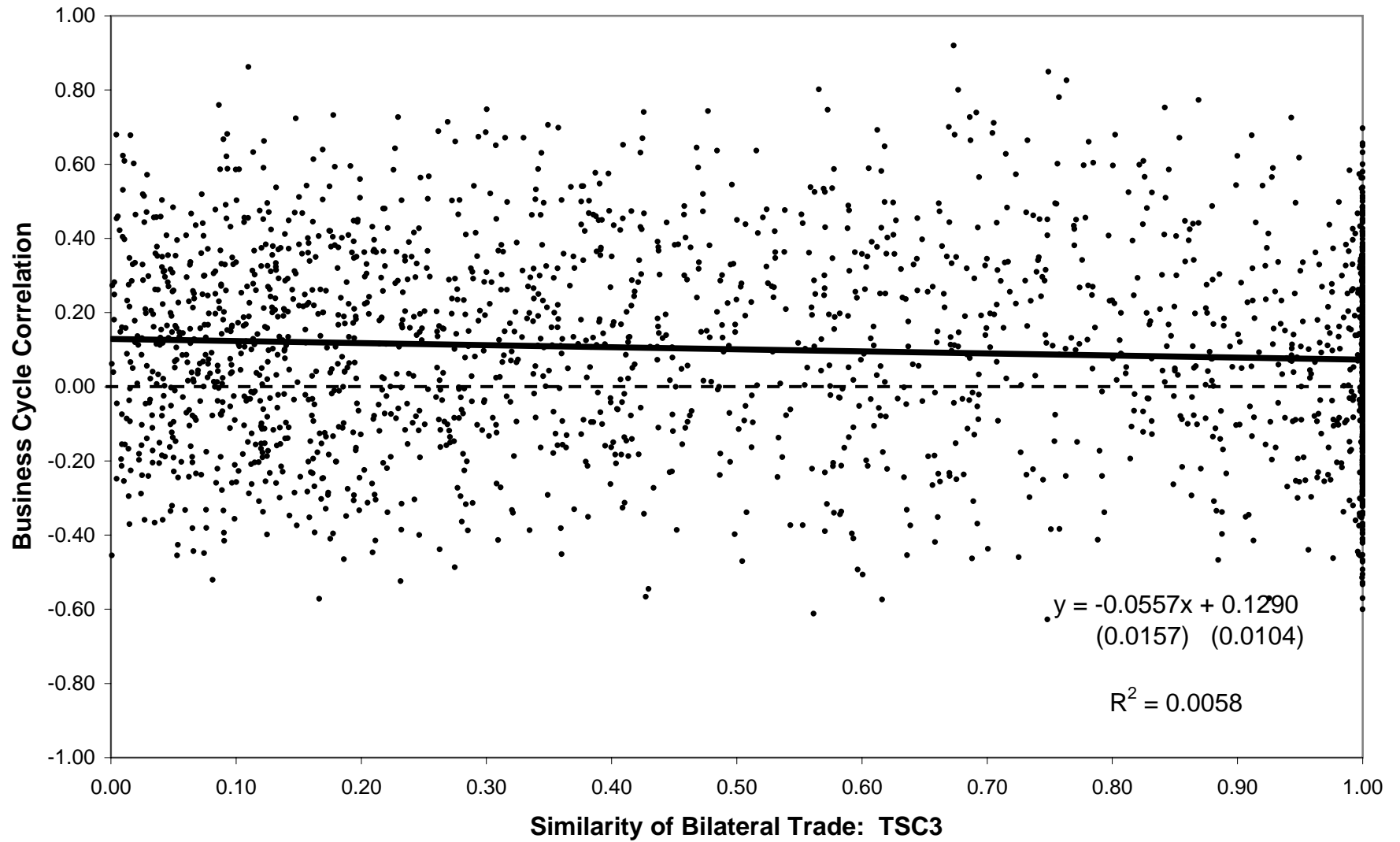
Figure 5: Minimum Education Level and Business Cycle Correlation

$y = 0.0905x - 0.0543$
(0.0070) (0.0095)

$R^2 = 0.0398$

Business Cycle Correlation

Minimum level of Human Capital: MINED
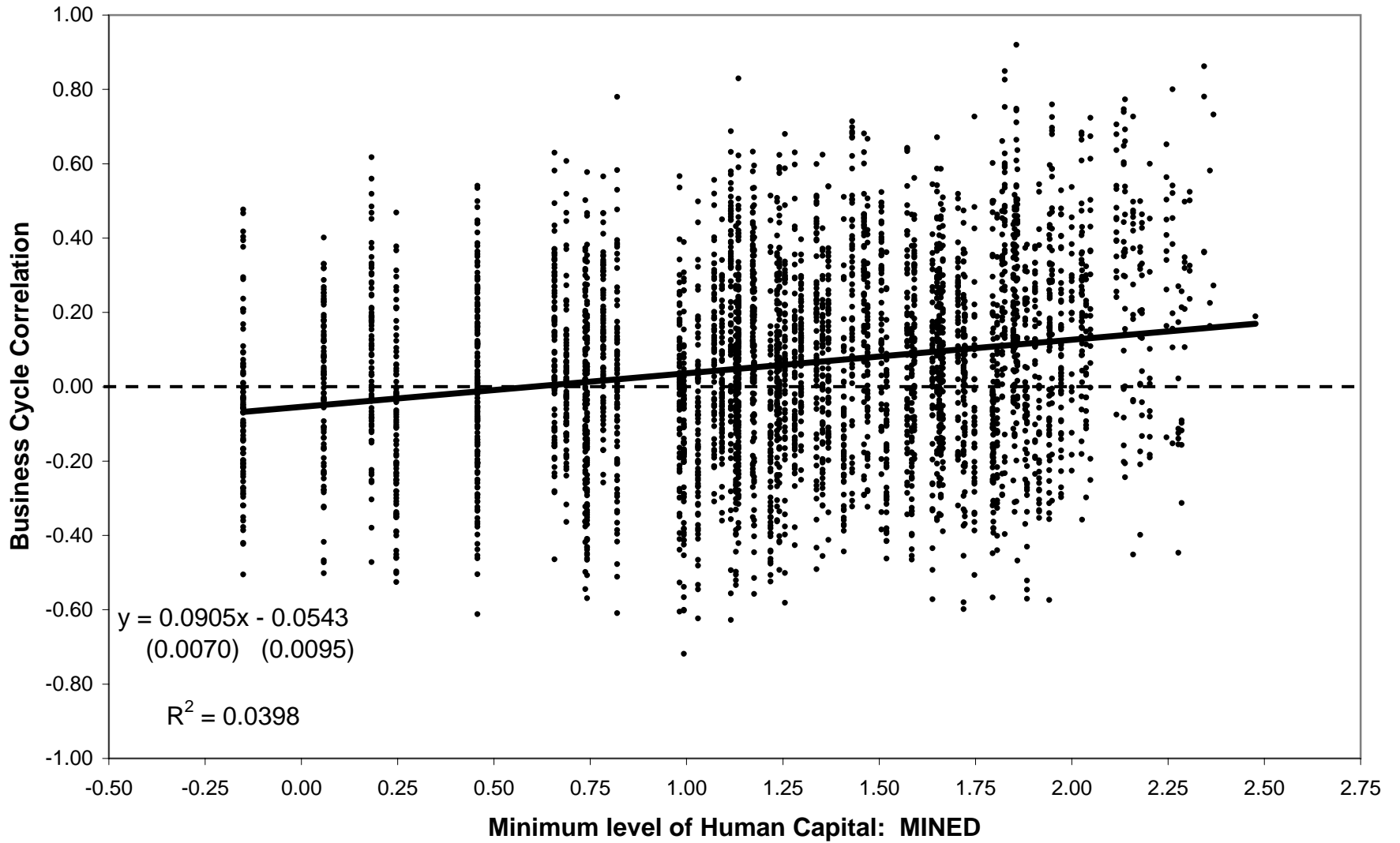
Figure 6:   Distance and Business Cycle Correlation

y = -3.28E-06x + 0.0777

(7.43E-07) (0.0068)

$R^2 = 0.0034$
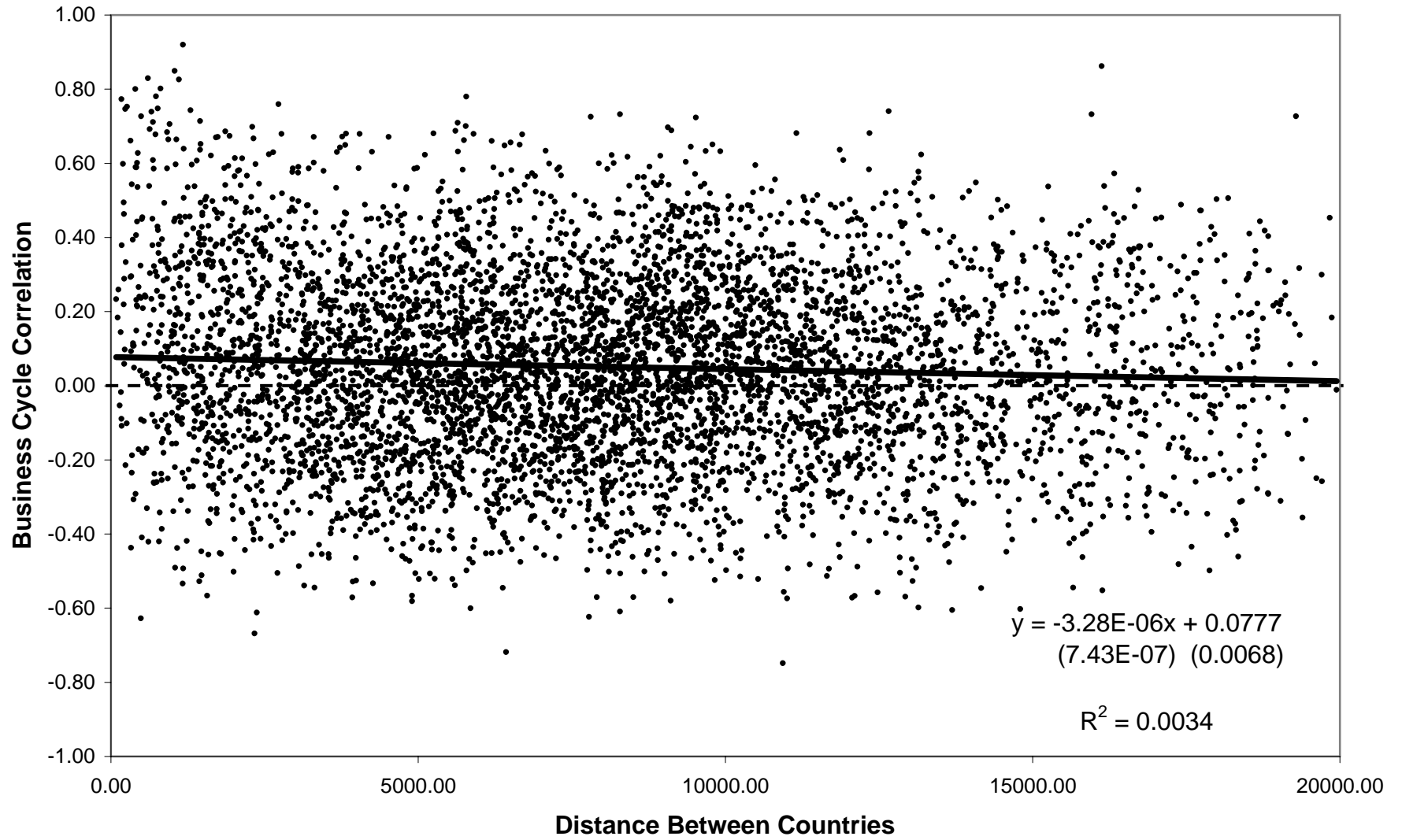
Comment on Baxter and Kouparitsas 's ``Determinants of Business Cycle Comovement: A Robust Analysis''*

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Abstract: Baxter and Kouparistas provide statistical evidence on the robust determinants of Business Cycle Comovement. They implement an original empirical method (*Extreme Bounds Analysis*) to the cross-countries correlation of the cyclical component of GDP. Their main findings are: bilateral trade is a robust explanatory variable but industrial structure and currency unions are not robust. In my discussion, I would essentially insist on two main limits of the empirical methodology adopted by the paper. First, the Extreme Bounds Analysis tells us nothing about the true determinants of Business Cycle Comovement, *i.e.* a robust variable is not necessary a causal variable and/or a causal variable is not necessary robust one. Second, there exists another statistical approach (*General to Specific*) that allows to better identifying the true economic determinants, as, with Extreme Bounds Analysis, nothing is robust!

Introduction

The research about the main determinants of Business Cycle Comovement (BCC, hereafter) has led to an enormous empirical literature. However, the reader will rapidly face a panel of empirical findings without any clear conclusions. Given the large number of potential candidates for an explanation of BCC, it becomes more and more difficult to determine the main mechanisms at work. Using an original empirical methodology, the paper of Baxter and Kouparistas delivers a clear answer to the question "*What are the main determinants of business cycle comovment?*". My comments will start with a brief summary of the paper. I will then describe the econometric methodology used y the authors and deliver my general excellent feelings about this contribution to international macroeconomics. I will then present some general comments about the econometric methodology adopted by this paper and then introduce a set of more specific comments.

A Brief Summary of the Paper

This paper proposes an empirical investigation on the main and robust determinants of BCC between countries (both developed and developing). When applied on BCC[1], this approach is really original as the paper tries to deliver a set of "*robust*" determinants of BCC. More precisely, the paper tries to determine a set of *robust explanatory variables* using the ``Extreme Bounds Analysis'' (EBA, hereafter) originally proposed by Leamer (1983). The paper also considers six main sets of variables: i) bilateral trade between countries, ii) total trade within counries, iii) sectoral structure, iv) trade similarity, v) factor endowments and vi) gravity variables. The main findings can be roughly summarized as follows: i) bilateral trade is a robust explanatory variable of BCC and ii) industrial structure and currency unions are not robust. These findings are interesting because they question previous empirical studies that conclude that similarity in industrial structure (Imbs (2003)) and currency unions would lead to more business cycle synchronization (Rose and Engle (2002)).

Econometric Methodology

In this section, I briefly present the econometric methodology adopted by this paper. EBA uses a linear equation of the form:

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[1] Levine and Renelt (1992) and Sala-i-Martin (1997) have already applied this method to cross-countries growth regressions.

$$Y = I\beta_I + M\beta_M + Z\beta_Z + u \qquad\qquad (1)$$

The dependent variable Y is the cross-correlations of the cyclical component of GDP for each country. The cyclical component is obtained from a Band Pass filter (see Baxter and King (1999)). The variable Y thus represents a vector of $N(N-1)/2$ cross-correlations. The independent variables are divided in three groups: I denote "always included variables"; M is the variable of interest, *i.e.* the variable that we want to evaluate the robustness; Z are all the other variables that previous studies have identified as important determinants of BCC. Given this simple linear equation, the EBA approach is conducted as follows:

i)   For M given, we modify Z and we perform a regression using OLS on (1),

ii)   We identify the highest and the lowest values for β_M that cannot be rejected at 5% level. EBA is thus defined as the maximum of β_M plus two standard deviations.

iii) M is a robust variable if the range of values for $\beta_M \in (\beta_{M,\min}, \beta_{M,\max})$ does not include zero.

The paper also enriches the linear equation (1) with considering a fixed effect for each country.

This study is an important and significant contribution to the empirical literature on the main determinants of BCC. The paper uses a large data set as 100 countries (both developed and developing) are considered (almost 5000 cross-correlations). The quantitative exercise is done carefully. This concerns the data construction and their use, the theoretical argumentation and the implementation of the quantitative method. More interestingly, the empirical results question some previous findings (industrial structure, currency unions) and clearly show what are the robust explanations of BCC. The paper provides a useful guidance for future works (both theoretical and empirical).

General Comments on the econometric method

My general comments point out some limits of the econometric method. More precisely, I first argue that EBA is not sufficiently informative about the true determinants of BCC and second that another approach (*General to Specific*) can provide better guidance concerning the choice of the main explanatory variables.

The meaning of robust variable

The basic idea of EBA is that an explanatory variable is robust if its parameter estimate does not present too much sensitivity to the presence or absence of other explanatory variables. When the two bounds are sufficiently close, the researcher can have some confidence in the parameter estimate. Sala-i-Martin (1997) argues that the use of EBA by Levine and Renelt (1992) is too strict and suggests modifying it such that the detection of robust variable is more permissive. Whatever the way the EBA is conducted, I think that the EBA cannot help the researcher to determine the true determinants of BCC. Is a robust variable necessary a causal variable? Or Is a causal variable necessary a robust variable? The EBA tells us nothing about this! In other words, there exists no reason to believe that a robust variable is necessary the true determinant of BCC and there is no reason to believe that a true determinant of BCC is necessary a robust variable! A true determinant of BCC is an explanatory variable whose variations imply predictable changes in the cross-countries correlation. EBA only produces some numbers and when some estimates do not appear too much sensitive to the presence or absence of other determinants of BCC, this variable is robust. But we see immediately, that a robust variable is not necessary the true one.

General to Specific Approach

There exists another (and less) restrictive approach, defined broadly as the *LSE methodology*. In the case of a linear equation, the *General to Specific* methodology starts with the idea that the truth can be represented by a regression that includes many variables, *i.e.* the general model. In comparison to equation (1), we specify a general model:

$$Y = \sum_{j=1}^{N} X_j \beta_j + \varepsilon , \qquad (2)$$

where X_j $(j=1,...,N)$ includes the variables *I*, *M* and *Z*. Equation (2) is equivalent to equation (1), except that it does not introduce *a priori* selection over the variables. Obviously, when a large number of explanatory variables are included in the regression, the general model tells us nothing about the key determinants of the endogenous variable. However, it is possible to determine a specific (and more parsimonious) model that allows selecting the main explanatory variables. In general, we consider that this specific regression is acceptable if (i)

it is determined from a set of restrictions consistent with the general model and (ii) it is well specified in a statistical sense. For example, this approach allows determining a specific regression of the form $Y = X_1\beta_1 + X_2\beta_2 + \varepsilon$. In this example, X_1 and X_2 are the main determinants of BCC.

Comparison of the two approaches

These two approaches are comparable as they are essentially descriptive. However, we can also assess their ability to select the true determinants of the endogenous variable. To my knowledge, there exist a recent study of Hoover and Perez (2004) that compares the relative performance of these two approaches in a controlled experiment. In the context of cross-countries growth regressions, Hoover and Perez have shown that the General to Specific approach performs better than the EBA used by Levine and Renelt (1992) and its modified version of Sala-i-Martin (1997). In their simulation experiments, Hoover and Perez have shown that with EBA nothing is robust! These results question the ability of EBA to select the main explanatory variables of BCC in the Baxter and Kouparistas'paper.

Specific Comments

My specific comments concern the implementation of EBA and the use of OLS regressions.

Stability and nonlinearity

The first look (unconditional regression) and EBA (sensitivity analysis in a conditional regression) assume a linear regression. Figures 1-6 (in appendix of the paper) presents strange clouds of points and also suggests many outliers. Is a non-linear model (stability over countries, thresholds effects, non--linear relation) is more suitable for the empirical analysis?

Endogeneity

The parameters in the linear equation are estimated using OLS, assuming implicitly that the explanatory variables are exogenous, *E(u I)=E(uM)=E(uZ)=0* One may easily think that many explanatory variables are endogenous!!! For example, an increase in the bilateral trade can be the consequence of higher business cycle comovement. In this case, OLS estimates are biased and thus we cannot conclude anything with EBA. I think that a simultaneous equation approach seems to be preferable. For example, the initial equation (1) can be supplemented with two additional equations:

$$Y = I\beta_I + M\beta_M + Z\beta_Z + u$$
$$M = I\gamma_I + v$$
$$Z = I\eta_I + w$$

In this system of equations, the variable I (always included variable) represents a set of weak exogenous variables, but the variables M and Z are not restricted to be exogenous.

Measurement errors

The paper considers measurement errors on the dependent variables (the cross-correlations of the cyclical component of GDP), but it does not consider that it may exist measurement errors in the explanatory variables (we can legitimately think that these constructed variables are subjected to measurement errors). In this case, OLS estimates are biased.

Data construction

Explanatory variables are constructed consistently with the sample of GDP. Some of them can be viewed as causal if they are constructed at the beginning of the sample period (see BT1 that use exports and imports in 1970). Other variables (constructed in the middle or at the end of the sample) can be in fact endogenous as they can react to a change in business cycle comovement during the period 1970-1995.

Sources of discrepancy

The possible sources of discrepancy with previous empirical findings are not discussed. For example, Imbs (2003) used quarterly data that cover the 80s and 90s in 24 countries. This gives rise to a cross-section of 276 bilateral correlations. Moreover, Imbs used a simultaneous equations approach, thus trade, specialization, integration are not considered *a priori* exogenous. Moreover, Frankel and Rose (2002) have estimated a positive and significant effect of currency union in a conditional regression framework. The main differences with the present paper are the following: the cyclical component of real GDP is obtained via a time trend and the use instrumental variable estimation. I think that much more effort can be made in order to clarify the sources of discrepancy.

Conclusion

The paper of Baxter and Kouparistas delivers a clear answer to the question "*What are the determinants of business cycle comovment?*" using the Extreme Bounds Analysis (having in

mind some important limits of this approach, especially if we compared to other empirical strategies). They find that bilateral trade is a robust determinant of Business Cycle Comovement. Conversely, industrial specialization as well as currency unions is not robust determinants. This paper represents an excellent reference for future (both theoretical and empirical) researches that aim at studying business cycle synchronization.

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ELECTORAL UNCERTAINTY, FISCAL POLICIES & GROWTH:
Theory and evidence from Germany, the UK and the US

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Abstract: In this paper we study the link between elections, fiscal policy and economic growth/fluctuations. The set-up is a dynamic stochastic general equilibrium model of growth and endogenously chosen fiscal policy, in which two political parties can alternate in power. The party in office chooses jointly how much to tax and how to allocate its total expenditure between public consumption and production services. The main theoretical prediction is that forward-looking incumbents, with uncertain prospects of re-election, find it optimal to follow relatively shortsighted fiscal policies, and that this lowers economic growth. The model is estimated using quarterly data for Germany, the UK and the US from 1960 to 1999. Our econometric results provide clear support for the main theoretical prediction. They also give plausible and significant estimates for the productivity of public production services, the weight which households place on public consumption services relative to private consumption and the time discount rate. Moreover, we find that changes in electoral uncertainty produce the longest lasting fluctuations in the European economies followed by the US.

Keywords: Political uncertainty, economic growth and fluctuations, optimal policy.
JEL classification numbers: D9, E6, H1, H5.

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1.   Introduction

Over the past forty years there is mounting evidence in most OECD economies suggesting both secular and cyclical changes in the composition of government expenditure in favor of public consumption at the expense of public investment.[1] Moreover, several authors (see e.g. Kneller *et al.* (1999), Alesina (1999) and Tanzi and Schuknecht (2000)) have suggested that these fiscal changes are possible contenders to explain lower than expected economic growth in recent decades. In an effort to provide one possible description of the process leading to the observed fiscal outcomes, we develop a dynamic stochastic general equilibrium model that examines the implications of electoral competition between incumbents and challengers for the choice of fiscal policies and in turn their impacts on aggregate growth and fluctuations.

The literature on elections, fiscal policy and economic growth is rich and still growing (very good surveys can be found in Alesina *et al.* (1997), Persson and Tabellini (1999) and Drazen (2000)). While there are several channels through which electoral uncertainty can affect policymakers' behavior,[2] a central result of the theoretical literature is that uncertainty about remaining in office pushes incumbent politicians to follow relatively short-sighted policies and engineer electoral business cycles, which in turn result in inefficient macroeconomic outcomes.[3] However, the econometric evidence to date is rather mixed. For instance, while there is some evidence of electoral effects on fiscal policy instruments, there is no evidence that this is translated into observed changes in macroeconomic activity (see Alesina *et al*. (1997, chapters 6 and 7) and Drazen (2000,

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[1] See e.g. Tanzi and Schuknecht (2000) and the references cited therein.

[2] See e.g. Drazen (2000, pp. 220-2) and Persson and Tabellini (1999, p. 1471) for a survey. More details will follow below.

[3] On the other hand, elections (or the fear of losing them) can work as a disciplinary device (see e.g. Drazen (2000, chapter 7.2)). For instance, they control the moral hazard of politicians, help voters to select the most competent politician, or help voters to select the policymaker whose ideology is closer to their own. Here,

chapters 7.3 and 11.6)).[4] More importantly, irrespective of the econometric results, there seems to be a gap between the theoretical literature and the final econometric specification. In particular, with few notable exceptions,[5] econometric estimations are based on simple autoregressive specifications in which various policy instruments and economic outcomes are regressed on lagged values, political dummies (e.g. election and partisan dummies) and measures of sociopolitical instability (e.g. government stability and regime changes). However, to more thoroughly evaluate the implications of electoral competition for economic policy and macroeconomic outcomes, it is important to formally identify the channel(s) through which electoral uncertainty affects policymakers' behavior.

To this end we construct and estimate a dynamic stochastic general equilibrium model of economic growth and endogenously chosen fiscal policy consisting of a private sector and two political parties. The private sector comprises a representative household and a representative firm. The household consumes, works and saves in the form of capital. The firm uses capital and labour to produce a single good. The political parties can alternate in power according to an exogenous stochastic reelection probability.[6] The party that wins the election forms a government that chooses economic policy during its term in office knowing that it might be out of the power in the future. It also plays non-cooperatively (Nash) vis-à-vis the out-of-power party. By economic policy, we mean here

following most of the related macroeconomics literature, we abstract from the benefits of electoral competition.

[4] Although there are several explanations for this (see Drazen (2000, pp. 244-6)), our reading of the literature is that this is still an open issue.

[5] Examples of papers which formally estimate theory-based models include: Alesina and Sachs (1988) for a partisan model of monetary policy for the US; Alogoskoufis *et al.* (1992) for a model of exchange-rate policy for the UK; and Lockwood *et al.* (1996) for a public-finance model for the UK.

[6] Assuming that re-election probabilities are endogenous (e.g. they depend also on the state of the economy) would not change our main theoretical results. More importantly, the assumption that reelection probabilities are exogenous is deliberate, i.e. we want to examine how electoral uncertainty affects policy choices and the macro-economy. Specifically, we will assume that the stochastic structure of our exogenous election process is first-order Markov. Dixit *et al.* (2000) assume a similar exogenous political process and provide empirical support. Note that this process reflects that there is persistence to political parties' popularity and competence (the realization of which determine the election outcome) across terms of office (see also e.g. Drazen (2000, p. 270 and p. 276) and Price and Sanders (1994) for the UK).

the income tax rate and the allocation of total tax revenues between public consumption

services (which provide direct utility to households) and public production services (which

provide production externalities to private firms and hence generate Barro (1990)-type

long-term growth). We solve for Markov policy strategies, and hence a Markov-perfect

general equilibrium, in which optimal decisions depend on the game's current position.

An advantage of our modeling framework is that it allows us to distinguish the effects of

electoral uncertainty upon economic policy from its effects upon macroeconomic outcomes

in a unified general equilibrium setting.[7] Another advantage is that it allows us to obtain

an explicit analytical solution for the general equilibrium, so that the model is easy to

interpret, tractable and useful for formal econometric estimation.[8]

Our main theoretical prediction is as follows. When the expected probability of

being re-elected decreases, the total government expenditure-to-output ratio (and the

associated tax burden) increases, while the share of tax revenue used to finance public

production services decreases. Both fiscal policy instruments work in the same direction,

so that - in general equilibrium - a lower re-election probability leads to lower economic

growth. Intuitively, when there is electoral uncertainty and the political parties do not care

(or care relatively little) about the economy when out of power, they effectively face a

quasi-finite time horizon.[9] The higher the electoral uncertainty (i.e. the smaller the

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[7] As Drazen (2000, p. 517) points out, it is necessary to estimate jointly the so-called "political" mechanism (the effect of socio-economic variables on the choice of policy instruments) and the so-called "economic" mechanism (the effect of policy instruments on macroeconomic outcomes).

[8] See e.g. Campbell (1994) for the advantages of analytical solutions especially in growth models.

[9] The mechanism is as in Lockwood *et al.* (1996). See Persson and Tabellini (1999, p. 1471) for a survey of the related literature, namely how electoral uncertainty induces more "myopic" fiscal policies. Economides *et al.* (2003) have shown that, only if there are extra rents from being in power *per se*, the parties find it optimal to care relatively more about economic outcomes when in power, and it is this that generates typical electoral cycles. Note that this mechanism is somewhat different from e.g. Rogoff and Sibert (1988) and Rogoff (1990) where the incumbent government manipulates policy instruments in an attempt to increase its re-election probability. It is also distinct from e.g. Persson and Svensson (1989) and Alesina and Tabellini (1990) where the incumbent government uses strategically the state variables (e.g. public debt) to reduce the choices of its successor. For a clear survey, see Drazen (2000, pp. 220-2).

probability of being re-elected), the less they care about the future. As a result, they choose shortsighted, inefficient policies.[10]

In our econometric work, we estimate the general equilibrium model by using quarterly data for Germany, the UK and the US over the period 1960 to 1999. To this end, we employ constrained maximum likelihood using the Kalman filter. In contrast to the calibration exercises conducted in the RBC literature, estimation of the model's structural parameters not only allows us to assess their individual significance, but also to undertake dynamic inference when conducting the impulse response analysis. Our econometric results provide clear support for the main theoretical proposition. Namely, in all three countries, electoral competition pushes governments to follow short-sighted, inefficient fiscal policies (in the form of a high tax burden and a preference for non-productive activities with short-term benefits) and this is in turn detrimental for the macro-economy.

Our main numerical results are as follows. The productivity of public production services relative to private capital is highest in Germany (0.309) followed by the US (0.279) and the UK (0.270). The estimates for the weight given to public consumption services relative to private consumption are 0.385, 0.475 and 0.600 for the US, Germany and the UK respectively. The estimates for the time discount rate are 0.954, 0.978 and 0.986 for the US, Germany and the UK respectively. Finally, persistence of political uncertainty is greatest in the UK (0.961), followed by Germany (0.918) and the US (0.889). The latter finding appears to be in line with business cycle stylised facts, i.e. the US cycle is the shortest followed by Germany and the UK (see, e.g., Zarnowitz (1992) and Woitek (1996)).

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[10] Svensson (1998) obtains a similar prediction in a model in which political instability pushes rational incumbents to under-invest in legal infrastructure, resulting in weak property rights and low investment.

The rest of the paper is organized as follows. Section 2 presents the theoretical model. Section 3 summarizes the data and the econometric methods employed. Empirical results are presented in Section 4, while Section 5 contains our conclusions. Finally, algebraic details pertaining to the model are gathered in the Appendices.

2.   The Theoretical Model

In this section, we solve for the optimal decisions of households, firms and political parties. The (Markov-perfect) general equilibrium solution will consist of a system of log-linear dynamic equations, which jointly specify the paths of private consumption, private investment, government consumption and production services, the tax burden and the share of tax revenues allocated to government production relative to government consumption services. That solution will be in terms of the predetermined capital stock and the expected values of exogenous electoral uncertainty. The underlying setup is a two-party variant of Barro's (1990) well-known model of long-term growth and optimally chosen fiscal policy.[11] The other difference is that here there are also public consumption services so that the incumbent party also chooses the allocation of total tax revenues between production and consumption services.[12]

2.1   Definition of equilibrium and how we are going to work

The time horizon is infinite. For simplicity, we assume that elections are held every time period. In each period t, the sequence of events is as follows: first, current uncertainty is resolved; in turn, the in-power political party chooses economic policy

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[11] See also e.g. Barro and Sala-i-Martin (1995, chapter 4) and Glomm and Ravikumar (1994, 1997). Benhabib *et al.* (2001) focus on the properties of optimal fiscal policy in this model.
[12] See also Park and Philippopoulos (2003, 2004) for growth models in which the government chooses the allocation of tax revenues to different activities (e.g. public investment, public consumption and redistributive transfers). However, these models assume a single benevolent government that chooses Ramsey-type optimal open loop policies.

during its term in office; finally, private agents make their allocation decisions.[13] We will solve the problem by backward induction: within each t, we will first solve the private agents' optimization problem for any feasible economic policy; in turn, we will endogenize economic policy by solving the political parties' optimization problem.

We will solve the optimization problems of private agents and political parties by using the method of dynamic programming. The solution will give Markov policy strategies and hence a Markov-perfect general equilibrium.[14] Thus, optimal policies will be subgame perfect and time consistent. Further, when we form a non-cooperative game between the political parties, the parties' Markov policy strategies will be a Nash equilibrium of that game.[15]

When exact analytical solutions cannot be obtained, we will use first-order Taylor approximations around the non-stochastic long-run values of the relevant exogenous variables. Specifically, this will enable us to obtain approximate closed-form analytical solutions for the value functions in the dynamic programming problems of private agents and political parties. Campbell and Viceira (2002, chapter 5) use a similar type of approximation to solve the Bellman equation in dynamic asset pricing models.[16] These approximations will hold in expected value - a certainty equivalence property.

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[13] Thus, all decisions are made after the current uncertainty is resolved, so that all economic agents can choose directly the value of next period's state variables. This makes the solution to the dynamic programming problem simpler, see e.g. Stokey and Lucas (1989, p. 240).

[14] Following Fudenberg and Tirole (1991, pp. 513-5), a Markov perfect equilibrium is defined to be a profile of optimal strategies that are a sub-game perfect equilibrium and depend on the current state of the game only. Specifically, optimal strategies depend only on the set of state variables that are payoff-relevant, i.e. they directly affect the current payoff function. As is known, Markov strategies are without memory.

[15] See also Ljungqvist and Sargent (2000, chapter 6) for examples of what they call "Nash-Markov perfect equilibria". See below for details.

[16] As Campbell and Viceira (2002, chapter 5) explain, this is the same type of approximation used in e.g. Campbell (1993), but instead of using it to linearize the budget constraint, here we use it to solve the Bellman equation. Campbell and Viceira also discuss how various authors have suggested different approximate analytical solutions for the Bellman equation.

2.2 Behavior of households

The representative household maximizes intertemporal utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t) \tag{1a}$$

where c_t and h_t are respectively private consumption and public consumption services at time t, $0 < \beta < 1$ is the discount rate, and E_t denotes the mathematical expectation conditional on information known at t. At time t, current and past values of all variables are assumed to be known. For simplicity, the utility function $u(.)$ is additively separable and logarithmic:

$$u(c_t, h_t) = \log c_t + \delta \log h_t \tag{1b}$$

where $0 \leq \delta \leq 1$ is the weight given to public consumption relative to private consumption.

At time t, the household rents its predetermined capital, k_t, to the firm and receives $r_t k_t$, where r_t is the market return to capital. It also supplies inelastically one unit of labor services per time-period so that the labor income is w_t. Further, it receives profits, π_t. Thus, the household's budget constraint is:

$$k_{t+1} + c_t = (1 - \theta_t)(r_t k_t + w_t + \pi_t) \tag{2}$$

where k_{t+1} is the end-of-period capital stock and $0 < \theta_t < 1$ is the income tax rate. For simplicity, we assume full capital depreciation (implying that the end-of-period capital stock is equal to investment). The initial capital stock, k_0, is given.

The household acts competitively by taking prices, tax policy and public services as given. From the household's viewpoint, the state variables at time t are the predetermined capital stock, k_t, and current economic policy. As is shown below, the independent economic policy instruments at any t are the income tax rate, θ_t, and the share of total tax

revenue used to finance public production services, b_t. Therefore, let $V(k_t; \theta_t, b_t)$ denote the value function of the household at any t.[17] This function satisfies the Bellman equation:

$$V(k_t; \theta_t, b_t) = \max_{c_t, k_{t+1}} \left[\log c_t + \delta \log h_t + \beta E_t V(k_{t+1}; \theta_{t+1}, b_{t+1}) \right]. \tag{3}$$

Using (2) for c_t into (3), the first-order condition for k_{t+1} and the envelope condition for k_t are respectively:[18]

$$\frac{1}{c_t} = \beta E_t V_k(k_{t+1}; \theta_{t+1}, b_{t+1}) \tag{4a}$$

$$V_k(k_t; \theta_t, b_t) = \frac{(1 - \theta_t) r_t}{c_t}. \tag{4b}$$

2.3   Behavior of firms

As in the literature introduced by Barro (1990), we assume that public services provide production externalities to private firms. We also assume that technology at the firm's level takes a Cobb-Douglas form.[19] Thus, the production function of the representative firm is:

$$y_t = A k_t^{\alpha} l_t^{1-\alpha} g_t^{1-\alpha} \tag{5}$$

where l_t is the labor input at t, g_t is public production services at t, $A > 0$ and $0 < \alpha < 1$ (we assume that aggregate productivity, A, is constant so as to focus on growth and fluctuations driven by electoral uncertainty).

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[17] As is known, with logarithmic preferences, Cobb-Douglas constraints and full depreciation, explicit closed-form solutions for the optimal controls, c_t and k_{t+1}, can be easily obtained by assuming that controls are time-invariant functions of the current state and using these conjectures into the Euler equation (see e.g. McCallum (1989, pp. 21-22)). Here, we choose to use dynamic programming to cope with any possible complications arising from the presence of the exogenous (from the viewpoint of private agents) stochastic policy instruments, θ_t and b_t. It is easy to show that the solutions for c_t and k_{t+1} (see (10a)-(10b) below) are the same independently of the solution technique. On the other hand, here we also obtain an approximate solution for the value function in (3) (details will be given in Appendix A).

[18] Equations (4a)-(4b) combined give the familiar Euler equation, $\dfrac{1}{c_t} = \beta E_t \left[\dfrac{(1 - \theta_{t+1}) r_{t+1}}{c_{t+1}} \right]$.

The firm maximizes profits, π_t, given by:

$$\pi_t \equiv y_t - r_t k_t - w_t l_t. \tag{6}$$

The firm also acts competitively by taking prices and public services as given. The first-order conditions, that also imply zero profits, are simply:

$$r_t = \frac{\alpha y_t}{k_t} \tag{7a}$$

$$w_t = \frac{(1-\alpha) y_t}{l_t}. \tag{7b}$$

2.4 Government budget constraint

At each time t, the government runs a balanced budget by taxing the household's income at a rate $0 < \theta_t < 1$.[20] Thus,

$$h_t + g_t = \theta_t \left(r_t k_t + w_t + \pi_t \right). \tag{8a}$$

Without loss of generality, we assume that a share $0 < b_t < 1$ of total tax revenues finances public production services, g_t, and the rest $0 < (1 - b_t) < 1$ finances public consumption services, h_t. Thus, (8a) is decomposed into:

$$g_t = b_t \theta_t \left(r_t k_t + w_t + \pi_t \right) \tag{8b}$$

$$h_t = (1 - b_t) \theta_t \left(r_t k_t + w_t + \pi_t \right) \tag{8c}$$

where inspection of (8a)-(8c) reveals that θ_t and b_t can summarize fiscal policy at t.

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[19] The firm is modeled as in Barro and Sala-i-Martin (1995, chapter 4).

[20] For simplicity, there is no public debt in the model since adding one more state variable would not change our main results (see e.g. Devereux and Wen (1998) who employ a similar setup). RBC papers that also omit public debt include Baxter and King (1993), McGrattan (1994), Ambler and Paquet (1996) and Klein, Quadrini and Rios-Rull (2003). Finally note that in a public finance model including debt, Lockwood *et al.* (1996) have shown that short-sighted fiscal policies - driven by electoral uncertainty - are also reflected into over-accumulation of public debt.

2.5 Competitive decentralized equilibrium (for given economic policy)

Given the time-path of economic policy $\{\theta_t, b_t\}_{t=0}^{\infty}$, a competitive decentralized equilibrium (CDE) is defined to be a sequence of allocations $\{k_{t+1}, c_t, h_t, g_t\}_{t=0}^{\infty}$ and prices $\{r_t, w_t\}_{t=0}^{\infty}$ such that: (i) households maximize utility and firms maximize profits by taking prices, policy and public services as given; (ii) all budget constraints are satisfied; (iii) all markets clear.[21] This CDE is described by equations (1)-(8) above. The rest of this subsection will take advantage of the specific functional forms used to obtain a convenient closed-form solution for the CDE.

Consider the economy-wide output. Using (7a), (7b) and (8b) into (5), we find:

$$y_t = r_t k_t + w_t + \pi_t = A^{\frac{1}{\alpha}} (b_t \theta_t)^{\frac{1-\alpha}{\alpha}} k_t \tag{9}$$

which shows that the model is a variant of the linear AK model. As in e.g. Barro (1990), the coefficient "A" is a function of policy instruments.[22]

Then, Appendix A shows:[23]

Result 1: *In a competitive decentralized equilibrium (for any feasible Markov economic policy), optimal private consumption and capital accumulation are:*

$$c_t = (1 - \alpha\beta) A^{\frac{1}{\alpha}} (1 - \theta_t)(b_t \theta_t)^{\frac{1-\alpha}{\alpha}} k_t \tag{10a}$$

$$k_{t+1} = \alpha\beta A^{\frac{1}{\alpha}} (1 - \theta_t)(b_t \theta_t)^{\frac{1-\alpha}{\alpha}} k_t. \tag{10b}$$

---

[21] In the labor market, the market-clearing condition is $l_t = 1$.

[22] Using (9) into (7a), we obtain $r_t = \alpha A^{\frac{1}{\alpha}} (b_t \theta_t)^{\frac{1-\alpha}{\alpha}}$, which is the return to capital that drives private decisions. On the other hand, (9) implies that the social return to capital is $\frac{\partial y_t}{\partial k_t} = A^{\frac{1}{\alpha}} (b_t \theta_t)^{\frac{1-\alpha}{\alpha}}$. Since $0 < \alpha < 1$, the social return to capital exceeds the perceived or private return. Thus, under production externalities, the decentralized growth rate is inefficiently low.

[23] As Appendix A shows, by taking first-order Taylor approximations around the long-run values of the exogenous variables, θ_t and b_t, we can also obtain an approximate solution for the value function in (3).

It is also useful for what we do next, to write the solutions for the two types of public services, g_t and h_t, in a CDE. Using (9), (8b) and (8c) become respectively:

$$g_t = (Ab_t\theta_t)^{\frac{1}{\alpha}} k_t \tag{10c}$$

$$h_t = (1-b_t)b_t^{\frac{1-\alpha}{\alpha}} A^{\frac{1}{\alpha}}\theta_t^{\frac{1}{\alpha}} k_t . \tag{10d}$$

To summarize results so far, equations (10a), (10b), (10c) and (10d) give c_t, k_{t+1}, g_t and h_t respectively in a CDE. This is a function of the predetermined capital stock, k_t, and the current policy instruments, θ_t and b_t, only. The next subsection will endogenize the choice of θ_t and b_t.[24]

Before we move on to choose economic policy, notice two features of the CDE. First, (10b) implies that the sign of $\frac{\partial k_{t+1}}{\partial \theta_t}$ is the sign of $(1-\alpha-\theta_t)$. If $(1-\alpha-\theta_t) > 0$, k_{t+1} increases with θ_t; if $(1-\alpha-\theta_t) < 0$, k_{t+1} decreases with θ_t. Thus, the effect of the tax rate on the growth rate is an inverse U-curve, as in Barro (1990).[25] Second, (10b) implies $\frac{\partial k_{t+1}}{\partial b_t} > 0$. Thus, a higher share of tax revenues used to finance public production services relative to public consumption services stimulates *ceteris paribus* economic growth monotonically.

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[24] Here we do not model voting behavior. We also assume that private agents are indifferent over which party wins the election (this is not restrictive because we will solve for symmetric equilibria). All this means that elections can affect the CDE only indirectly via the choice of economic policy, θ_t and b_t. This is deliberate since our focus is on the implications of electoral uncertainty. For voting behavior, see e.g. Persson and Tabellini (2000, chapter 4.5).

[25] Intuitively, when the tax rate is initially low, any marginal increase will lead to higher tax revenues and higher public production services which increase the productivity of private capital; this more than offsets the distortionary effect of higher taxation. The opposite happens when the tax rate is initially high.

2.6   *The electoral system, political parties and definition of political equilibrium*

To endogenize economic policy, we form a non-cooperative (Nash) game between two political parties, denoted by i and j, which alternate in power according to an exogenous stochastic reelection probability.[26] Specifically, if elections take place in each time-period, we assume that the party in power at t has a probability $0 \leq q_{t+1} \leq 1$ of winning the next election and remaining in power at $t+1$, and a probability $(1-q_{t+1})$ of losing the election and being out of power at $t+1$. In other words, q_{t+1} denotes the probability that the incumbent wins the election.

To specify the motion of q_{t+1} we assume that it follows an exogenous first order autoregressive process. Thus,

$$q_{t+1} = q_0 + \rho q_t + \varepsilon_{t+1} \tag{11}$$

where $q_0 > 0$ is a constant, $0 < \rho < 1$ is the autoregressive parameter, ε_t is $IID(0,\sigma^2)$ and $0 \leq q_t \leq 1$ for all t.[27] That is, q_t is a non-negative stochastic variable that is bounded from above with probability 1.

Given the above, a political general equilibrium is defined as follows: (i) The elected party i chooses θ_t and b_t to maximize the utility of the representative household

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[26] Assuming that re-election probabilities depend also on the state of the economy would not change our main theoretical results. For instance, assume that the reelection probability is a positive function of recent economic growth. This would give an incentive to the incumbent party to follow more long-sighted policies (so as to stimulate growth and increase its chances of reelection) than in the case in which the reelection probability is exogenous. However, it would still be the case that, since the reelection probability is less than one, policies are less long-sighted than in the case without electoral uncertainty.

[27] We include a constant, $q_0 > 0$, since otherwise the mean of q_t would be zero, which is counter intuitive in the case of reelection probabilities given that electoral uncertainty is always present. Also note that the autoregressive process we have chosen is consistent with previous empirical studies. For instance, when Price and Sanders (1994) examine the determinants of government popularity in post-war Britain, they find evidence of substantial history-dependence in popularity. Finally, note that while the theoretical model can be solved using higher order processes for q, we find in our econometric estimation below that only first order terms are significant. To preserve space, these results are not reported here but will be made available upon request.

in (1a)-(1b) subject to the CDE summarized by (10a)-(10d), and by taking as given the policy of the other party, $j \neq i$, which may be in power at $t+1$. That is, the in-power party plays Nash *vis-a-vis* the out-of-power party. The out-of-power party takes no action until it wins an election. (ii) We solve for Markov policy strategies, i.e. θ_t and b_t can be functions of the current state of the game. (iii) We solve for a symmetric Nash equilibrium in Markov policy strategies, i.e. parties' policies will be symmetric *ex post*.[28] (iv) We assume that political parties do not care about the economy when out of power. Implicit here is the assumption that they earn extra rents when in power.[29] (v) The solution for θ_t and b_t, in combination with the CDE above, will give a Markov-perfect political general equilibrium.

2.7   Problem formulation and chosen fiscal policies

Recall that all current and past values are known at the beginning of t. Then, from the political parties' viewpoint, the state variables at t are the economy's inherited capital stock k_t, and the current value of the exogenous $AR(1)$ shock, q_t.[30] Therefore, let $V^{P_i}(k_t; q_t)$ and $V^{N_i}(k_t; q_t)$ denote the value functions of party i at time t when in power and when out of power respectively (party j's problem is symmetric). These value functions must satisfy the following pair of Bellman equations:[31]

$$V^{P_i}(k_t; q_t) = \max_{\theta_t^i, b_t^i} \left[\log c_t + \delta \log h_t + \beta E_t \left[q_{t+1} V^{P_i}(k_{t+1}; q_{t+1}) + (1 - q_{t+1}) V^{N_i}(k_{t+1}; q_{t+1}) \right] \right] \quad (12a)$$

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[28] Thus, there are no partisan effects. Here, the focus is on the effects of electoral uncertainty. Note that partisan effects do not have a persistent impact on growth [for evidence, see e.g. Alesina *et al*. (1997)].

[29] This is for simplicity. Our results do not change if we assume that parties care less about the economy when out of power than when in power. See Economides *et al*. (2003) for the micro-economic determinants of these political preferences in a similar setup. See also Lockwood *et al*. (1996) for references from the political science literature that support this approach.

[30] Since k_t and q_t are the payoff-relevant state variables, this selection of state variables is consistent with the definition of Markov strategies (see also Appendix B).

[31] See Alesina and Tabellini (1990) and Lockwood *et al*. (1996) for a similar approach.

$$V^{N_i}(k_t;q_t) = \left[0 + \beta E_t \left[(1-q_{t+1})V^{P_i}(k_{t+1};q_{t+1}) + q_{t+1}V^{N_i}(k_{t+1};q_{t+1})\right]\right] \tag{12b}$$

where c_t, k_{t+1} and h_t follow (10a), (10b) and (10d) respectively. Notice that in (12a), the incumbent has a probability q_{t+1} of remaining in power, and a probability $(1-q_{t+1})$ of losing the coming election. In (12b), the party out of power knows that there is a probability q_{t+1} of continuing to be out of power and a probability $(1-q_{t+1})$ of coming back to power in the next election. When out of power, parties do not care about macro outcomes; hence the zero term on the right hand side of (12b). In (12a), all policy instruments are chosen by the incumbent party i, while in (12b) all policy instruments are those of party j since party i is out of power.[32] Finally, notice that the optimization problem in (12a)-(12b) has a recursive structure.[33]

Then, Appendix B shows:[34]

Result 2: *In a Markov-perfect general equilibrium of a symmetric Nash game between the political parties, the income tax rate, θ_t, and the share of total tax revenues used to finance public production services, b_t, are equal to:*

$$1-\alpha < \theta_t = \frac{\delta + (1-\alpha)E_t\Omega_{t+1}}{\delta + E_t\Omega_{t+1}} < 1 \tag{13a}$$

$$1-\alpha < b_t = \frac{(1-\alpha)(\delta + E_t\Omega_{t+1})}{\delta + (1-\alpha)E_t\Omega_{t+1}} < 1 \tag{13b}$$

---

[32] That is, in (12a) $k_{t+1} = \alpha\beta A^{\frac{1}{\alpha}}\left(1-\theta_t^i\right)\left(b_t^i\theta_t^i\right)^{\frac{1-\alpha}{\alpha}}k_t$ because party i has been in power at t, while in (12b) $k_{t+1} = \alpha\beta A^{\frac{1}{\alpha}}\left(1-\theta_t^j\right)\left(b_t^j\theta_t^j\right)^{\frac{1-\alpha}{\alpha}}k_t$ because party j has been in power at t.

[33] It is recursive in the sense that, given the other party's policy choices, current policy choices affect returns dated t and later but not earlier (see Sargent (1987)). In a recursive formulation, optimal policies are time consistent (see also Ljungqvist and Sargent (2000)).

[34] As before, to obtain closed-form analytical solutions for the value functions defined in (12a)-(12b), we use first-order Taylor approximations around the long-run value of the exogenous variable, q_t. See Appendix B for details.

where, $E_t\Omega_{t+1} = \dfrac{(1+\delta)(1-\beta E_t q_{t+1})}{(1-\beta)(1+\beta-2\beta E_t q_{t+1})} - \delta > 0$ and $E_t q_{t+1} = q_0 + \rho q_t$ from (11). Thus,

the solution has the certainty equivalence property in the sense that it holds in expected

value.[35]

In what follows, we focus on the effects of electoral uncertainty, as summarized by

the expected re-election probability, $E_t q_{t+1}$. The expected "effective discount rate",

defined as $E_t\Omega_{t+1}$, increases with $E_t q_{t+1}$. In other words, as the probability of being

reelected increases, policymakers care effectively more about the future. In turn, (13a) and

(13b) imply $\dfrac{\partial \theta_t}{\partial E q_{t+1}} < 0$ and $\dfrac{\partial b_t}{\partial E_t q_{t+1}} > 0$. In other words, as the probability of being

reelected increases, the total government expenditures-to-output ratio (and the associated

required tax rate, θ_t)[36] decreases, while the share of tax revenues earmarked for financing

government production services, b_t, increases. Then, since $\dfrac{k_{t+1}}{k_t} = \alpha\beta A^{\frac{1}{\alpha}}(1-\theta_t)(b_t\theta_t)^{\frac{1-\alpha}{\alpha}}$ is

decreasing in θ_t and increasing in b_t along the optimal path,[37] it follows that, as q_{t+1}

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[35] Notice three features of the solution in (13a)-(13b). First, if q_t is constant, it is optimal to keep the policy instruments flat over time. This is as in the basic Barro (1990) setup, in which the optimal open loop tax rate that maximizes the utility of the representative agent (or equivalently the growth rate) is flat over time and there is no time inconsistency problem (for details, see Benhabib *et al.* (2001)). Second, $\theta_t > (1-\alpha)$, where $(1-\alpha)$ is the productivity of public services. By contrast, $\theta_t \equiv \theta = (1-\alpha)$ in Barro (1990). This is because here there are also public consumption services and electoral competition; both lead to larger public sectors and higher tax rates. Third, the two policy instruments, θ_t and b_t, should move in opposite direction in each period. Intuitively, when the government allocates a larger share of tax revenues to public production services (i.e. b_t increases), it can afford a lower tax rate (i.e. θ_t decreases) since public production services stimulate private investment and hence increase the tax base. Thus, θ_t and b_t are substitutes along the optimal path (see also Park and Philippopoulos (2003)).

[36] This follows from (8a), where $\dfrac{g_t + h_t}{y_t} = \theta_t$.

[37] Since $(1-\alpha-\theta_t) < 0$ along the optimal path, it follows from (10b) that k_{t+1} decreases with θ_t. Intuitively, when policy is chosen endogenously, it is not possible for any further increases in tax policy actions to be welfare increasing (compare it with (10b) above where policy was exogenous).

increases, both policy instruments work in the same direction leading to an increase in capital and output growth.

The intuition is as follows. When there is electoral uncertainty (in the sense that there is a non-zero probability of being out of power in the next election), and the political parties care less about economic outcomes when out of power than when in power, they face a quasi-finite time horizon (see also Lockwood *et al.* (1996)). As a result, the party in power, which is the party that sets policy, cares effectively less about the future. Specifically, the higher the electoral uncertainty (i.e. the smaller the probability of being re-elected), the less it cares about the future. In our model, higher electoral uncertainty pushes policymakers to go for a higher total expenditures-to-output ratio and also spend more on non-productive activities relative to productive activities. Here, the benchmark case is the second-best case without any electoral uncertainty, $q_{t+1} = 1$. In turn, the effects of these two policy instruments work in the same direction and discourage private capital accumulation and economic growth. We summarize results in the following proposition:

Proposition 1: There is a unique Markov-perfect general equilibrium in symmetric Nash strategies among political parties. In this equilibrium, when the probability of being re-elected decreases, it is optimal for incumbent politicians to follow relatively shortsighted fiscal policies (in the form of relatively high total expenditure-to-output ratio and low share of tax revenues used to finance government production services) and this is detrimental for economic growth.

3.   The Econometric Model

In this section we jointly estimate the general equilibrium (GE) model given the exogenous process for q_t developed in Section 2 for Germany, the UK and the US using quarterly data from 1960 to 1999. The GE model consists of equations (10a-10d) and (13a-13b) which gives respectively closed-form solutions for c_t, k_{t+1}, g_t, h_t, θ_t, b_t. The

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exogenous process for q_t is given by equation (11). The internal and external dynamics of the model are captured respectively by the capital stock, k_t, and the reelection probability, q_t. To focus attention on the effects that political uncertainty has on policy outcomes and in turn the aggregate economy, we have only specified one explicit stochastic process, namely q_t. When moving to the econometric specification, we have to account for the fact that our data measures for q_t are at best proxies. This is because actual q_t embodies multiple dimensions of electoral certainty and political stability in general, which make it different from the q_t implied by the model (i.e. the "probability of staying in office"). The remaining deterministic equations of the system are made stochastic by the introduction of measurement errors.[38]

Given that the model in (10a-10d) and (13a-13b) is non-linear, both in variables and parameters, prior to estimation, we transform it into its log-deviations form by using the long-run restrictions imposed by the theory developed in Section 2. This has two advantages: (i) the transformed model is in a form more tractable for estimation, i.e. it becomes log-linear (with the non-linearity only entering in the parameters); (ii) the log-linear structure is necessary when using the Kalman Filter. The latter procedure is a natural choice for this exercise since, as mentioned above, we need to account for both measurement errors and an unobservable component of q_t.

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[38] This treatment is particularly relevant when it comes to the distinction between government consumption and production services, h_t and g_t. Typically, national income accounting practice fails to recognise the investment characteristics of many categories of government expenditure. Examples include expenditure on education, or expenditure on social security programs. This is widely recognized in the literature (see e.g. Devarajan *et al.* (1996) and Gemmell and Kneller (2001)).

3.1   The Data

The quarterly time series for private and public consumption and investment are from the OECD Business sector database. As mentioned above, since it is not possible to measure the probability of staying in office directly, we have to use proxies for q_t. In the case of the UK and Germany, the political data are from the data-set collected by Carmignani (2003). Since we do not have a direct measure for the probability of staying in office, we convert the information from Carmignani's measures for political uncertainty to an index varying between 0 and 1, e.g. $q_t = \exp(\widetilde{q}_t)/(1+\exp(\widetilde{q}_t))$. Our choice of measures is based on data availability: for Germany, we use an index of portfolio volatility and ideological diversity of the cabinet; for the UK, we use the share of parliamentary support. Portfolio volatility measures the number of changes in the structure of portfolio allocation between two consecutive cabinets. The lower the portfolio volatility, the higher the probability a minister stays in office. Ideological diversity reflects the potential conflict of interest between coalition partners, based on the ideological location of the parties involved in the coalition on a ten points Left-Right continuum (see Carmignani (2003) and the reference cited therein for details). The more diverse the coalition, the smaller is the probability of staying in office. In the case of the UK, and since the UK is a typical single-party majority system, we cannot use measures based on potential conflicts within a coalition. Instead, we will use the share of parliamentary support (share of seats controlled by the government) as a proxy for the survival probability. In the case of the US, we have (relatively more direct) data on the presidential job approval for the entire observation period collected by the Gallup Organization,[39] which we convert from the bi-weekly to the quarterly frequency.

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[39] Source: http://roperweb.ropercenter.uconn.edu/. We are aware that similar data exist for the UK and Germany, but using this would restrict the sample size considerably. For example, in the case of Germany, published opinion poll series do not start before 1977.

3.2 The Model in log-deviations form

Taking logs in (10a-10d), (13a-13b) and (11) and differentiating with respect to time (where derivatives are evaluated at long-run values), we obtain (for any variable x,

$\hat{x}_t \equiv \dfrac{\dot{x}_t}{\overline{x}}$, where $\dot{x}_t \cong x_t - x_{t-1}$ and $\overline{x}$ is the non-stochastic long-run value of x_t):

$$\hat{c}_t = \frac{\left(1-\alpha-\overline{\theta}\right)}{\alpha(1-\overline{\theta})}\hat{\theta}_t + \frac{(1-\alpha)}{\alpha}\hat{b}_t + \hat{k}_t \tag{14a}$$

$$\hat{k}_{t+1} = \frac{\left(1-\alpha-\overline{\theta}\right)}{\alpha(1-\overline{\theta})}\hat{\theta}_t + \frac{(1-\alpha)}{\alpha}\hat{b}_t + \hat{k}_t \tag{14b}$$

$$\hat{g}_t = \frac{1}{\alpha}\hat{b}_t + \frac{1}{\alpha}\hat{\theta}_t + \hat{k}_t \tag{14c}$$

$$\hat{h}_t = \left(\frac{\left(1-\alpha-\overline{b}\right)}{\alpha(1-\overline{b})}\right)\hat{b}_t + \left(\frac{1}{\alpha}\right)\hat{\theta}_t + \hat{k}_t \tag{14d}$$

$$\hat{\theta}_t = \frac{-\alpha\delta}{(\delta+\overline{\Omega})[\delta+(1-\alpha)\overline{\Omega}]}\left(\frac{\partial\overline{\Omega}}{\partial\overline{q}}\overline{q}\right)\hat{q}_{t+1} \tag{14e}$$

$$\hat{b}_t = \frac{\alpha\delta}{(\delta+\overline{\Omega})[\delta+(1-\alpha)\overline{\Omega}]}\left(\frac{\partial\overline{\Omega}}{\partial\overline{q}}\overline{q}\right)\hat{q}_{t+1} \tag{14f}$$

$$\hat{q}_{t+1} = \rho\hat{q}_t + \frac{1}{\overline{q}}\dot{\varepsilon}_{t+1} \tag{14g}$$

where $\overline{\theta} = \dfrac{\delta+(1-\alpha)\overline{\Omega}}{\delta+\overline{\Omega}}$, $\overline{b} = \dfrac{(1-\alpha)(\delta+\overline{\Omega})}{\delta+(1-\alpha)\overline{\Omega}}$, $\overline{\Omega} = \dfrac{(1+\delta)(1-\beta\overline{q})}{(1-\beta)(1+\beta-2\beta\overline{q})} - \delta$,

$\dfrac{\partial\overline{\Omega}}{\partial\overline{q}} = \dfrac{(1+\delta)\beta}{(1+\beta-2\beta\overline{q})^2}$, $\left(\overline{c}, \overline{k}, \overline{g}, \overline{h}\right)$ are deterministic quadratic trends of (c, k, g, h) from the actual data and $\overline{q} = 0.5$.[40]

3.3   *The Kalman Filter set-up*

To estimate the parameters, we first cast the model in equations (14a) – (14g) in state space form. The transition equation system is given by the economic model and determines the dynamics of the (7×1) state vector $\mathbf{a}_t$:

$$\mathbf{a}_t = \mathbf{T}\mathbf{a}_{t-1} + \mathbf{R}\hat{\varepsilon}_{t+2} \tag{15}$$

with

$$\mathbf{a}_t = \begin{pmatrix} \hat{c}_t^* \\ \hat{k}_{t+1}^* \\ \hat{g}_t^* \\ \hat{h}_t^* \\ \hat{\theta}_t^* \\ \hat{b}_t^* \\ \hat{q}_{t+2}^* \end{pmatrix}; \mathbf{T} = \begin{pmatrix} 0 & 1 & 0 & 0 & \tilde{a} & \tilde{b} & 0 \\ 0 & 1 & 0 & 0 & \tilde{a} & \tilde{b} & 0 \\ 0 & 1 & 0 & 0 & \tilde{c} & \tilde{c} & 0 \\ 0 & 1 & 0 & 0 & \tilde{c} & \tilde{d} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -\tilde{e} \\ 0 & 0 & 0 & 0 & 0 & 0 & \tilde{e} \\ 0 & 0 & 0 & 0 & 0 & 0 & \rho \end{pmatrix}, \mathbf{R} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix},$$

where,

$$\tilde{a} \equiv \frac{\left(1-\alpha-\overline{\theta}\right)}{\alpha(1-\overline{\theta})}; \; \tilde{b} \equiv \frac{(1-\alpha)}{\alpha}; \; \tilde{c} \equiv \frac{1}{\alpha}; \; \tilde{d} \equiv \frac{\left(1-\alpha-\overline{b}\right)}{\alpha(1-\overline{b})}; \; \tilde{e} = \left(\frac{-\alpha\delta}{(\delta+\overline{\Omega})[\delta+(1-\alpha)\overline{\Omega}]}\right)\left(\frac{(1+\delta)\beta}{(1+\beta-2\overline{\beta}q)^2}\overline{q}\right)$$

$$\overline{\theta} \equiv \frac{\delta+(1-\alpha)\overline{\Omega}}{\delta+\overline{\Omega}}, \; \overline{b} \equiv \frac{(1-\alpha)(\delta+\overline{\Omega})}{\delta+(1-\alpha)\overline{\Omega}}, \; \overline{\Omega} \equiv \frac{(1+\delta)(1-\beta\overline{q})}{(1-\beta)(1+\beta-2\beta\overline{q})} - \delta, \text{ and } \hat{\varepsilon}_t \sim N\left(0, \sigma_{\hat{\varepsilon}}^2\right).$$

In the measurement equation, the state vector is linked to observable $\hat{c}_t$, $\hat{k}_{t+1}$, $\hat{g}_t$, $\hat{h}_t$, and $\hat{q}_{t+2}$:

$$\mathbf{y}_t = \mathbf{Z}\mathbf{a}_t + \boldsymbol{\varepsilon}_t \tag{16}$$

where

$$\mathbf{y}_t = \begin{pmatrix} \hat{c}_t \\ \hat{k}_{t+1} \\ \hat{g}_t \\ \hat{h}_t \\ \hat{q}_{t+2} \end{pmatrix}; \quad \mathbf{Z} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}; \quad \boldsymbol{\varepsilon}_t = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t+1} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t+2} \end{pmatrix},$$

$\boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \mathbf{H})$, and the variance-covariance matrix $\mathbf{H}$ is assumed to be diagonal. We do not require proxies for $\hat{\theta}_t$ and $\hat{b}_t$, since they can be linked via the $\hat{c}_t$ and $\hat{k}_{t+1}$ equations to observable data. The error vector reflects the fact that all variables in the system are subject to measurement error, or have to be seen as proxies, as in the case of $\hat{q}_{t+2}$.

3.4 Constrained Maximum Likelihood

Given that the parameters (i.e. $\tilde{a}, \tilde{b}, \tilde{c}, \tilde{d}, \tilde{e}$) are comprised of complex non-linear convolutions of the underlying "deep" parameters $(\alpha, \beta, \delta, \rho)$, which also embody the within- and cross-equation restrictions imposed by the theory, we find it appropriate to employ constrained maximum likelihood estimation. Maximizing the likelihood function using standard numerical methods in these circumstances does not guarantee that the estimated parameters will lie within the ranges suggested by the theory. To ensure this, we could use parameter transformations such as *b=exp(a)/(1+exp(a))* which ensures that *b* lies in [0,1] interval. However transformations such as these lead to problems with convergence (see Schoenberg (1997)). Accordingly, we will restrict the structural parameters α, β and δ to stay within acceptable ranges (see below).

Before we move on, it is important to point out that, in contrast to standard calibration exercises, our proposed methodology has several advantages. First, we are able to assess the individual statistical significance of each of the structural parameters. Second, when performing the impulse response analysis to ascertain the transition

dynamics and long-run effects of changes in political uncertainty, we are able to undertake dynamic inference.

To estimate the state space model given by (15) and (16), we calculate the likelihood function using the Kalman filter. As discussed above, when maximising the likelihood, we take into account that all of the variables (with the exception of ρ) are bounded. The restricted ranges we use are as follows: α (i.e. the productivity of private capital relative to public production services) is in between 0.6 and 0.8, β (i.e. the time discount rate) lies in between 0.95 and 0.99, and δ (i.e. the weight given to public consumption services relative to private consumption) cannot be greater than 1 or less than 0.[41]

The range for α was motivated by Barro and Sala-i-Martin (1995, see e.g. pp 82-87), who undertake calibrations using a point estimate of $\alpha = 0.75$ for private capital. They argue that a value around 0.75 (which is higher than the one usually used) gives reasonable transitional dynamics, generates predictions that accord well with historical growth experiences in advanced economies and is consistent with a broad measure of private capital. The range for β reflects values most often used in the theoretical DSGE literature (see, e.g. Baier and Glomm (2001) and Lansing (1998) who set β to 0.98 and 0.96 for the US respectively). Finally, concerning the range for δ, since as Baier and Glomm (2001) state, "little is known about this value", we employ the 0 to 1 range. Note that values of δ used in calibration studies for the US include 0.287 (see Lansing (1998)), 0.368 (see Guo and Lansing (1999)), 0.107 (see Ambler and Paquet (1996)), while Baier and Glomm (*op cit*) experiment with values of $(0.15, \ 0.0075, \ 0)$.

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[41] The variances are also bounded, in the sense that they cannot be negative. Forcing the algorithm to take this property into account is straightforward: we maximize with respect to standard deviations and calculate the variances within the optimization procedure.

To impose the above restrictions on α, β and δ, we use the GAUSS module for constrained maximum likelihood estimation version 1.0 (for a detailed description, see Schoenberg (1997)). Since the standard errors for the parameters have to allow for the possibility that the true values are near or actually on the constraint boundaries, we construct bootstrap confidence intervals at the 95 % level.

4.   Econometric Results

We next present the results of estimating the econometric model setout in Section 3 (see Table 1) as well as the results of impulse response analysis (see Table 2 and Figures 1-3).   Examination of the results in Table 1 reveals that all parameters are significantly different from zero and some interesting cross-country differences. More specifically, the physical productivity of public production services relative to private capital, $(1-\alpha)$, is highest in Germany (0.309) followed by the US (0.279) and the UK (0.270). The difference between Germany and the UK is significant, but the US does not differ significantly from either country. Estimates of the time discount rate, β, are 0.954, 0.978 and 0.986 for the US, Germany and the UK respectively and are all statistically significantly different from each other. The estimates for the weight private consumers place on public consumption services relative to private consumption, δ, are 0.385, 0.475 and 0.600 for the US, Germany and the UK respectively. The UK and German results differ significantly from each other, while the US differs significantly from the UK but not from Germany.

Table 1: Estimation Results

Parameter	Restriction	United Kingdom			Germany			United States		
		Point Estimate	*Lower limit*	*Upper limit*	*Point Estimate*	*Lower limit*	*Upper limit*	*Point Estimate*	*Lower limit*	*Upper limit*
$\bar{q}$	0.5	-	-	-	-	-	-	-	-	-
α	$0.20 \leq 1 - \alpha \leq 0.40$	**0.270**	0.255	0.279	**0.309**	0.293	0.325	**0.279**	0.242	0.320
β	$0.95 \leq \beta \leq 0.99$	**0.986**	0.982	0.990	**0.978**	0.973	0.980	**0.954**	0.950	0.958
δ	$0 \leq \delta \leq 1$	**0.600**	0.595	0.605	**0.475**	0.405	0.555	**0.385**	0.314	0.510
ρ		**0.961**	0.934	0.991	**0.918**	0.882	0.956	**0.889**	0.863	0.929
$\bar{\theta}$		**0.277**	0.262	0.289	**0.318**	0.301	0.336	**0.297**	0.261	0.338
$\bar{b}$		**0.972**	0.966	0.980	**0.970**	0.959	0.976	**0.941**	0.915	0.955
Log-Likelihood		-2.946			-3.157			-5.428		
N		140			153			149		

Notes: Estimation method: constrained Maximum Likelihood (Gauss CML module Version 1.0); parameter restrictions are displayed in column 2. The 95% confidence intervals are based on 1000 re-samplings.

We now turn to the estimated policy parameters reported in Table 1. Persistence of political uncertainty, captured by ρ in equation (11), is highest in the UK (0.961) followed by Germany (0.918) and the US (0.889). The UK and German results do not statistically differ from each other, while the US differs significantly from the UK but not from Germany. The estimates for the long-run values of the optimal tax rate ($\bar{\theta}$) and the optimal share of total tax revenues allocated to public production services relative to consumption ones ($\bar{b}$) are all within the ranges predicted by the theory (see equations (13a-13b)). Specifically, the long-run tax rates are 0.277, 0.297 and 0.318 for the UK, the US and Germany respectively. The British and German tax rates ($\bar{\theta}$) are statistically different from each other, but the US does not differ from either of the European countries. Finally, the optimal long-run share of tax revenues allocated to public production services ($\bar{b}$) is 0.941, 0.970 and 0.972 for the US, Germany and the UK respectively.[42] The British and German values are not significantly different from each other, while the US differs from both the UK and Germany.

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[42] The estimated long-run values of $\bar{b}$, although consistent with the theory (see equation (13b)), seem to be too high. However, recall that here the engine of perpetual economic growth is public production services as defined in (8b). Also recall that the provision of public (production, consumption, etc) services requires large

To more fully assess the persistence of fluctuations resulting from a change in the probability of being reelected (q), as well as the effects on the steady-state values of the endogenous variables, we next undertake impulse response analysis. To do so, we analyze a temporary positive unit shock to $\hat{q}$. Results are reported in Table 2.

Table 2: Summary Impulse Response Results

Parameter	United Kingdom			Germany			United States		
	Point Estimate	Lower limit	Upper limit	Point Estimate	Lower limit	Upper limit	Point Estimate	Lower limit	Upper limit
Standard deviation of estimated $\hat{q}$	**0.963**	0.221	1.660	**0.333**	0.126	0.582	**0.179**	0.145	0.221
Long-run response of $\hat{y}$	**0.375**	0.107	0.838	**0.355**	0.184	0.640	**0.933**	0.464	1.547
t^*	**17.424**	10.152	76.670	**8.102**	5.520	15.404	**5.891**	4.704	9.412

Notes: t^*: time (quarters) in which the initial shock to $\hat{q}$ halves ($t^* = \ln(0.5)/\ln(\rho)$). The responses of $\hat{y}$ are based on a unit shock to $\hat{q}$.

As predicted by the theory, Figures 1-3 show that the endogenous policy instruments $\hat{\theta}$ and $\hat{b}$ move in opposite directions. Specifically, in all three countries, as a result of a temporary rise in $\hat{q}$, $\hat{\theta}$ decreases before monotonically increasing to its steady state (i.e. zero), whereas $\hat{b}$ increases prior to decreasing to its steady state deviation of zero. The confidence bands also suggest that these changes (as well as all changes reported in Figures 1-3) are statistically significant for the duration of the simulation.

Turning to effects of a temporary rise in the re-election probability upon macroeconomic outcomes, we can see for all countries that private consumption and investment (c and i), as well as public investment (g), all monotonically increase before converging to new balanced growth paths which are higher than their pre-shock paths. On the other hand, public consumption (h) increases before monotonically decreasing to its

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tax bases and this can be achieved by relatively high $\bar{b}$ and low $\bar{\theta}$. This is especially true in the long run where tax bases are fully endogenous.

new balanced growth path that is higher than the pre-shock one.[43]   If we concentrate on

output, the point estimates appear to indicate that long-run growth in the US is relatively

most affected by the increase in the re-election probability. For example, Figures 1-3 and

Table 2 (see row 2) show that steady-state growth is about 0.4 points higher for the UK and

Germany and nearly a point for the US.   However, closer inspection of the confidence

bands in Table 2 indicates that there is no significant difference between these countries.

Nonetheless, an increase in the probability of being re-elected has a statistically significant

and positive effect on the steady-state growth rate of output for all countries. Finally, to

demonstrate the relative importance of the four components of output (c, i, g and h) in the

transmission of a shock to $\hat{q}$ to output growth, Figure 4 contains a decomposition of the

output growth response into the contributions of each component.

Figure 1: Percentage Deviation Responses to a Unit Shock to $\hat{q}$
(United Kingdom)

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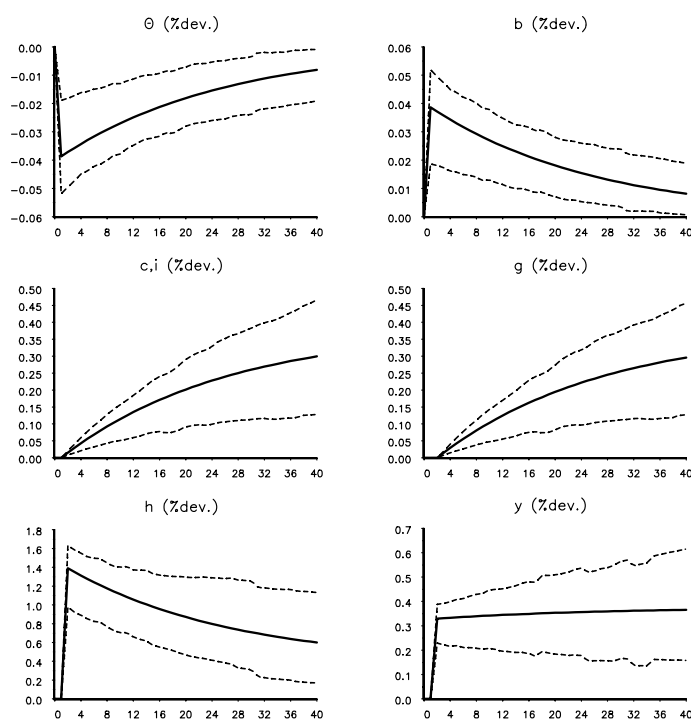
[43] Recall that this is a model of endogenous growth (an AK model). This means that even temporary shocks
in fiscal policy can have permanent effects on levels and growth rates (see also e.g. King and Rebelo (1990),
Ambler and Paquet (1996) and Gemmel and Kneller (2001)).

Figure 2: Percentage Deviation Responses to a Unit Shock to $\hat{q}$
(Germany)
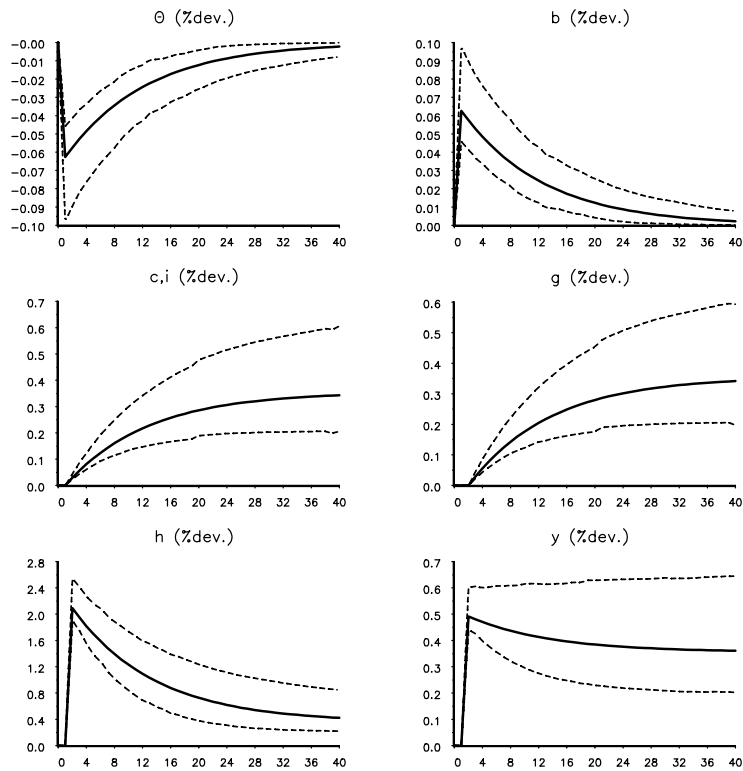
Figure 3: Percentage Deviation Responses to a Unit Shock to $\hat{q}$
(United States)
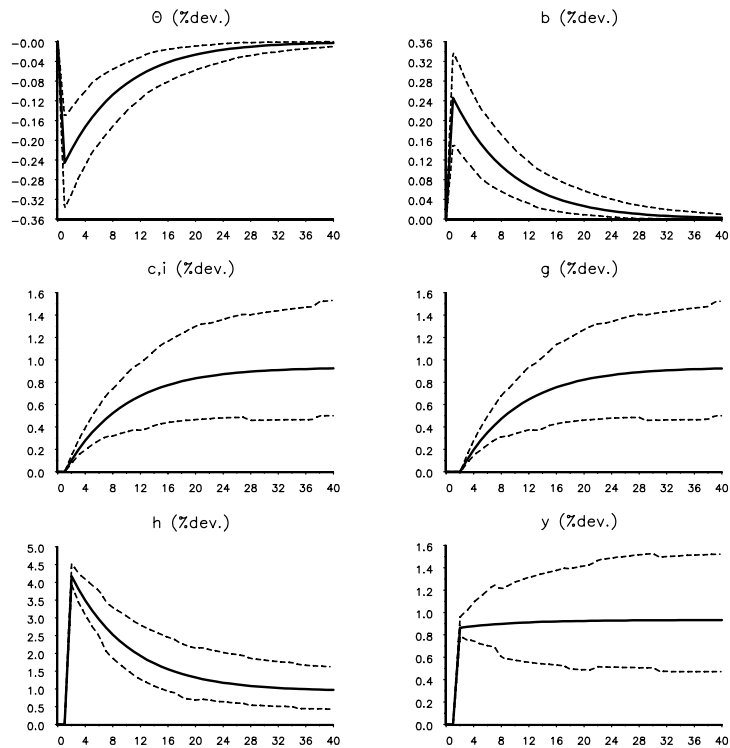
Figure 4: Relative Contribution of Components of $\hat{y}$ to Output Growth Response
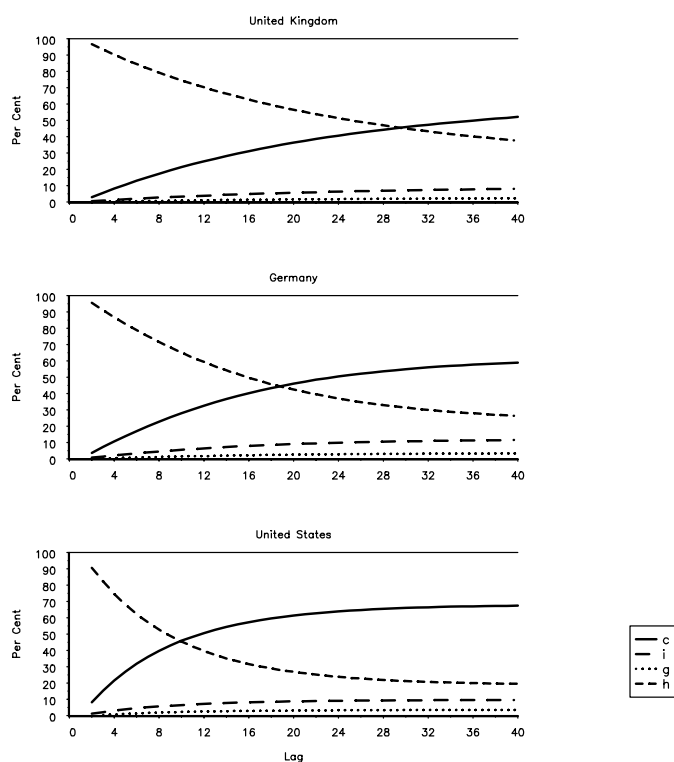
We now return to the issue pertaining to the persistence of shocks discussed in relation to the estimates of ρ in Table 1. Table 2 (see row 3) shows the time (in quarters) it takes for the initial shock to $\hat{q}$ to half. The point estimates suggest that it takes approximately 4 years for the UK, 2 years for Germany and 1.5 years for the US.[44] Broadly speaking, this rank ordering is consistent with business cycle stylized facts, i.e. the US cycle is shorter, which is reflected in the lower modulus/higher damping that we find (see, e.g., Zarnowitz *op cit*. and Woitek *op cit*.).

5.   Conclusions

This paper has solved and estimated a tractable dynamic stochastic general equilibrium model to study the link between elections, fiscal policy and

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[44] Note however that the confidence bands for the US and Germany overlap.

fluctuations/growth. The model was formally estimated for Germany, the UK and the US, which are generally believed to be the economies closest to the neoclassical paradigm. The focus has been on the effects of electoral uncertainty and party competition upon the choice of fiscal policy instruments and in turn upon the macro-economy. The main result is that electoral competition pushes governments to follow relatively short-sighted fiscal policies and this is detrimental for the macro-economy. Our econometric results provide clear support for this proposition from both fluctuations and growth perspectives. By explicitly modeling the channel through which political uncertainty affects the economy, we found a statistically significant effect of electoral uncertainty on output growth. This effect is small in magnitude, which might help to explain why previous empirical studies can at best identify a political business cycle in policy instruments.

Our research contributes to both the literature on political business cycles, as well as the quantitative RBC literature. It adds to the former mainly because, to the extent that we formally estimate the solution of the theoretical model, we fill the gap between theoretical and empirical research. To date, there has been very little econometric work, which has successfully made the formal link between political uncertainty, endogenous fiscal policy and ultimately aggregate outcomes. Our research also adds to the RBC literature mainly because, instead of relying only on non-sample information, we combine this with observed data to obtain estimated values of a number of parameters which are of key interest in a variety of general equilibrium modeling contexts.

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7.   Appendices

7.1   *Appendix A: Result 1*

This appendix solves for a Competitive Decentralized Equilibrium (CDE) as defined in the text. Note that the household's problem is only a part of this CDE. The log-linear objective (1a)-(1b), the Cobb-Douglas functional forms for the production function in (9) and government consumption services in (10d), and the assumption that policy instruments (θ_t and b_t) are Markov, imply a value function of the form $V(k_t; \theta_t, b_t) = u_0 + u_1 \log k_t + u_2 \theta_t + u_3 b_t$, where ($u_0, u_1, u_2, u_3$) are time-invariant undetermined coefficients. Substituting this conjecture for the value function into the optimality conditions (4a) and (4b), and using (7a) and (9), we get (10b). Then, (10a) follows from (10b) and (2). See also e.g. McCallum (1989, equations (1.16-1.21) for a similar solution.

We now have to solve for (u_0, u_1, u_2, u_3) and verify our conjecture for the value function. To do so, we substitute (10a), (10b) and (10d) back into (3) and equate coefficients on both sides of the Bellman. For instance, by equating coefficients on $\log k_t$, the Riccati equation for u_1 gives $u_1 = \dfrac{1+\delta}{1-\beta} > 0$. Notice that u_1 is the crucial coefficient; namely, it is the coefficient that matters for the optimal decisions, (c_t, k_{t+1}), in (4a)-(4b). The other undetermined coefficients (u_0, u_2, u_3) may matter for the solution of the value function, but not for (c_t, k_{t+1}). Hence, we will only sketch their solution here. To solve for (u_0, u_2, u_3), we need to contend with $\log \theta_t$, $\log(1-\theta_t)$, $\log b_t$ and $\log(1-b_t)$ [recall that we have substituted (10a), (10b) and (10d) for c_t, k_{t+1} and h_t back into the Bellman in (3)]. To do so, we take first-order Taylor approximations of θ_t and b_t around their long-run values, denoted as $\bar{\theta}$ and $\bar{b}$ (see Appendix B below for $\bar{\theta}$ and $\bar{b}$). That is, we have

$$\log\theta_t \cong \log\overline{\theta} + \frac{1}{\theta}(\theta_t - \overline{\theta}), \qquad \log(1-\theta_t) \cong \log(1-\overline{\theta}) - \frac{1}{(1-\overline{\theta})}(\theta_t - \overline{\theta}) \qquad \text{and} \qquad \text{similar}$$

expressions for $\log b_t$ and $\log(1-b_t)$. Using these approximations into (3), and if the policy instruments (θ_t and b_t) are Markov, we can equate coefficients on both sides of the Bellman to get Riccati equations for (u_0, u_2, u_3). It is important to point out that those solutions for (u_0, u_2, u_3) can be obtained only after we solve for optimal policy, θ_t and b_t (see Appendix B below). This is how it should be, since this is a general equilibrium model in which policy instruments are chosen endogenously [see also Economides *et al.* (2003)]. By contrast, if policy were exogenous, we could simply assume (exogenous) statistical processes driving θ_t and b_t over time. This also verifies (approximately) our conjecture for the value function.

7.2   *Appendix B: Result 2*

We conjecture that the two value functions in (12a)-(12b) take the form $V^{P_i}(k_t; q_t) = u_0^P + u_1^P \log k_t + u_2^P q_t$ and $V^{N_i}(k_t; q_t) = u_0^N + u_1^N \log k_t + u_2^N q_t$, where $(u_0^P, u_1^P, u_2^P, u_0^N, u_1^N, u_2^N)$ are time-invariant undetermined coefficients. Party j solves a symmetric problem, so that we have two pairs of equations like (12a)-(12b). We will solve party i's problem. If we use the above conjectures into (12a)-(12b), differentiate the right-hand side of (12a) with respect to the controls θ_t^i and b_t^i, and impose the *ex post* symmetry conditions $\theta_t^i = \theta_t^j \equiv \theta_t$, $b_t^i = b_t^j \equiv b_t$, $u^{Pi} = u^{Pj} \equiv u^P$ and $u^{Ni} = u^{Nj} \equiv u^N$, then the first-order conditions for θ_t and b_t in a symmetric Nash equilibrium in Markov strategies are (13a) and (13b) respectively, where $E_t\Omega_{t+1} \equiv 1 + \beta[u_1^P E_t q_{t+1} + u_1^N(1 - E_t q_{t+1})] > 0$.

We now have to solve for $(u_0^P, u_1^P, u_2^P, u_0^N, u_1^N, u_2^N)$ and verify our conjecture for the value functions. To do so, we substitute (13a)-(13b) back into (12a)-(12b) by using (10a),

(10b) and (10d), and then equate coefficients on both sides of the two Bellman equations (12a)-(12b). The crucial coefficients are u_1^P, u_1^N. Namely, these are the coefficients that solve $E_t \Omega_{t+1}$ and hence matter in the solution for the optimal strategies in (13a)-(13b). Equating coefficients on $\log k_t$ in (12a)-(12b), we obtain two Riccati equations,

$u_1^P = 1 + \delta + \beta[u_1^P E_t q_{t+1} + u_1^N (1 - E_t q_{t+1})]$ and $u_1^N = \beta[u_1^P (1 - E_t q_{t+1}) + u_1^N E_t q_{t+1}]$, which

can be solved for u_1^P and u_1^N. Their solution gives

$$E_t \Omega_{t+1} = \frac{(1+\delta)(1-\beta E_t q_{t+1})}{(1-\beta)(1+\beta - 2\beta E_t q_{t+1})} - \delta > 0.$$

The solution for the rest of undetermined coefficients $(u_0^P, u_2^P, u_0^N, u_2^N)$, and hence for the value functions, will be based on first-order Taylor approximations around long-run values. Notice that $(u_0^P, u_2^P, u_0^N, u_2^N)$ do not affect the optimal strategies, (θ_t, b_t), in (13a)-(13b). Since they are not of particular interest, we will only sketch their solution here.

Using (13a), we get $\log \theta_t \cong \log \bar{\theta} + \left[\frac{(1-\alpha)}{\delta + (1-\alpha)\bar{\Omega}} - \frac{1}{\delta + \bar{\Omega}} \right] \frac{\partial \bar{\Omega}}{\partial \bar{q}} (E_t q_{t+1} - \bar{q})$ and

$\log(1-\theta_t) \cong \log(1-\bar{\theta}) + \frac{\delta}{(\delta + \bar{\Omega})\bar{\Omega}} \frac{\partial \bar{\Omega}}{\partial \bar{q}} (E_t q_{t+1} - \bar{q})$, where $\bar{\theta} = \frac{\delta + (1-\alpha)\bar{\Omega}}{\delta + \bar{\Omega}}$,

$\bar{\Omega} = \frac{(1+\delta)(1-\beta\bar{q})}{(1-\beta)(1+\beta - 2\beta\bar{q})} - \delta$, $\frac{\partial \bar{\Omega}}{\partial \bar{q}} = \frac{(1+\delta)\beta}{(1+\beta - 2\beta\bar{q})^2}$ and $\bar{q}$ denotes the long-run value of

q_t. Working similarly and using (13b), we can get analogous approximations for $\log b_t$ and $\log(1-b_t)$. This implies that $\log \theta_t$, $\log(1-\theta_t)$, $\log b_t$ and $\log(1-b_t)$ are linear functions of $E_t q_{t+1}$ only. Also notice that $E_t(q_{t+1}^2) \cong \bar{q}^2 + 2\bar{q}(E_t q_{t+1} - \bar{q})$, where $E_t q_{t+1} = q_0 + \rho q_t$. Thus, we only have intercepts and terms with q_t on the RHS of (12a)-(12b). We can therefore equate coefficients on q_t and intercepts on both sides of (12a)-

(12b) to get Riccati equations for ($u_0^P, u_2^P, u_0^N, u_2^N$). This also verifies (approximately) our conjecture for the value functions.

Notice that this also completes the solution of the competitive decentralized equilibrium in Appendix A. This is because θ_t (the same arguments apply to b_t) on the LHS of the Bellman in (3) is a function of $E_t q_{t+1}$ and hence [since $E_t q_{t+1} = q_0 + \rho q_t$] a linear function of q_t, while $E_t \theta_{t+1}$ on the RHS of (3) is a function of $E_t q_{t+2}$ and hence [since $E_t q_{t+2} = (1+\rho)q_0 + \rho^2 q_t$] also a linear function of q_t. Accordingly, we can equate coefficients on both sides of the Bellman to solve for (u_0, u_2, u_3) in the private agents' problem.

Discussion of Electoral Uncertainty, Fiscal Policies and Growth

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December 15, 2004

1 Goal

This paper tries to investigate the link between elections, fiscal policy and growth and fluctuations. The production function used is of the AK type and therefore fluctuations are the result of changes in the growth regime.

2 Comments on the model and estimation results

In the model posed by the authors, consumers derive utility from private consumption (c_t) and from the consumption of a good provided by the public sector (h_t). Output is produced according to the following production function:

$$y_t = Ak_t^{\alpha}l_t^{1-\alpha}g_t^{1-\alpha},$$

which is borrowed from Barro [1990] where g_t is capital provided by the public sector, k_t is private capital and l_t is hours worked.

The government revenues (R_t^g) are collected through a uniform income tax (θ_t). Imposing balanced budget every period, the authors can express g_t and h_t as follows:

$$
\begin{aligned}
g_t &= b_t R_t^g \\
h_t &= (1 - b_t)R_t^g
\end{aligned}
$$

where b_t is the share of public revenues that goes for the production of the public consumption good.

In the economy there are two political parties. The utility function of each party is such that whenever they are in power the instantaneous utility flow is equal to GDP and whenever they are not is zero. The electoral system is exogenous. Specifically, the probability that the incumbent party is reelected next period (q_{t+1}) follows an AR(1) process with autocorrelation coefficient ρ. Since parties face a positive probability of not being reelected, their policies tend to be too shortsighted relative to the constrained maximum. Specifically, in equilibrium there tends to be too high tax rates (θ_t) and too much spending on the public consumption good ($1 - b_t$).

This specification is a bit artificial and also abstracts from important special interest considerations.

More fundamentally, this specification is hard to rationalize. One might think that the rents the party in power gets are proportional to GDP, but then that should be reflected in the consumers budget constraint. On the other hand, it might be the case that the prestige a party gets while in power is proportional to current GDP, but then that should be reflected on the probability of reelection.

The authors can solve the model and linearize the solution around the steady state. Then they estimate the structural parameters of the model. In this exercise the authors use various measures to estimate the law of motion for q. I am going to digress slightly about this issue since it is one interesting aspect that highlights the costs of diverging from the most natural modelling strategy. Namely, introducing political economy considerations through lobbies or parties that make contributions to influence the votes or decisions of the political authority.

This is the predominant line of research that the theoretical literature on political economy has taken in the last 15 year or so and it has been for good reasons. First, we know that politicians are not benevolent agents that value only social welfare. instead, they care about their probability of reelection, the monetary contributions they receive from private agents, the prestige of being in power and so on. Second, we know that these distortions of the political process make a difference in that they affect not only the outcomes but also the set of feasible actions agents can take. Finally, Even if qualitatively we did not observe important differences when taking opposite approaches to the modellling of political interactions, quantitatively there may be important differences.

Avoiding the natural route has a toll. Here the toll consists in estimating the process for the probability of reelection. This is enormously difficult. One way to do it consists in looking at

prediction markets. Recently, economists have discovered the relevance of these markets to calibrate and estimate the expectations of the agents in their models. Take for example the last election in the US. Throughout the campaign and election day (and night) there was an active betting market on the internet. Presumably the premia in this market was correlated to the aggregate of the opinions about the outcomes. If the persons that participated in the market had beliefs about the preferences of the american electorate that were in line with reality, then this can be taken as a good predictor of the election outcome. It has been proven that even thoug prediction markets are imperfect, they are more accurate and precise than an average of the opinions of the experts.

Of course, one challange with prediction markets is that they sometimes the premia fluctuate a lot. This makes it harder for researchers to estimate the type of stochastic processes that the authors want to estimate in this piece. However, they are still a good resource to take advantage of. This finishes my digression.

Coming back to the estimation, this type of econometric exercises consist on forcing the data through the restrictions imposed by the model. If these restrictions are unreasonable this will show up in the form of weird parameter estimates. However, there is one potential problem with this approach that is important to bear in mind. Namely, that different models may be observationally equivalent in terms of the restrictions they impose on the data.

Where does the data cry?

1. Forcing the labor and the $g-shares$ to be the same in the production function is probably unreasonable. This claim is supported by the low estimate the authors obtain for the labor share (1/3 vs. the actual 2/3).

2. The share of government consumption over GDP implied by the model for the US and Germany are very similar. In the data, probably there are important differences. This maybe the result of either a poor theory for the motivations of political parties to determine government consumption or a poor measure of the probability of reelection (q).

3. A similar remark applies to the income tax rate (θ).

3   Conclusions

This is an interesting attempt to answer an important question. The authors have tried to be very serious in the estimation of a political economy model but in the process have relaxed the rigourosity of the modelling approach. I think it is possible to answer this question without compromising the

modelling side. To do that I would suggest the authors two variations with their current approach.
1. Stick to a neoclassical production function. The currently used endogenous production function is too primitive. I think that if you want to do endogenous growth you must go all the way; otherwise the misspecifications in production contaminate all the other parameters. 2. I would set up a simple political economy model where parties get some private benefit from staying in power. this benefit is sustracted from the consumers budget constraint. The probability of reelection is increasing in the GDP level. These two modifications would make the model more reasonable and would still keep it sufficiently simple to solve it and estimate it.

Are European Business Cycles Close Enough to be just One?[*]

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Abstract

We propose a comprehensive methodology to characterize the business cycle co-movements across European economies and some industrialized countries, always trying to "leave the data speak". Out of this framework, we propose a novel method to show that there is no an "Euro economy" that acts as an attractor to the other economies of the area. We show that the relative comovements across EU economies are prior to the establishment of the Monetary Union. We are able to explain an important proportion of the distances across their business cycles using macro-variables related to the structure of the economy, to the directions of trade, and to the size of the public sector. Finally, we show that the distances across countries that belong to the European Union are smaller than the distances across newcomers.

Keywords: Business Cycle Synchronization, Economic Integration, European Union Enlargement, Cluster analysis, Multidimensional Scaling.

JEL Classification: E32, F02, C22

1 Introduction

The academic literature and the press are full of references to the importance of globalization and the links across economies. Several economists talk about the "world business cycle" and, assuming from the beginning that this cycle exists, estimate it and calculate its importance in explaining country specific movements. Recent examples are Lumsdaine and Prasad (2003), Canova, Ciccarelli and Ortega (2003), or Gregory, Head and Raynauld (1997). At the same time, many other economists talk about the "European business cycle", also assuming that there exist European-specific business cycle driving forces, or Euro-area specific factors. Supporting this view, significant examples are Mansour (2003), Del Negro and Ottrok (2003), Artis, Krozlig and Toro (1999), and obviously all the literature behind the well known coincident indicator for the Euro-area economies by Forni, Hallin, Lippi and Reichlin (2001a and 2001b). Most of the previous papers, when dealing with international business cycle movements, spend serious amount of effort in explaining how much or how little the common business cycle explains the cyclical behavior of the different economies. In addition, an important part of those papers deal with estimating the law of motion for the unobserved common business cycle that better fits the individual economies data.

The purpose of our paper is to go behind the assumptions of this literature. We want to analyze the comovements across economies without previously assuming that they should or should not move together. We want to "leave the data speak" without imposing any kind of *a priori* restrictions. This approach will allow us to draw a map of comovements across economies where we can check which economies are close together and which are further away from each other. At the same time, this approach will allow us to answer the leading question about the existence of either a world or an European attractor: Do the economies move according to a common driving force? We think that our answer to this question is more careful than any that we can previously find in other papers of the literature and require serious investment in applying and mixing different techniques to

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the data, much more when we do not pretend to impose a particular model or a particular framework to the data. To that extend, we think that we present different contributions to the literature. First, we propose a two by two comparison across economies without taking any of them as "reference" for the others. Second, we calculate different measures of comovements across economies, in order to check for the robustness of our results and not to condition our findings to a given framework. Third, we propose new measures of business cycle synchronization. Finally, we analyze the role of macroeconomic and policy variables in explaining distances across economies.

To deal with these questions, we will concentrate in this paper on European economies, although we will extend the usual European sample of countries in two different ways. On the one hand, we will include a set of industrialized economies that will allow us to understand how close or how far European economies are from those major industrialized countries. On the other side, we will include the Eastern European economies which represent most of the enlargement of the European Union. Extending the sample in this way allow us to address additional questions which are key to measure the gains and costs of the enlargement of the Union (and the future enlargement of the Euro-area) for both the accession and the existing countries. When countries join a monetary union they leave to a supranational decision maker traditional instruments for the control of the business cycles. Obviously, the optimality of this delegation of the decisions to a higher authority will be a direct function of the similarities across these economies. If the economies move together, we might think that they need the same type of economic policy decisions at the same time. If, there is no synchronization of their business cycle comovements, we might think that different solutions are optimal for different economies and probably, the costs associated to an economic union might be higher than the gains. In this context, little has been written about the business cycles of emerging economies and even less about Euro-accessing countries. All the literature about these economies have to do with convergence criteria and convergence tests as in Brada, Khutan and Zhou (2003). Other authors like Babetski, Boone and Maurel (2002), and Frenkel and Nickel (2002) try to identify demand and supply shocks, with the identification restrictions that this specific purpose implies. Finally, other authors take as given a "leading" economy and analyze the transmission of

shocks from this economy to the accessing economies as in Boone and Maurel (2002), but we do not find in any paper a careful analysis of the comovements of each of the accessing economies with each of the European and other major industrialized economies.

In addition, with this European focus in mind, there is an additional set of economic questions that we can address; for example, so far, the European economies linked their decisions together without any major trauma in their economies, but was the link across these economies not traumatic because these economies had previous linkages? Have these economies increased their comovements since they decided to join their policies? Is there an attractor across these economies? Is there a limit to the expansion of the EU? Finally, a more general question is analyzed in the last section of the paper; is there a role for macroeconomic variables in explaining the possible links across these countries' business cycles?

We think that an appropriate answer to these questions is necessary to understand deeply the benefits and the costs that for different economies imply leaving traditional instruments for controlling aggregate demand to a supranational decision maker.

The paper is structured as follows. Section 2 characterizes the concept of business cycles synchronization and checks whether the economies move together and how far are these economies from each other. Section 3 analyzes the existence of a common attractor or leader among European economies. Section 4 relates all these distances across economies with macroeconomic variables. Section 5 concludes.

2 Business cycles synchronization

2.1 Data

In our business cycle analysis, we have used the monthly (seasonally adjusted) Industrial Production series as an indicator of the general economic activity. We understand that choosing the Industrial Production as a measure of aggregate activity could be controversial. Obviously we are measuring only one sector and only the supply side of the economy. However, there is a trade off between the statistical reliability of the series and how representative this series is of the overall economic activity. We tried to use a more

comprehensive measure activity using aggregate GDP. However, the frequency of this series is quarterly, not monthly, the sample is shorter and, for most of these countries, the GDP is not calculated from national accounts on a quarterly basis but the series is annual and converted into a quarterly frequency using indicators.[1] We have also tried to create a diffusion index for each economy, following the diffusion index approach of Stock and Watson (1999). However, the results were disappointing when we analyzed the calculated series, probably due to the small number of series available for the accessing economies.

The sample of the countries include all the European Union countries, all the accession countries but Malta, and all the negotiating countries but Bulgaria.[2] Finally, we also include some industrialized countries: Canada, US, Norway and Japan. The source of the data is the OECD Main Economic Indicators and the IMF International Financial Statistics. In the analysis of European and industrialized countries we use data from 1965.01 to 2003.01. The exercises including the accession countries use data from 1990.01.[3] In order to facilitate a quick visual inspection of our data set, given the big number of countries, we plot the industrial production index for each country in Figure A1 of Appendix A.[4]

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[1] In a preliminary version of this paper, we also constructed a composite index for each country by using a Kalman filter specification of the type proposed by Stock and Watson (1991), with the series of Industrial Production, Total Sales, Employment and a measure of income for the different economies. However, this specification gave in many cases a weight of 0.99 to the Industrial Production series and almost 0 to the others. In addition, we found in the all cases very high correlation with the GDP quarterly series of the country.

[2] The accession countries are Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, the Slovak Republic and Slovenia. The negotiating countries are Bulgaria, Romania and Turkey.

[3] Even though we have statistical information for most of the accession countries from 1990, we do not use the first two years of observations. Blanchard (1997) or The World Bank (2002) point out the atypical characteristics of the transition period in which falls experienced in output can not be considered as sign of a conventional recession.

[4] See Appendix D for a more detailed description of data sources, missing data, and the nomenclature used for the different countries.

2.2 Correlation as measure of comovements

We will spend a serious amount of time and effort computing the degree to which the economies move together. However, as a preliminary approach, we think that a few pictures could help the reader to understand the nature of the problem. Figure 1 plots the the industrial production series of Italy, Spain, Romania and Ireland as well as the first difference of the logs of the industrial production series of Italy and Spain. Looking at the pictures in levels, it seems that the industrial production of some, but not all, of these countries move together. A first glance to the picture would say that Italy and Spain (both of them, Mediterranean countries) industrial productions present synchronized business cycles, which lead us to think that they should not have major problems linking their economies. However, in the case of Italy and Romania or Italy and Ireland the synchronization of their industrial production business cycles do not seem to be so evident, which leads us to think that joining these economies with a supranational decision maker should reduce the optimality of the stabilization policies for at least one of the economies.

Figure 1 also raises an additional question. The most standard measures to deal with the comovements across time series are the correlations among the series. However, what it is not so obvious is to choose between the correlations in levels (or log levels) and the correlations in rates of growth. For example, using the industrial production of Italy and Spain, the correlation between the log levels of the series is 0.94 whereas the correlation between their growth rates is 0.09. That is, the log levels of the series seem to show that the comovements of the series are very important, while the first differences lead to the opposite conclusion. In order to illustrate why this puzzling result occurs, let us to propose the following clarifying example. Let us assume that the data generating process for the series x_t and y_t be equal to

$$x_t = a + x_{t-1} + \phi(y_{t-1} - y_{t-2}) + e_t, \tag{1}$$

$$y_t = b + y_{t-1} + u_t, \tag{2}$$

with serially uncorrelated errors, $e_t \sim N(0, \sigma_e^2)$, $u_t \sim N(0, \sigma_u^2)$, and with $E(e_t, u_t) = 0$. Finally, let us assume that both x_1 and y_1 are zero. Using these assumptions, the

correlation between the series in log levels is

$$Corr\left(x_t, y_t\right) = Corr\left((a + \phi b)(t-1) + \phi \sum_{j=1}^{t-1} u_j + \sum_{i=2}^{t} e_i, b(t-1) + \sum_{j=2}^{t} u_j\right), \quad (3)$$

which clearly tends to unity because it is dominated by the trend effect. However, the correlation between the first differences of the log levels is

$$Corr\left(x_t - x_{t-1}, y_t - y_{t-1}\right) = Corr\left(a + \phi(b + u_{t-1}) + e_t, b + u_t\right), \quad (4)$$

which is cero. This example illustrates a general problem in defining the correlation across industrial productions as a measure of business cycle comovements: we can not use series in levels or log levels because in these series dominates the long-term rather than the business cycle correlation. In addition, we can not simple take first differences of the logs because the correlation between these transformations is dominated by the short-term noise. Thus, it is clear that we need some kind of filtering (more sophisticated that just taking the differences) in order to extract the information of the series about the short term movements (and comovements) of the series. Obviously, the chosen filter will affect the shape of the cycle, and, of course, the comovements across economies. In order to give robustness to our results we propose three different measures of comovements. The first is based on VAR estimations, following Den Haan (2000); the second, based on spectral analysis, following Reichlin, Forni and Croux (2001); and the third, based on business cycle dummy variables, following Harding and Pagan (2002). Our first definition tries to relate the business cycle comovements with the "rate of growth cycle", the second definition relates to the "growth cycle" and the third definition is close to the "classical cycle". A good review of these definitions can be found in Harding and Pagan (2002).

2.3   Synchronization of cycles. Measure 1. Den Haan (2000)

Den Haan (2000) argues that unconditional correlation coefficients lose important information about the dynamic aspects of the comovement across variables. In addition, in the case of non-stationary variables (as the ones in the previous example), the unconditional correlation produces spurious estimates. In order to solve these problems he proposes

to use the correlations of the VAR forecast errors at different horizons as a measure of comovements of the series.

He proposes the following identification scheme:

$$Z_t = \mu + \sum_{j=1}^{N} A_j Z_{t-j} + \varepsilon_t, \tag{5}$$

where Z_t represents in our case, the logs differences of the industrial production indexes for each pair of countries at time t, A_j is a (2×2) matrix of regression coefficients, μ is a vector of constants, N is the number of necessary lags, and ε_t are serially uncorrelated errors with zero mean and covariance matrix $\;$.[5] Out of this specification, the k-period ahead forecast error is

$$Z_{t+k} - Z_{t+k/t} = \sum_{j=0}^{k-1} \Theta_j \varepsilon_{t+k-j}, \tag{6}$$

where $Z_{t+k/t}$ is the k-period ahead forecast, and Θ_j may be obtained recursively from $\Theta_j = \sum_{i=1}^{N} A_i \Theta'_{j-i}$, with $\Theta_0 = I$, and $\Theta_\tau = 0$ for any $\tau < 0$. Therefore, the covariance matrix of this k-period ahead forecast error $\widetilde{Z}_{t+k/t} = Z_{t+k} - Z_{t+k/t}$ becomes

$$E\left(\widetilde{Z}_{t+k/t}\widetilde{Z}'_{t+k/t}\right) = \sum_{j=0}^{k-1} \Theta_j \; \Theta'_j. \tag{7}$$

Finally, the correlation between the k-period ahead forecast error between the two variables that form Z_t will be the element $(2, 1)$ of the previous matrix divided by the product of the two forecasted standard deviations for the two series (elements $(1, 1)$ and $(2, 2)$ of the previous matrix).

To facilitate comparisons, we present the empirical results by using distances instead of correlations. These distances are measured by one minus the value of the correlations. In this respect, Table A1 of Appendix A shows all the distances computed from the correlation of 48 months ahead forecasting errors.[6] Of special interest is the correlation of 0.60 computed for Italy and Spain (distance of 0.40), which represents a less extreme

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[5]Den Haan presents a more general model by allowing for both linear and quadratic deterministic trends. In our case, for the sample considered, these trends were not necessary for most of the countries. In addition, he shows that the results are robust to estimate the model in level and in first differences. We present the results of the estimation in first differences but the results using the leves are very similar.

[6]Hence, we consider business cycle horizons of four years.

value than the correlations of almost one (using the logs levels) and of almost cero (using first differences). In order to illustrate this point, let us consider the correlation computed from the 2 months ahead forecast error in the example outlined in equations (1) and (2). In this case, the VAR representation of the 2-period ahead forecast error is:

$$\begin{pmatrix} \widetilde{Z}^x_{t+2/t} \\ \widetilde{Z}^y_{t+2/t} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} e_{t+2} \\ u_{t+2} \end{pmatrix} + \begin{pmatrix} 1 & \phi \\ 0 & 1 \end{pmatrix} \begin{pmatrix} e_{t+1} \\ u_{t+1} \end{pmatrix}, \tag{8}$$

where $\widetilde{Z}^x_{t+2/t}$ and $\widetilde{Z}^y_{t+2/t}$ represent the 2-period ahead forecast errors for the logs of the industrial production series x and y, respectively. For $k = 2$, the correlation of the forecast errors would be

$$Corr\left(\widetilde{Z}^x_{t+2/t}, \widetilde{Z}^y_{t+2/t}\right) = \frac{\phi\sigma_u^2}{\sqrt{2\left[\sigma_e^2 + \sigma_u^2\left(1 + \phi^2\right)\right]}}, \tag{9}$$

that is clearly between the extreme values of zero and one for any reasonable values of ϕ, σ_e^2, and σ_u^2.

Table 1 shows a summary of the distances (one minus correlation coefficient) computed from the industrial production series since the nineties.[7] The table shows that the Euro economies are more interlinked across them than with the accession countries economies (distances of 0.61 versus 0.82). In fact, if we test the null hypothesis of no correlation with respect the alternative of positive correlation, we reject the null in more than 50% of the occassions in the case of Euro countries with themselves, but only in 27% in the

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[7]The correlation between two variables in a sample is not the average correlation of the subsamples. Therefore, the correlation across the Euro-area economies is not the average of the correlations between each pair of countries. There is one transformation in the statistical literature, the hyperbolic tangent, that allows us to obtain a statistic with a known distribution for the correlation and combine several correlation coefficients. It consists on:

$$\zeta = \tanh^{-1}(r) = \frac{1}{2}(\ln(1+r) - \ln(1-r)),$$

where $\zeta \backsim N(r, 1/n)$, r is the correlation coefficient and n is the sample size. This is also call the Fisher's z-transformation (David, F. N, 1949). When we want to combine different correlations coefficients (e.i. two correlations r_1 and r_2), we operate in the following way:

$$\zeta' \backsim N(\frac{1}{n_1 + n_2}(n_1 \tanh^{-1}(r_1) + n_2 \tanh^{-1}(r_2)), \frac{1}{n_1 + n_2}).$$

Hence, we undo the transformation to get a correlation coeffcient which summarizes both ($r = \tanh(\zeta')$). In the case of correlation coefficients, this is a more suitable form of combination than a simple average.

case of accession countries with themselves.[8] However, according to this measure, this link is previous to the creation of the Eurozone (the distance computed from series since the sixties to the eighties is 0.56, and the null of no correlation is rejected in 73% of cases). A summary of the information about all the pair of cross correlation across European economies is displayed in Figure 2. This figure plots the kernel estimation of the density function of the distances for two groups of countries, the Euro economies and the accession countries. The former countries presents a distribution of the distances more concentrated around a smaller mean than the latter countries. In addition, and as explained in the figure, a test of equality of the correlation mean of these two groups clearly rejects the null of equality for any standard critical value.

2.4 Synchronization of cycles. Measure 2. Forni et al. (2001)

It is well-known that a time series can be expressed as a sum of infinite sinusoidal functions or waves with different frequencies and amplitudes. This is what is called the *spectral decomposition* of a time series. This decomposition allows the disaggregation of a time series into components of different periodicities. The study of business cycles is based on the components with periodicities ranging from 1.5 to 8 years. In terms of frequencies, this implies frequencies from 0.07 to 0.35 radians.

If we want to know the explanatory power of each component in the behaviour of the original series, it is possible to use the spectral and cross-spectral density functions. Thus, the spectral density would be a function that assigns the variance of variable x_t to intervals of frequencies (ω). This function has the following form,

$$S_x\left(\omega\right) = \frac{1}{2\pi} \sum_{h=-\infty}^{\infty} e^{-ih\omega} \gamma_x\left(h\right) = \frac{\gamma_x\left(e^{i\omega}\right)}{2\pi}, \tag{10}$$

where $\gamma_x(h)$ is the autocovariance function, ω holds $-\pi \leq \omega \leq \pi$, and $\gamma_x\left(e^{i\omega}\right)$ is the autocovariance generating function. In the bivariate case, the spectral function is known as the cross-spectral density function, which assigns the covariance between two variables

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[8]We have bootstrapped the VAR forecasts errors for different forecast horizons. With this distribution, we are able to calculate a 90% confidence interval for each correlation coefficient.

to different frequencies,

$$S_{x,y}(\omega) = \frac{1}{2\pi} \sum_{h=-\infty}^{\infty} e^{-ih\omega} \gamma_{x,y}(h) = \frac{\gamma_{x,y}(e^{i\omega})}{2\pi}, \qquad (11)$$

where $\gamma_{x,y}(h)$ is the cross-covariance function, ω again holds $-\pi \le \omega \le \pi$, and $\gamma_{x,y}(e^{i\omega})$ is the cross-covariance generating function.

Using this decomposition of variance, through both functions calculated in the frequency band of the business cycle, we are able compute the correlation in frequency domain. In particular, we choose the measure of correlation defined by Forni et al (2001) that is called *dynamic correlation*:

$$\rho_{x,y}(\omega) = \frac{\text{Real}(S_{x,y}(\omega))}{\sqrt{S_x(\omega) S_y(\omega)}}. \qquad (12)$$

The main advantages of this measure of correlation is that it is a real number, takes values between -1 and 1, incorporating the sign of the relation and that it permits to calculate the correlation for each band of frequencies.[9]

We need some final remarks concerning the estimation of the spectrum. First, Granger and Hatanaka (1964) showed that the spectral and cross-spectral methods applied to non-stationary series should be used with caution, since the variance of these series tends to infinite. In these cases, the spectrum should be estimated as an approximation (pseudo-spectrum) and the series should be transformed to stationary. Hence, before estimating the spectrum, we need some filter to reduce or eliminate the lower frequencies of the series. The filter used for removing trends depends on what subsequent analysis one intends to perform. If, for example, one is interested in studying long cycles, the first differences appear to be inappropriate as although they attenuate the power of low frequencies, they give a lot of importance to the high frequencies. The resulting distortion may obscure important features of the original series. In order to be as general as possible, we use the most popular filter to remove low frequency movements of the data, the Hodrick Prescott (HP) filter (see Hodrick and Prescott, 1980 and 1997). The HP filter is a symmetric

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[9]This measure overcomes some problems of other measures used in the literature. The "coherency" can take imaginary values and the "squared coherence" does not keep the sign of the relation. See Forni et al. (2001) for further details.

linear filter that decomposes a time series into two components: a long-term trend and a stationary cycle. This filter requires the specification of one parameter (usually called lambda) which penalizes the bad fit and the lack of smoothness in the trend component. This parameter depends on the periodicity of the data and the band of frequencies which we are interested in.[10] Second, to overcome the asymptotic inconsistency of the estimates, we use the standard Barlett's lag spectral window (this weights the sample covariance in the spectral estimator and reduces the variance). Third, as it is impossible to calculate the sum of infinite terms, we truncate it with a truncation parameter equals to the sample size to the power of one third.[11]

The dynamic correlations for all the pairwise combination of countries are collected in the Appendix A, Table A2, and they are summarized in Table 2. These tables confirm the results of the previous section. The Euro area countries are closer than accession countries (distances of 0.55 versus 0.66). Besides, if we test the null hypothesis of no correlation with respect the alternative of positive correlation, we reject the null in more than 65% of the occasions in the case of Euro countries with themselves, and 45% in the case of accession countries with themselves.[12] And, with respect the Euro Area countries, this link is also previous to the creation of the EMU (distance of 0.44 since the sixties to the eighties, and 83% of rejections of the null of no correlation among Euro countries). As in the previous section, we complete the description of the results in Figure 3 where we also present the test that clearly reject the equality of means.

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[10] We have applied the most commonly used lambda for monthly series of $14,400.$. However, we have come to similar results using other values which extract longer cycles as, for example, the lambda of $129,119$ proposed by Maravall and del Río (2001).

[11] Whichever lag window function is used, either if the truncation parameter M tends to infinite or if it is a function of the sample size T, the asymptotic unbiasedness is guaranteed (see Priestley, 1981). Andrews (1991), proposes using $M = O(T^{1/3})$ when we work with Bartlett window. In our work we employed values from 3 to 6, according to the formula $M = T^{1/3}$.

[12] We use, as in the previous section, the Fisher transformation in order to obtain a standard error for the correlation coefficient. Obviously, after calculating the Fisher transformation, we use the delta method to obtain the standard errors of the correlation coefficients.

2.5 Synchronization of cycles. Measure 3. Harding and Pagan (2002)

In this section, we describe a third approach to assess the degree of synchronicity among the countries' business cycle. In this respect, Harding and Pagan (2002) propose to consider the pairwise correlation coefficient among their reference cycles, that is a binary variable having value one when the country is in recession and zero otherwise.[13] Unfortunately, with the exception of the US economy, for which the NBER dates its official peaks and troughs, no generally accepted reference cycles appear to be available for the other countries. In this paper, we follow the well-known procedure of Bry and Boschan (1971) to identify the countries' business cycle turning points.[14] These authors develop an algorithm that isolates the local minima and maxima in a series, subject to reasonable constraints on both the length and amplitude of expansions and contractions. Table B in Appendix B shows the output results (classified by decades) of this dating procedure applied to the thirty industrial production series. Note that the NBER reference dates, also shown in the table, provides an obvious standard of comparison for the results of our procedure applied to US data. This shows that the Bry-Boschan procedure identifies US turning points that are either identical or close to the official NBER turning points.[15]

Having a look at these tables, it is easy to anticipate two conclusions about the business cycle synchronization. First, as noted by Massmann and Mitchel (2003), the timing of the European business cycle phases is more synchronous during the period before 1990 than in the period from this date. For example, all of the countries that experienced the first recession of the seventies showed the peak in 1974. However, it does not happen with the first recession of the nineties which depending on the country starts in a range from 1989 to 1992. Second, the synchronization between European and accessing countries is rather limited. In this respect, while more than 80% of the European countries experienced

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[13]These authors show the advantages of using the correlation index instead of the concordance index of Artis et. al (1997) to analyze business cycle synchronicity.

[14]Several authors propose slightly different versions of the Bry-Boschan dating rule. In this respect, Garnier (2003) finds that they lead to similar turning points for most of the industrialized countries.

[15]One noticeable exception is the peak in the last eighties. This seems to be a characteristic of non-parametric dating rules based on industrial production indexes, as documented by Artis et al. (1997) and Garnier (2003).

the first recession of the new century, this percentage is less than 40% for the group of accessing countries.

Harding and Pagan (2002) measured the degree of business cycles synchronicity between country i and country j with the sample correlation between their reference cycles. A simple way to obtain this measure is by the regression

$$\sigma_i^{-1} D_{it} = a_{ij} + \rho_{ij} \sigma_j^{-1} D_{jt} + u_t, \qquad (13)$$

where D_i is the reference cycle of country i, σ_i is its standard deviation, and ρ_{ij} is the sample correlation between the reference cycle of countries i and j. Table 3 shows the mean distance estimated among each of the countries within the Euro area and the accessing countries. With respect to the Euro countries, the distance across Euro economies has not decreased with the implementation of the EMU. At the same time, as in the other previous measures, distances across Euro economies are slightly smaller than distances across accessing countries (0.7 versus 0.73) although in this case, it is remarkable the big distances from accessing countries to the Euro economies (0.93). Information in Table 3 is complemented with the display in Figure 4, where it is clear that, by contrast with the previous distances, it is in the dispersion, and not in the mean where the differences between Euro and accession countries are more evident. Table A3 in the appendix A shows all the individual correlations.

In contrast to the previous measures of business cycle correlations, Harding and Pagan (2002) propose a simple test of the null of no business cycle synchronization by using the t-ratios of the null that the correlation coefficient is zero, allowing for heteroskedasticity and serial correlation. However, we think that this test may be biased to reject the null of no correlation simply because there are more zeroes than ones in the countries' reference cycles since expansions are typically longer than recessions. In this respect, we propose a new approach to develop the test of no business cycle synchronization between countries i and j based on the bootstrap approximation of the t-ratio's true distribution. First, we compute the countries' reference cycles D_{it} using the Bry-Boschan dating procedure. Second, for each country we estimate the probability of being in recession, the probability of being in expansion, and the probability of switching the business cycles phase. Third, given these

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estimates, we generate $10,000$ reference cycle variables sharing the same business cycles characteristics than these two countries. Finally, we compute the p-value associated to the null of zero correlation coefficient. The results of applying this test show that correlation has decreased since the 60s in the Euro area. The percentage of rejections of the null of no correlation is 52% since the sixties, becoming 46% in the nineties. As detected by Garnier (2003), the business cycle phases in the EU countries have become more idiosyncratic. At the same time, the results of the comparison Euro area and accessing countries confirm previous results, correlation across accessing countries is smaller than across Euro countries (46% of rejections of the Euro versus 27% of the accessing) and the same happens with the average rejection in the correlation across Euro and accessing countries (9.84%).

2.6 A comprehensive measure of distance

The result from the previous sections is a collection of distances among countries, applying three different methodologies, which measure the degree of business cycle synchronization among several European and Non-European countries. However, despite the heterogeneity of the approaches, they come to the same two conclusions: synchronization between Euro-zone countries with themselves is higher than synchronization between accession countries with themselves, and there are no appreciable gains in synchronization between EMU countries in the last decade.

As frequently stated in the literature, a mixing of techniques should give more robust results than individual measures by themselves. Given that we do not have any a priori on which is the most accurate measure, we again follow the Fisher transformation to combine them into a comprehensive measure of distance.[16] Following this strategy, Table A4 (in Appendix A) displays all distances across all the economies. We summarize these combined distances in Table 4 and Figure 5. A test of the null hypothesis that the mean or the volatility of distances across Euro and accessing economies are equal rejects both

[16]The reader could think of ways to give more weight to some measure versus the others. However, it is worth mention, that potential ways of weighting the measures as could be the dispersion of rates (more weight to the measure with less dispersion) do not help in this case because the standard error of the distribution of distances for each measure is the same.

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hypothesis. Again, the conclusion is that Euro economies seem to be more homogeneous and closer together than the accession countries.

We explore the combined distances in the following subsections by using both *multidimensional scaling* techniques, that are designed to represent distance measures among objects on a plane (such as a map), and *cluster analysis* techniques, that are designed to classify objects into groups. The former is concerned with the geometric representation, while the latter is concerned with the group identification.

2.6.1   Multidimensional Scaling

Multidimensional Scaling (MDS) techniques (Cox and Cox, 1994) seek to find a low dimensional coordinate system to represent n-dimensional objects and create a map of lower dimension (k) which gives approximate distances among objects. The k-dimensional coordinates of the projection of any two objects, r and s, are computed by minimizing a measure of the squared sum of divergences between the true distances $(d_{r,s})$ and the approximate distances $(\widehat{d}_{r,s})$ among these objects.[17] That is,

$$min_{\widehat{d}_{rs}} \frac{\sum_{r,s}(d_{r,s} - \widehat{d}_{r,s})^2}{\sum_{r,s} d_{r,s}^2}, \tag{14}$$

with

$$\widehat{d}_{r,s} = (||z_r - z_s||^2)^{1/2} = \left[\sum_{i=1}^{k}(z_{ri} - z_{si})^2\right]^{1/2}, \tag{15}$$

where z_r and z_s are the k-dimensional projection of the objects r and s, and z_{ri} and z_{si} are the k dimensions of each object. It is noticeable that MDS is equivalent to using k principal components.[18]

In the case of 2-dimensional representations, the resulting picture is much easier to interpret than distances in higher dimensional spaces because it allows plotting the distances in a plane. In the resulting map, countries which present big dissimilarities have representations in the plane which are far away from each other. Figure 6 represents the map of the average distances (mean of distances among countries obtained with the above three methods) using MDS. This representation gives us a glimpse of the how close are

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[17]This measure is usually called the *Stardardized Residual Sum of Square* (STRESS).

[18]We refer the reader to Kruskal (1964) and Timm (2002) for more details.

the cycles among countries. It can be seen, for example, that United Kingdom cycles are closer to those of Canada and United States than to the Euro area countries. Euroarea countries are closer to each other than to any other group of countries, and the accessing countries are far from each other.

2.6.2 Cluster analysis of business cycle synchronization

In this section, we try to identify clusters of countries attending to their business cycle synchronization. Countries in the same cluster will have more syncronization across them than countries in other groups. There are different methods to do this grouping. First, we use *hierarchical clustering* algorithms, which enable us to determine the number of clusters (explanatory method). Secondly, we use this information to apply *non-hierarchical clustering* or *partitioning* algorithms (confirmatory method), which search the best partition given the number of clusters.[19]

1st step: Hierarchical clustering.

Hierarchical algorithms are used to generate groups from a set of individual items. The algorithms begin with each item forming its own cluster. Then, the clusters are combined iteratively with the two "most similar" clusters employing some criteria, until all of them form a single cluster.[20]

When we represent the sequence of cluster solutions in a plot we obtain a *tree diagram or dendogram*. The tree starts with the leaves at the bottom, which are the original items. Then, the pair with the lowest distance forms the first group. In the following steps, the items or clusters are successively combined, forming the branches of the tree until we get at the top of the graphic. The height of the tree represents the level of dissimilarity at which observations or clusters are merged. The higher the height of the tree, the more dissimilar are the observations contained in the clusters. When a great jump has to be given to join two groups, it implies a big intergroup dissimilarity. The optimal number of groups is often situated at those junctures.

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[19] In this section we just describe an overview of clustering methods. For a more detailed view, see chapter 9 in Timm (2002).

[20] We use the "most similar" criterium of Ward (1963) that is based on the minimal increment of within-group sum of squares.

Figure 7 shows the dendogram for our set of distances among countries.[21] This algorithm joins items or clusters based upon minimizing the increase in the sum of squares of distances within clusters. Looking at the figure, we can observe big jumps in forming two, three and four groups. We do not have a clear tool to decide which is the optimal number of groups. We will try in the next step these three possible options. However, just looking at the tree, we can observe a group formed by most of the EU countries, another group formed by the US and relatives, a third group with most of the accession countries, and a fourth group with three "atypicals", Cyprus, Greece and Portugal.

2nd step: Non-hierarchical clustering.

These algorithms try to find a "good" partition, in the sense that objects of the same cluster should be closed to each other, whereas objects of different clusters should be far away. They classify the data into k groups (k is given by the user) satisfying the requirements that each group must contains at least one object, and that each object must belong to exactly one group. These methods are usually called partitioning methods since they make a clear-cut decision. In this paper, we follow Kaufman and Rousseeuw (1990) to employ the k-medoid method.[22]

In the previous step, the data have revealed us that there may be between two and four clusters of countries. Hence, we start by considering four groups. The fact that one of the cluster includes countries that are basically atypicals implies that once we decide four groups, these atypicals do not form a group but they get integrated in the other groups, because the distance across them is too big to link themselves together. On the other side, allowing just for two groups make one group too big, including the atypicals, all the EU countries and the US and others, with very high heterogeneity across them. Therefore, we try three groups, obtaining the most sensible characterization of the data with the first cluster that includes Euro Area economies (except Finland) plus Denmark, Sweden, Cyprus, Lithuania, Slovenia and Hungary, the second cluster includes the United States and other industrialized economies as Canada, United Kingdom, Japan and Finland. The

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[21]For robustness, we constructed the dendograms for two other criteria, the average link and complete link methods, leading to similar results.

[22]These authors show the advantages of the k-medoid method of Vinod (1969) with respect to others clustering method as the k-means method of McQueen (1967).

last cluster is the cluster of accession countries: Latvia, Estonia, Slovakia, Czech Republic, Romania, Turkey, Norway and Poland. Figure 8 displays the resulting clusters from the k-medoid method when imposing three groups.[23]

3   Is there a European attractor?

Most of the papers cited in the introduction that deal with the problem of European business cycle comovements or even world business cycle comovements, consider a leading economy or an attractor formed by a weighted average of all the economies of the area. In this section we want to check if this attractor matches with what we find in the pictures and maps previously showed in the paper. The papers that analyze how important is an attractor in defining the comovements across economies usually try to decompose the idiosyncratic and common components in each of the series analyzing how much of the variance can be explained from each of them.[24] In order to check if a common attractor could explain the comovements across economies we propose a new methodology that, to our knowledge has not been used in the previous literature.

The idea is the following: If there exist an attractor, most of the distances between the leading country and the rest of countries would be small, and we would observe a great amount of small distances and a very few large ones. In practical terms, looking at Figure 6, the question to ask is: are those points (countries) in the map randomly distributed or is there any kind of attractor that keep them together? In order to answer this question, we propose the following exercise. First, we normalize the distances to include them in a square of dimensions 1 by 1. Second, we generate 27 observations (30 countries minus Japan, US and Canada) from a bivariate uniform distribution and we calculate the

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[23]A word of caution must be said when interpreting Figure 8. Even though we plot three groups, the average similarities between groups are very small in all cases. We have computed the "silhouette width" (Rousseeuw, 1987), a measure of cohesion within a cluster with respect to the neighbour clusters. A value close to one means that countries are well clustered. A small coefficient means poor clustering structure. In our case we have obtained silhouette width values of 0.2 or 0.3 for each cluster. Special mention deserves the case of Hungary with a high negative value for its silhouette width which suggest that the methodology has trouble in assigning this economy to any of the existing groups.

[24]Bordo and Helbling (2003) is a good example.

distances between each pair of points.[25] We repeat this exercise $10,000$ times and we generate the density function of those distances between each pair of countries (Figure 9 top). The plotted distribution represents the distances across economies when there is no attractor across them (they have been generated by a uniform distribution).[26] Third, we generate 27 observations with the same support space but coming from a bivariate normal distribution, where an attractor is clear. We repeat the exercise $10,000$ times and show the distribution of the distances (Figure 9 middle). As we can see, in the case of one attractor, there is a concentration of small distances across the points, implying a higher value for the skewness than in the case of the uniform distribution.

Additionally, we consider the possibility of the existence of two attractors. In order to simulate economies with two attractors we consider a mixture of bivariate normals. If this is the data generating process of the data and the distances between the two attractors is big enough, we will expect a bimodal distribution as the one plotted in Figure 9 (bottom). We have generated the plot by extracting $10,000$ times observations from a mixture of normals. The bimodality comes from the fact that there is a set of short distances associated with observations that are generated by the same normal and a set of long distances associated with observations that has been extracted from different normals.[27]

We then represent the estimated distribution of the distances of the actual data, plotted in Figure 10. There are a few basic statistics that could help us to distinguish which is the distribution that best describe the data generating process of the observations. High values of the skewness will imply evidence of the existence of one attractor and bimodality will be evidence of two attractors. Table 5 presents the basic statistics of the different distributions of the simulated and observed data. Even though we concentrate our explanation on the combined measure of distance, the results are extremely robust to any of the three other measures, as shown in Table 5. We can observe that the estimated skewness of the

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[25]For this exercise, we consider all the European economies in order to maximize the number of observations used for the kernel density estimation.

[26]The plot represents the density function of the distances across the 27 points, generated $10,000$ times. The density function has been approximated with a kernel estimator following Silverman (1986).

[27]We use a 0.5 probability for mixing the two normals.

observed data is -0.08, which is statistically different than the estimated value for one attractor, 0.65 (p-value of equality of the coefficients is 0.00) but not different from the value estimated for the uniform, 0.20 (p-value 0.15). With respect to the existence of two attractors, the bimodality index of the data is 0.41, below the critical value of 0.55.[28] However, the hypothesis of two attractors implies an estimated modality index of 0.59. Out of this experiment, we obtain no evidence of the existence of one or two attractors in the comovements across European economies. The null of no attractor can not be rejected.

4 Can distances across economies be explained?

In the paper, we have shown that some economies are closer than others. However, as economists, we might want to understand what is behind those distances. Are there any macroeconomic variables that could help us to explain these distances? The attempt to answer these questions is not new in the literature. Some papers have tried to explain these facts but in different contexts. A seminal paper in this literature is Frankel and Rose (1998), where they introduce the importance of trade in explaining the correlations across economies, carefully considering the endogeneity of this variable in the regression of correlation measures and trade. Clark and Van Wincoop (2001) analyze correlations across regions in the US and Europe, with a different measure of correlations (basically annual rates of growth). Bordo and Helbling (2003) analyze annual data from 1880 to 2001, trying to measure the effect of the exchange rate regime on the correlations.[29] The results are mixed but they all coincide that trade linkages are relevant in explaining comovements.

We want to explain comovements using our measures trying to incorporate in the analysis as much variables as we can with the only restriction that they should be available

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[28]The bimodality index Timm (2002, pag. 535) is defined by:

$$BM = (m_3^2 + 1)/[m_4 + 3(n-1)^2/(n-2)(n-3)],$$

where m_3 is the skewness coefficient, m_4 is the kurtosis coefficient, and n is the number of observations.

[29]They use also three different measures of the correlations, different to ours because they concentrate more on the static correlations rather than in the dynamics concepts that we consider. In their case, it makes more sense to contemplate different measures of static correlations because they observe long series of annual data.

for all the countries in the sample. We careful explain in Appendix D the data sources and the exact definition of each variable used. After trying different specifications, the most successful one is displayed in Table 6.[30] In this table, all the variables represent differences from country i to j. For example, the variable called percentage of industry means the differences in percentage of industry output divided by total output in country i and country j. As we can see, the distances can be explained, partially by the specialization of the economy, captured by differences in the percentage of industry production in total production and percentage of agriculture in total production. Other significant variables are differences in average saving ratio and average labor productivity. These variables are basically related to the structure of the economy, both, on the production side (the productivity) and on the consumer's side (the saving ratio).

Obviously, the trade variable is fundamental in explaining the relations across economies. We move slightly away from the standard measures of trade linkages in the literature.[31] We want to capture the transmission of the business cycle comovements through trade. We assume that a country i can export or import its cycle to another country j if the proportion of imports or exports coming in or going to the other country is high. In order to account for those relations, we create the trade variable as the maximum of two different averages (over the sample): the proportion of exports of country i that go to country j and the proportion of exports of country j to country i.[32] For example, in the case of Austria and Germany, the average proportion of exports of Austria going to Germany is 37%. The average proportion of exports of Germany going to Austria is 5%. Therefore, for this pair of countries we will use 37% as the trade linkages across them.[33]

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[30]Table 6 presents the results for the combination of distances. Just for completeness, the results for each of the individual distances are displayed in Appendix C.

[31]We also include the definition of trade linkage proposed by Frankel and Rose (1998) in terms of the sumation of exports and imports from country i to country j, divided by the total amount of export and imports of country i plus country j, with very similar results.

[32]We tried the same measure with imports with extermely similar results. Actually, the correlation between both measures is 0.93.

[33]The idea behind using the maximum is that, if business cycles are linked to trade, when a small economy has strong trade linkages with a big economy, we will observe that the business cycle of the small

However, the trade variable presents a serious problem of endogeneity.[34] We solve this problem by estimating the equation by instrumental variables. We use the standard instruments in the literature for explaining trade, a border dummy, a Euro dummy, a European Union dummy, the log of geographical distances, and the absolute difference of the log population.[35] The results of Table 6 show that this is a very important variable in explaining the business cycle comovements and with the appropriate (negative) sign. Pairs of countries with a high level of this variable are closer together, which implies that there is a transmission of the cycle through trade. Countries that are more linked by trade are more linked in their business cycles.

Finally, it is important to remark the role of the policy variables. Fiscal variables are significant (the size of the public balance on the GDP) but monetary policy related variables seem not to explain any of the cyclical differences. We tried lots of possible combinations to include monetary policy variables (inflation differentials, inflation correlations, etc), but the results were not very satisfactory. In all cases, the macro variables used as explanatory variables are sample means for the longer period of information available. We pretend to capture "structure" of the economy and avoid as much as possible all the cyclical variation in the variables. We consider that our results are fundamentally different from the previous results found in the literature where most of the variables but trade were non significant. We find a role for different macro-variables in explaining the comovements across economies.

economy is linked to the business cycle of the big one.

[34]It might be a problem for some other variables used in the estimation, particularly the policy ones. However, we think that the problem is partially solved by taking averages at the beginning of the sample as explanatory variables for future comovements. This caveat do not apply so clearly to trade because trade structures and trade relations are deeply related with business cycle comovements.

[35]The dummies take the value 1 when both countries share a common border or both belong to the Euro-area or EU, respectively. Sargan test for the correct specification of the orthogonality restrictions accepts the null of correct specification (p-value 0.33).

5   Conclusion

We think that this paper has different lessons according to the interest of the reader. Much of the papers that analyze international links among economies usually assume that there is an "European business cycle", which is usually associated to some economies with a leading role in the area. This paper tries to go further by testing if such business cycle attractor actually exists. For this attempt, we present a comprehensive methodology to characterize the comovements across the economies. In addition, we propose a new method to test for statistical support of the supposed attractor. Using this test, we show that there is no evidence of the existence of neither one nor two attractors in the comovements across European economies. Obviously, this result put a question mark in those papers that either implicitly or explicitly assume that it exists.

In addition, we consider two features of the international business cycles. The first one, is related to the evolution of the business cycle synchronization. As Stock and Watson (2003) have recently documented, we show that the international economies seem to be less (rather than more) synchronized in the last fifteen years. The second one, is related to the role of trade in explaining international business cycle transmissions. In contrast to the standard results in the literature, we find that, apart from trade, there is a significant role for other macroeconomic variables (structural and some economic policy variables) to explain business cycle comovements.

Finally, due to the imminent incorporation of ten new members to the European Union, we think that the analysis of similitudes and differences among the actual members and the newcomers is going to be a source of many studies. In the context of the business cycles, this is the first paper that proposes a systematic analysis of these countries' linkages. We show that the distances across Euro economies are more closely linked than distances across newcomers, and these newcomers are on average further away from the Euro countries than across themselves. Finally, we have shown that the linkages across Euro economies are prior to the establishment of the union, showing that the smooth transition towards a more integrated economic area could be due to previous strong business cycles correlations, fundamentally through trade. This is not the case of the current enlargement because the

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differences among the newcomers and the current members (and among themselves) seem to be much more important than the differences that the actual members exhibited prior to the establishment of the union.

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Distances across economies

(Sample: 1990.1*-2003.01)

Table 1
Measure 1: Distances based on *VAR estimations*

	Euro	Candidates
Euro	0.61	0.83
	(0.06)	*(0.05)*
Candidates	-	0.82
		(0.04)

The distance across the Euro area countries from 1965.1-1989.12 is 0.56 (0.04).

Table 2
Measure 2: Distances based on the Spectrum

	Euro	Candidates
Euro	0.55	0.7
	(0.06)	*(0.06)*
Candidates	-	0.66
		(0.05)

The distance across the Euro area countries from 1965.1-1989.12 is 0.44 (0.05) .

Table 3
Measure 3: Distances based on Harding and Pagan (2002)

	Euro	Candidates
Euro	0.7	0.93
	(0.05)	*(0.05)*
Candidates	-	0.73
		(0.04)

The distance across the Euro area countries from 1965.1-1989.12 is 0.65 (0.04).

Table 4
Distances based on a combination of the before three measures

	Euro	Candidates
Euro	0.62	0.82
	(0.06)	*(0.05)*
Candidates	-	0.73
		(0.04)

The distance across the Euro area countries from 1965.1-1989.12 is 0.55 (0.05).

Notes:

Tables 1 to 4 describe the combined distance across economies.

Distance is measured as 1 minus the correlation. Standard errrors are in parenthesis.

* The sample starts in 1992 for all the accession countries but Turkey and Cyprus , because the first two
years after the fall of the communist regimen had exceptional characteristics (see footnote 3 in the main text).

Table 5
Is there an European Attractor? Some important statistics

		Mean	Median	Min	Max	Std. Dev	Skewness	Kurtosis	BM[*]
SIMULATED	no attractor	0.52	0.51	0.00	1.36	0.25	0.20	-0.68	0.44
	one attractor	0.36	0.33	0.00	1.28	0.19	0.65	0.26	0.42
	two attractors	0.44	0.41	0.00	1.18	0.24	0.19	-1.19	0.59

	Our Sample	Mean	Median	Min	Max	Std. Dev	Skewness	Kurtosis	BM[*]
OBSERVED	Measure 1	0.79	0.81	0.03	1.40	0.26	-0.15	-0.44	0.40
	Measure 2	0.68	0.67	0.11	1.47	0.27	0.24	-0.41	0.40
	Measure 3	0.84	0.84	0.05	1.47	0.27	-0.16	-0.45	0.40
	Combined Dist.	0.76	0.77	0.18	1.31	0.23	-0.08	-0.56	0.41

[*] BM refers to the bimodality index. Values bigger than 0.55 indicate the existence of bimodal or multimodal distributions.

Notes: The table collects the summary of most relevant statistics for the distributions of our three measures of business cycles distances and for the combination of these three measures. We have only into account the sample of european countries (all the countries considered except US, Canada and Japan). At the top of the table there are those statistics for the simulation exercises of distances associated with the existence of no attractors, one and two attractors. (More details in the main text.)

Table 6

Can distances be explained?
Dependant variable:
Combined Distances of Business Cycles

	OLS	IV
Constant	0.578	0.583
	(0.0249)	(0.0311)
%Industry	0.839	0.830
	(0.1825)	(0.1863)
%Agriculture	1.547	1.549
	(0.259)	(0.2591)
Saving Ratio	0.362	0.356
	(0.1665)	(0.1680)
Labor Productivity	0.080	0.078
	(0.0441)	(0.0446)
Public Balance	0.557	0.545
	(0.2356)	(0.2412)
Trade (%Exports)	-0.585	-0.638
	(0.1371)	(0.2656)
R squared	30%	

Notes: The table shows the estimated coefficients for the OLS and instrumental variables (IV) regression of the distances across business cycles in different economies and distances of those economies in each of the macroeconomic variables.The instruments employed to solve the possible endogeneity problem of trade variable are: log of the geographical distance between countries, border dummy, euro dummy, EU dummy and the absolute differences between the logs of population.
The results for each of the alternative measures of distances are displayed in the tables of Appendix C.
All the explanatory variables are explained in Appendix D.
Standard errors are in parenthesis.

Figure 1
A first graphical approach
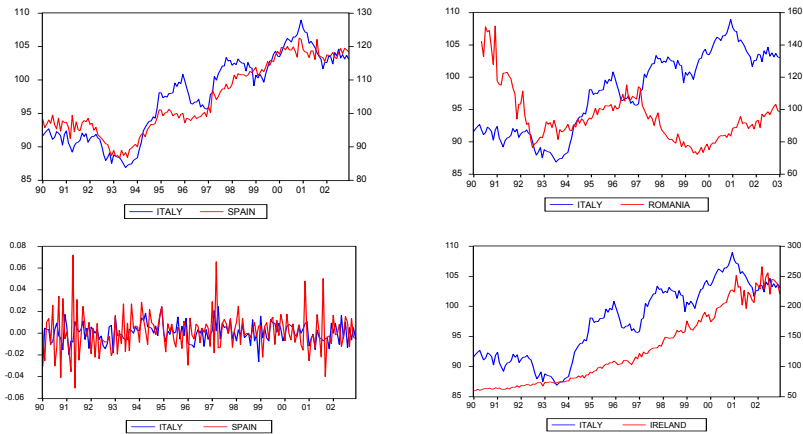
Note: The top left figure plots the levels of the Industrial Production series for Italy and Spain and the top right, for Italy and Romania. The bottom left figure represents the rates of growth of the Industrial Production for Italy and Spain, and the bottom right the levels for Italy and Ireland.

Figure 2
Distribution of distances based on *VAR estimations*.
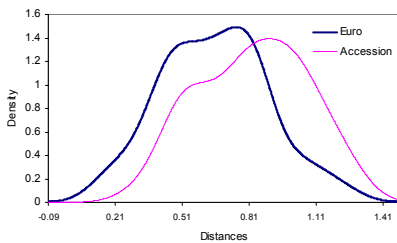
H_o: Euro mean = Acces. mean

p-value: < 0.01

H_o: Euro variance = Acces. variance

p-value: 0.90

Note: The figure plots the estimated density function of the distribution of distances. The dark line represents the Euro area data, the clear line is the accessing countries data.

Figure 3
Distribution of distances based on *Spectrum*.
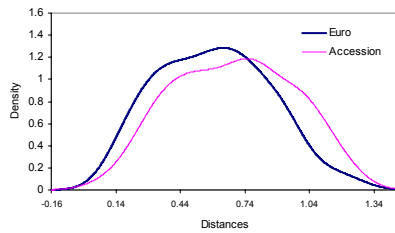
H_o: Euro mean = Acces. mean
p-value: 0.03
H_o: Euro variance = Acces. variance
p-value: 0.68

Note: The figure plots the estimated density function of the distribution of distances. The dark line represents the Euro area data, the clear line is the accessing countries data.

Figure 4
Distribution of distances based on *Harding and Pagan, 2002*.
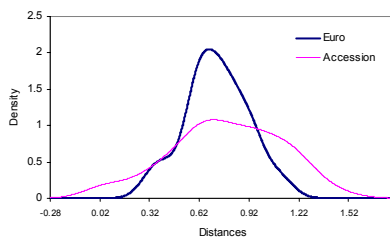
H_o: Euro mean = Acces. mean
p-value: 0.12
H_o: Euro variance = Acces. variance
p-value: 0.00

Note: The figure plots the estimated density function of the distribution of distances. The dark line represents the Euro area data, the clear line is the accessing countries data.

Figure 5
Distribution of distances based on *Combined distances*
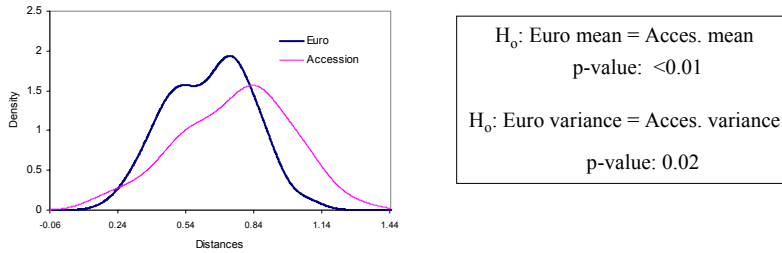
	H_o: Euro mean = Acces. mean
	p-value: <0.01
	H_o: Euro variance = Acces. variance
	p-value: 0.02

Note: The figure plots the estimated density function of the distribution of distances. The dark line represents the Euro area data, the clear line is the accessing countries data.

Figure 6
Map of average distances (Multidimensional Scaling)
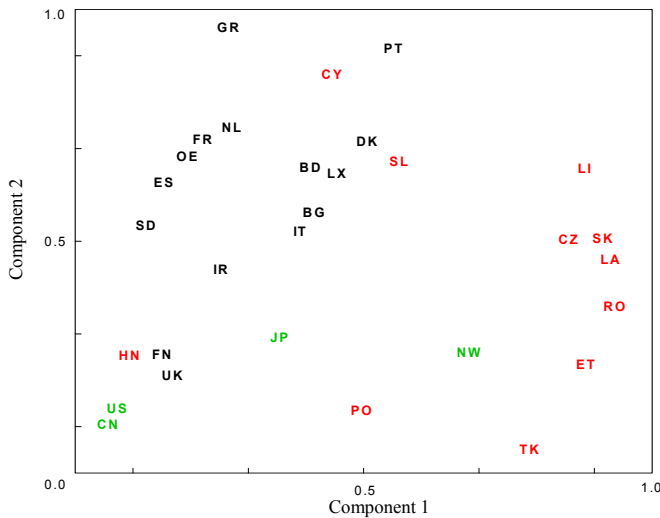
Note: The figure plots in a two dimensional scale the distances across the economies.
* The symbols used to represent countries are collected in Appendix D.

Figure 7
Hierarchical clustering (Timm, 2002)

Tree of combined distances
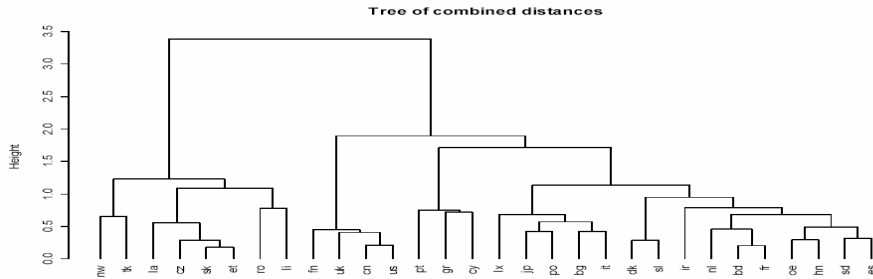
Note: The graph plots a tree where the height represents the level of dissimilarity at which observations or clusters are merged.
* The symbols used to represent countries are explained in Appendix D.

Figure 8
Non-hierarchical clustering (Kaufman and Rousseeuw, 1990)
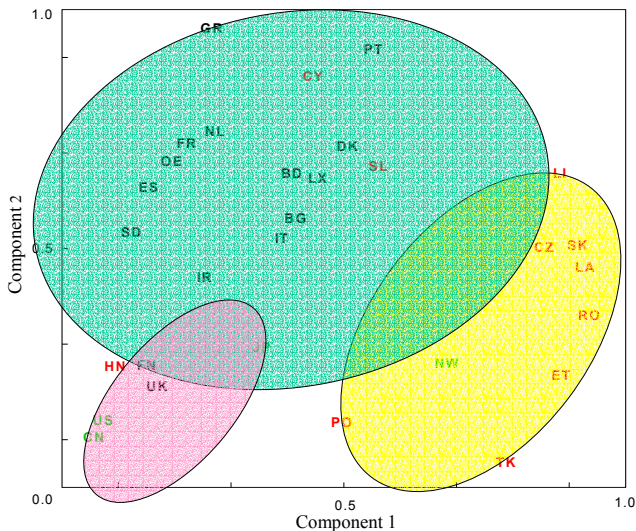
1- **Group " Europeans":** All EMU countries (except Finland), Denmark, Sweden, Cyprus, Lithuania, Slovenia and Hungary.

2- **Group "United States and relatives":** US, Canada, United Kingdom, Japan and Finland.

3- **Group"Accession countries":** Estonia, Slovakia, Czech Republic, Romania, Turkey, Norway, Latvia and Poland.

Note: The figure plots in a two dimensional scale the distances across the economies. And the circles represent the groups obtained in the clustering analysis.
* The symbols used to represent countries are explained in Appendix D.

Figure 9

Density functions of distances across 27 points

Density Function – No attractors

Density Function – One attractor

Density Function – Two attractors
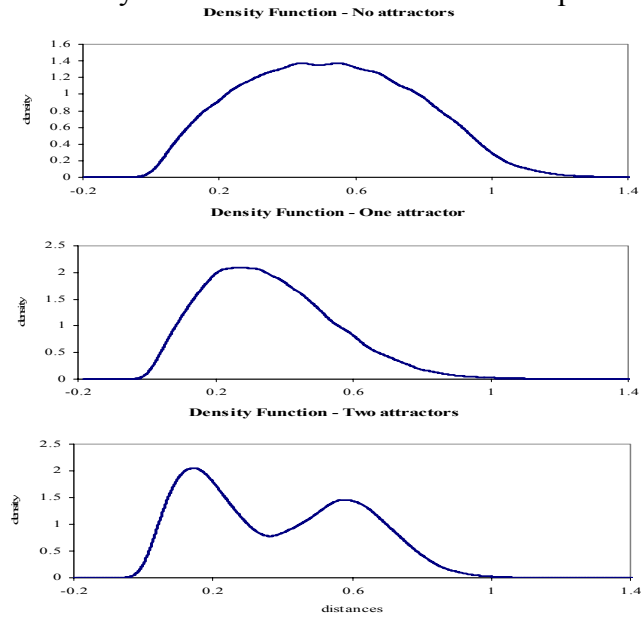
Figure 10

Density function of distances across 27 European countries

Density Function (European Combinated Distances)
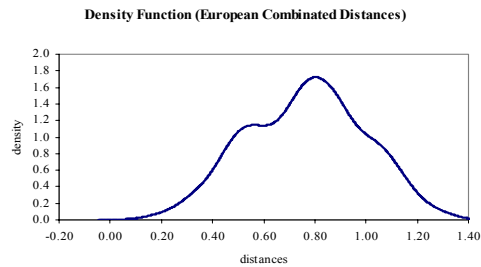
Note: The density function has been approximated with a Kernel estimator
developed in more detail in Silverman, 1986.

Table A1: *Measure 1 - Distances across countries based on VAR (4-years forecast errors)*

	Austria	Belgium	Germany	Greece	Finland	France	Italy	Luxemburg	Netherland	Portugal	Sweden	UK	Canada	Norway	Japan	USA	Spain	Denmark	Ireland	Cyprus	Czech	Hungary	Latvia	Poland	Slovenia	Turkey	Romania	Slovakia	Estonia	Lithuania
Austria	-	0.27	0.15	0.45	0.73	0.49	0.53	0.87	0.45	0.98	0.27	0.86	0.37	0.97	0.64	0.52	0.26	0.43	0.36	1.15	0.95	0.21	1.02	0.46	0.41	0.80	1.29	0.87	0.81	0.03
Belgium		-	0.36	0.57	0.59	0.51	0.42	0.43	0.49	0.49	0.52	0.82	0.85	0.62	0.35	0.45	0.40	0.57	0.51	1.13	1.18	0.54	0.80	0.59	0.54	0.82	1.15	0.62	0.75	0.35
Germany			-	0.72	0.68	0.18	0.61	0.80	0.40	0.87	0.47	0.62	0.86	0.84	0.40	0.55	0.58	0.47	0.75	0.90	0.78	0.65	0.75	0.87	0.40	1.00	1.40	0.70	0.38	0.45
Greece				-	0.86	0.38	0.84	0.68	0.83	1.02	0.73	0.81	1.03	1.04	0.96	0.68	0.82	0.92	0.48	0.85	0.96	0.91	1.11	0.88	0.95	1.19	1.18	1.21	1.16	0.48
Finland					-	0.58	0.65	0.89	1.18	0.84	0.25	0.70	0.23	0.77	0.46	0.49	0.50	0.83	1.00	0.84	1.02	0.22	0.88	0.84	0.77	0.69	1.37	0.73	0.77	0.99
France						-	0.45	0.67	0.41	0.80	0.82	0.59	0.54	0.95	0.57	0.46	0.47	0.35	0.77	1.09	0.79	0.46	0.93	0.89	0.55	0.94	1.35	0.88	0.81	0.94
Italy							-	0.74	0.41	0.76	0.69	0.48	0.44	0.78	0.35	0.56	0.40	0.61	0.64	0.97	0.54	0.56	0.46	0.51	0.67	0.86	1.11	0.69	0.55	0.69
Luxemburg								-	0.84	1.03	0.80	0.64	0.83	0.64	0.82	0.76	0.77	0.83	0.64	0.99	0.77	0.83	0.64	0.60	1.09	1.13	1.22	0.83	0.59	1.20
Netherland									-	1.10	0.68	0.63	0.79	0.93	0.59	0.79	0.45	0.56	0.81	0.83	0.89	0.61	0.92	0.94	0.68	1.11	1.14	0.89	0.81	1.31
Portugal										-	1.25	1.11	0.85	0.95	0.86	0.92	0.97	1.01	0.89	0.83	0.90	1.09	0.85	0.88	1.14	0.87	1.12	0.87	0.91	1.31
Sweden											-	0.58	0.76	0.77	0.45	0.68	0.31	0.59	0.58	0.99	1.24	0.80	1.19	0.82	0.41	0.96	0.95	0.74	1.15	1.14
UK												-	0.22	0.69	0.53	0.34	0.77	0.71	0.62	0.93	1.06	0.58	1.14	0.25	0.65	1.04	1.11	1.05	0.85	1.05
Canada													-	0.92	0.22	0.19	0.71	0.71	0.61	0.98	0.79	0.26	1.02	0.29	0.77	0.98	1.03	0.88	0.72	1.11
Norway														-	1.07	0.87	0.92	0.85	0.94	1.01	0.96	0.98	0.77	0.79	0.97	0.78	1.11	0.80	0.81	1.18
Japan															-	0.30	0.46	0.84	0.68	1.17	0.67	0.60	0.85	0.33	0.81	0.65	0.65	1.02	0.58	0.78
USA																-	0.59	0.66	0.59	0.82	1.13	0.32	1.07	0.35	0.74	0.70	1.42	0.90	0.59	0.97
Spain																	-	0.35	0.63	0.94	0.77	0.43	0.60	0.68	0.42	0.84	1.35	1.02	0.68	1.15
Denmark																		-	0.79	0.66	0.84	0.70	0.74	0.55	0.29	1.15	0.98	0.65	0.62	1.15
Ireland																			-	1.14	0.89	0.86	0.95	0.96	0.78	0.86	1.09	0.89	1.14	1.06
Cyprus																				-	0.90	0.63	1.01	1.19	0.75	1.00	1.20	0.72	0.61	1.19
Czech																					-	0.84	0.54	0.60	0.65	1.01	0.97	0.80	0.49	1.29
Hungary																						-	1.11	0.80	0.72	0.91	1.12	0.85	0.64	1.17
Latvia																							-	0.86	0.82	1.07	1.01	0.68	0.53	1.28
Poland																								-	0.50	0.76	1.02	0.83	0.46	1.06
Slovenia																									-	1.04	0.90	0.53	0.79	0.95
Turkey																										-	1.06	0.95	0.90	0.93
Romania																											-	0.48	0.77	0.54
Slovakia																												-	0.31	0.41
Estonia																													-	0.49
Lithuania																														-

Appendix A

Table A2: *Measure 2 - Distances across countries based on Spectrum (Dynamic correlation at business cycle periodicities)*

	Austria	Belgium	Germany	Greece	Finland	France	Italy	Luxemburg	Netherland	Portugal	Sweden	UK	Canada	Norway	Japan	USA	Spain	Denmark	Ireland	Cyprus	Czech	Hungary	Latvia	Poland	Slovenia	Turkey	Romania	Slovakia	Estonia	Lithuania
Austria	-	0.39	0.21	0.82	0.44	0.21	0.31	0.60	0.45	0.77	0.16	0.52	0.55	0.86	0.48	0.52	0.26	0.44	0.55	0.62	0.71	0.18	0.83	0.39	0.33	0.95	0.99	0.67	0.58	0.96
Belgium		-	0.38	0.94	0.63	0.44	0.33	0.62	0.57	0.77	0.45	0.74	0.68	0.63	0.55	0.60	0.42	0.40	0.46	0.59	0.64	0.47	0.63	0.36	0.45	0.67	0.80	0.52	0.49	0.92
Germany			-	0.93	0.67	0.16	0.29	0.64	0.26	0.68	0.31	0.70	0.84	0.82	0.41	0.74	0.21	0.33	0.66	0.45	0.50	0.32	0.56	0.30	0.20	1.05	0.79	0.61	0.37	0.79
Greece				-	1.06	0.76	0.89	0.93	0.95	0.87	0.90	0.98	1.00	1.30	1.28	1.07	0.77	0.86	0.78	0.64	1.11	0.98	1.19	1.18	0.86	1.42	1.33	1.07	1.47	1.00
Finland					-	0.56	0.53	0.85	0.78	1.23	0.35	0.20	0.26	0.77	0.69	0.27	0.58	0.65	0.65	0.97	0.80	0.20	0.82	0.56	0.48	0.87	1.06	0.77	0.59	0.98
France						-	0.17	0.54	0.38	0.73	0.28	0.57	0.66	0.97	0.65	0.63	0.13	0.29	0.59	0.47	0.48	0.33	0.46	0.38	0.25	1.21	1.01	0.59	0.48	0.61
Italy							-	0.50	0.36	0.77	0.31	0.54	0.51	0.81	0.52	0.54	0.19	0.34	0.39	0.55	0.46	0.29	0.47	0.30	0.41	0.98	0.87	0.48	0.46	0.80
Luxemburg								-	0.72	0.90	0.67	0.67	0.60	0.75	0.59	0.65	0.53	0.70	0.86	0.72	0.70	0.68	0.81	0.33	0.73	1.12	1.03	0.88	0.65	1.34
Netherland									-	0.56	0.40	0.61	0.95	0.78	0.53	0.90	0.47	0.50	0.60	0.55	0.68	0.51	0.78	0.57	0.49	1.26	0.65	0.57	0.82	0.83
Portugal										-	0.77	1.16	1.36	0.97	0.93	1.28	0.83	0.96	0.66	0.74	0.97	1.21	0.92	1.05	1.04	0.79	1.04	1.35	0.68	0.86
Sweden											-	0.42	0.57	0.68	0.53	0.60	0.27	0.42	0.58	0.59	0.71	0.34	0.87	0.50	0.31	1.08	0.83	0.73	0.62	0.94
UK												-	0.29	0.87	0.62	0.30	0.62	0.70	0.73	0.94	0.89	0.29	0.97	0.50	0.55	1.22	0.90	0.83	0.70	1.18
Canada													-	0.98	0.56	0.10	0.58	0.77	0.72	1.00	0.91	0.27	1.04	0.50	0.67	0.84	1.08	0.95	0.74	1.45
Norway														-	0.82	0.93	0.94	0.68	0.89	0.72	0.62	0.87	0.71	0.60	0.75	0.63	0.83	0.87	0.58	1.05
Japan															-	0.54	0.59	0.75	0.82	0.97	0.78	0.49	0.98	0.29	0.72	0.73	0.54	0.80	0.60	1.39
USA																-	0.63	0.72	0.69	0.87	0.82	0.26	0.96	0.40	0.70	0.70	1.16	0.87	0.65	1.30
Spain																	-	0.34	0.70	0.48	0.68	0.37	0.71	0.47	0.27	1.16	1.02	0.78	0.58	0.94
Denmark																		-	0.75	0.43	0.42	0.48	0.47	0.41	0.24	1.09	0.92	0.68	0.41	0.67
Ireland																			-	0.77	0.68	0.54	0.75	0.71	0.79	0.80	1.00	0.59	0.92	0.87
Cyprus																				-	0.77	0.80	1.08	0.71	0.59	1.18	1.17	0.83	0.97	1.05
Czech																					-	0.71	0.11	0.36	0.53	0.79	1.01	0.48	0.27	0.42
Hungary																						-	0.77	0.38	0.42	0.87	0.94	0.75	0.53	0.96
Latvia																							-	0.49	0.63	0.63	1.03	0.32	0.27	0.30
Poland																								-	0.47	0.79	0.81	0.56	0.24	1.03
Slovenia																									-	1.18	0.78	0.69	0.43	0.64
Turkey																										-	1.00	0.84	0.55	0.98
Romania																											-	0.66	0.77	1.01
Slovakia																												-	0.35	0.38
Estonia																													-	0.53
Lithuania																														-

Appendix A

Table A3: *Measure 3 - Distances across countries based on Harding-Pagan (2002)*

	Austria	Belgium	Germany	Greece	Finland	France	Italy	Luxemburg	Netherland	Portugal	Sweden	UK	Canada	Norway	Japan	USA	Spain	Denmark	Ireland	Cyprus	Czech	Hungary	Latvia	Poland	Slovenia	Turkey	Romania	Slovakia	Estonia	Lithuania
Austria	-	0.75	0.57	0.80	0.87	0.36	0.66	0.54	0.33	0.69	0.64	0.94	0.86	0.89	0.62	0.91	0.49	0.57	0.73	0.70	0.91	0.64	1.31	0.97	0.62	1.20	1.19	0.94	1.21	1.11
Belgium		-	0.57	0.74	0.86	0.62	0.54	0.71	0.70	0.65	0.43	0.69	0.70	1.02	0.64	0.76	0.41	0.74	0.77	0.98	0.55	0.61	0.90	0.68	0.53	0.87	0.92	0.46	0.62	1.00
Germany			-	1.16	0.94	0.29	0.75	0.92	0.56	0.93	0.80	0.96	0.78	1.00	0.67	0.92	0.57	0.63	0.70	1.09	0.59	0.70	0.75	0.81	0.62	1.03	1.00	0.53	0.75	0.99
Greece				-	0.95	1.08	0.82	0.58	0.85	0.38	0.58	0.81	1.02	1.15	1.06	0.95	0.76	0.79	1.14	0.69	1.08	1.15	1.37	1.23	0.67	1.31	1.11	1.15	1.19	1.28
Finland					-	0.82	0.63	0.86	0.93	1.11	0.74	0.71	0.32	1.07	1.26	0.95	0.76	1.11	0.76	0.79	1.28	0.61	0.84	0.94	1.20	1.21	1.41	1.29	1.28	0.94
France						-	0.74	0.74	0.41	0.82	0.62	1.06	0.63	1.15	0.52	0.78	0.36	0.81	0.69	0.97	0.84	0.62	1.19	0.95	0.77	1.22	1.16	0.85	1.18	1.19
Italy							-	0.54	0.65	0.78	0.60	0.85	0.63	0.84	0.81	0.65	0.86	0.55	0.66	0.82	0.81	0.58	0.73	0.74	0.60	1.02	0.87	0.60	0.69	1.04
Luxemburg								-	0.76	0.40	0.63	0.94	1.07	1.05	0.72	1.12	0.70	0.67	1.14	0.56	0.62	1.17	0.97	1.00	0.38	1.18	0.98	0.64	0.85	0.85
Netherland									-	0.74	0.63	0.67	0.94	0.78	0.63	0.79	0.62	0.50	0.70	0.88	0.89	0.63	1.39	0.95	0.61	1.22	1.21	0.93	1.20	1.30
Portugal										-	0.64	1.01	1.22	1.20	0.75	1.10	0.84	0.67	1.13	0.72	0.82	1.16	1.30	1.23	0.52	1.24	1.10	0.82	1.15	1.07
Sweden											-	0.63	0.61	1.15	0.62	0.55	0.40	1.04	0.72	1.18	1.06	0.49	1.27	0.83	0.81	1.06	1.01	1.15	1.14	1.21
UK												-	0.71	0.56	1.10	0.43	0.89	0.82	0.75	0.98	0.96	0.61	1.18	0.63	0.90	0.79	1.11	0.89	0.79	1.24
Canada													-	1.06	1.09	0.47	0.34	1.24	0.68	1.12	1.20	0.46	1.18	0.81	1.30	0.99	1.29	1.21	1.19	1.21
Norway														-	0.95	0.95	1.18	0.68	0.84	1.08	0.75	0.87	1.01	0.45	0.64	0.55	0.70	0.71	0.56	1.08
Japan															-	0.94	0.77	0.89	0.76	1.15	0.66	0.68	1.25	0.72	0.68	1.05	0.73	0.69	0.82	1.31
USA																-	0.63	1.18	0.58	1.00	1.18	0.38	1.33	0.75	1.26	0.94	1.25	1.18	1.17	1.25
Spain																	-	0.92	0.74	0.97	0.94	0.58	1.23	0.91	0.79	1.14	1.11	0.98	1.17	1.11
Denmark																		-	1.08	0.67	0.51	1.12	0.94	0.87	0.34	0.99	1.03	0.52	0.64	1.11
Ireland																			-	1.15	1.09	0.22	1.16	0.59	1.13	1.00	1.12	1.09	1.08	1.12
Cyprus																				-	0.90	1.19	0.95	1.28	0.93	1.31	1.47	0.99	1.25	0.97
Czech																					-	1.11	0.68	0.53	0.36	0.70	0.76	0.07	0.05	0.99
Hungary																						-	1.20	0.61	1.16	0.97	1.16	1.11	1.10	1.15
Latvia																							-	0.88	0.73	0.72	0.87	0.61	0.64	0.47
Poland																								-	0.72	0.50	0.71	0.55	0.33	1.14
Slovenia																									-	0.78	0.61	0.26	0.33	0.89
Turkey																										-	0.65	0.61	0.37	0.64
Romania																											-	0.65	0.49	0.83
Slovakia																												-	0.05	0.90
Estonia																													-	0.98
Lithuania																														-

Appendix A

Table A4: D*istances across countries (Combination of the before three measures)*

	Austria	Belgium	Germany	Greece	Finland	France	Italy	Luxemburg	Netherland	Portugal	Sweden	UK	Canada	Norway	Japan	USA	Spain	Denmark	Ireland	Cyprus	Czech	Hungary	Latvia	Poland	Slovenia	Turkey	Romania	Slovakia	Estonia	Lithuania
Austria	-	0.44	0.27	0.68	0.67	0.34	0.48	0.66	0.41	0.81	0.31	0.76	0.57	0.91	0.58	0.64	0.32	0.48	0.53	0.81	0.86	0.30	1.05	0.58	0.44	0.98	1.16	0.82	0.86	0.39
Belgium		-	0.43	0.75	0.69	0.52	0.43	0.58	0.58	0.63	0.46	0.75	0.74	0.75	0.50	0.60	0.41	0.56	0.57	0.89	0.78	0.54	0.77	0.53	0.51	0.79	0.96	0.53	0.62	0.73
Germany			-	0.93	0.76	0.20	0.53	0.78	0.39	0.83	0.50	0.75	0.83	0.89	0.48	0.73	0.42	0.46	0.71	0.79	0.62	0.53	0.68	0.62	0.38	1.03	1.07	0.61	0.48	0.73
Greece				-	0.96	0.71	0.85	0.73	0.88	0.73	0.73	0.87	1.02	1.16	1.10	0.90	0.72	0.86	0.78	0.72	1.05	1.02	1.23	1.10	0.83	1.31	1.21	1.15	1.28	0.91
Finland					-	0.65	0.60	0.87	0.96	1.06	0.41	0.49	0.27	0.87	0.78	0.46	0.55	0.86	0.80	0.86	1.04	0.31	0.84	0.77	0.80	0.92	1.28	0.93	0.88	0.97
France						-	0.40	0.65	0.40	0.78	0.54	0.73	0.61	1.03	0.58	0.62	0.29	0.45	0.68	0.83	0.69	0.46	0.84	0.71	0.49	1.13	1.18	0.77	0.80	0.91
Italy							-	0.59	0.46	0.77	0.51	0.61	0.58	0.80	0.50	0.64	0.36	0.52	0.60	0.77	0.53	0.50	0.55	0.46	0.50	0.95	0.95	0.59	0.56	0.84
Luxemburg								-	0.77	0.69	0.77	0.80	0.76	0.88	0.65	0.86	0.66	0.72	0.94	0.75	0.70	0.89	0.80	0.61	0.70	1.14	1.08	0.78	0.69	1.14
Netherland									-	0.79	0.56	0.64	0.89	0.83	0.58	0.83	0.51	0.52	0.70	0.75	0.82	0.58	1.04	0.81	0.59	1.20	1.00	0.79	0.94	1.15
Portugal										-	0.88	1.09	1.15	1.04	0.85	1.10	0.88	0.88	0.89	0.76	0.90	1.15	1.02	1.06	0.89	1.05	1.00	0.79	1.14	1.08
Sweden											-	0.54	0.64	0.87	0.53	0.61	0.32	0.66	0.62	0.91	1.00	0.52	1.11	0.71	0.48	1.03	0.93	0.87	0.97	1.10
UK												-	0.37	0.70	0.74	0.36	0.76	0.74	0.70	0.95	0.97	0.47	1.10	0.44	0.69	1.02	1.04	0.92	0.78	1.16
Canada													-	0.99	0.56	0.22	0.53	0.90	0.67	1.03	0.97	0.32	1.08	0.50	0.91	0.94	1.14	1.02	0.88	1.26
Norway														-	0.95	0.92	1.02	0.73	0.89	0.93	0.77	0.90	0.83	0.60	0.78	0.65	0.88	0.79	0.64	1.11
Japan															-	0.56	0.60	0.83	0.75	1.10	0.70	0.59	1.03	0.42	0.73	0.81	0.64	0.84	0.66	1.17
USA																-	0.61	0.85	0.62	0.90	1.04	0.32	1.12	0.48	0.89	0.78	1.28	0.98	0.80	1.18
Spain																	-	0.50	0.69	0.78	0.79	0.45	0.84	0.67	0.46	1.05	1.16	0.92	0.80	1.07
Denmark																		-	0.87	0.58	0.57	0.75	0.70	0.59	0.29	1.08	0.97	0.62	0.55	0.97
Ireland																			-	1.02	0.88	0.49	0.95	0.75	0.90	0.89	1.07	0.85	1.05	1.01
Cyprus																				-	0.86	0.87	1.01	1.06	0.75	1.17	1.29	0.84	0.94	1.07
Czech																					-	0.88	0.37	0.49	0.50	0.83	0.91	0.32	0.20	0.88
Hungary																						-	1.02	0.58	0.75	0.92	1.07	0.90	0.74	1.09
Latvia																							-	0.73	0.73	0.80	0.97	0.52	0.46	0.63
Poland																								-	0.56	0.68	0.85	0.64	0.34	1.08
Slovenia																									-	1.00	0.76	0.47	0.50	0.82
Turkey																										-	0.90	0.80	0.58	0.84
Romania																											-	0.59	0.67	0.78
Slovakia																												-	0.18	0.54
Estonia																													-	0.65
Lithuania																														-

Appendix A

Figure A1- Industrial Production Index Euro Area Countries
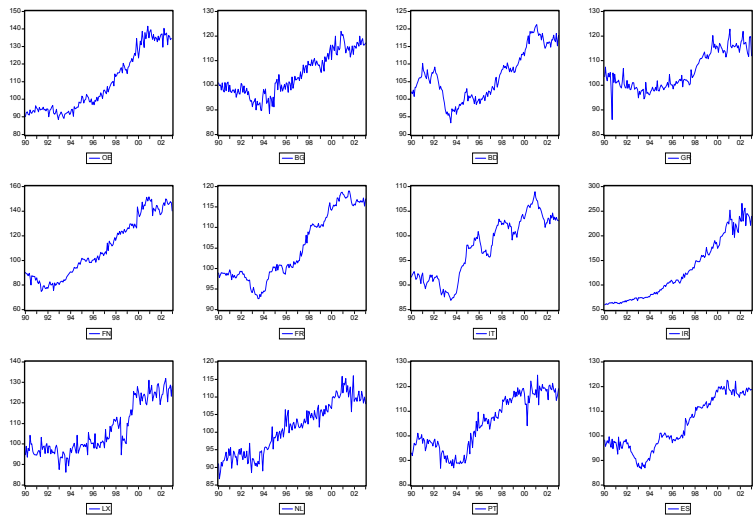
Levels of monthly Industrial Production Index (S.A.)
Source: OECD Main Economic Indicators.
* The symbols used to represent countries are collected in Appendix D.

Figure A1 (cont.)- Industrial Production Index Rest of the EU and other industrialized countries
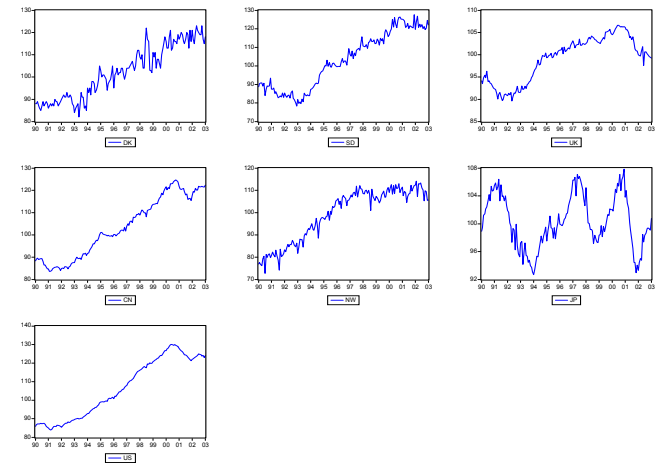
Levels of monthly Industrial Production Index (S.A.)
Source: OECD Main Economic Indicators.
* The symbols used to represent countries are collected in Appendix D.

Figure A1 (cont.)- Industrial Production Index Accession and negotiating countries
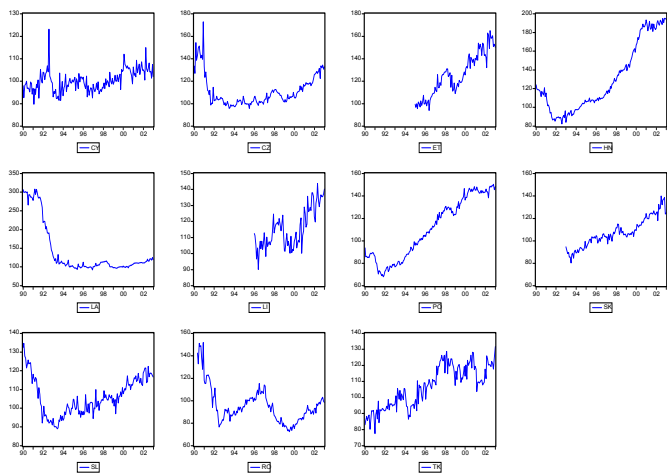
Levels of monthly Industrial Production Index (S.A.)   * The symbols used to represent countries are collected in Appendix D.

Source: OECD Main Economic Indicators and IMF International Financial Statistics.

Appendix B

Table B. Classical business cycle chronologies of Euro-area countries.

	OE	BG	BD	GR	FN	FR	IT	IR	LX	NL	PT	ES
60's												
T									62.05		62.04	
P			66.03			64.04	64.01		65.02		66.04	
T			67.05			64.12	64.08		67.08		67.02	
70's												
P					70.07				70.01			
T					71.03				70.10			
P	74.06	74.06	73.08	74.02	74.07	74.07	74.06		74.08	74.08	74.03	74.08
T	75.10	75.04	75.07	74.07	75.09	75.05	75.04		75.08	75.08	75.08	75.04
P		76.11				76.09	77.01		76.05	76.09		
T		77.09				77.12	77.11		77.08	77.11		
P	79.12	79.12	79.12			79.07		79.09	79.12	79.11		79.08
T	81.07	80.12	82.11			81.04		80.12	81.04	82.11		82.08
80's												
P	82.01	82.04		80.04	81.07	81.12	80.03		82.02			
T	83.01	82.12		81.04	82.07	82.08	83.05		82.12			
P	86.03	85.11		82.05						84.06		
T	86.11	87.01		83.05						86.05		
P		89.07		85.12	89.07		89.12			87.01		89.07
T		91.08		87.06	91.06		91.04			88.04		91.03
90's												
P	91.08	92.01	92.02	89.04		91.12	91.09		90.06	92.01	90.08	91.12
T	93.06	93.11	93.07	93.01		93.08	93.07		93.08	93.06	93.10	93.04
P	95.06		94.12		95.01	95.03	95.12		95.08			95.05
T	96.02		95.10		95.11	95.12	96.12		96.05			96.01
P		98.07	98.07	99.08			97.10		98.02		99.06	
T		99.02	99.02	00.10			98.12		98.07		00.04	
00's												
P	00.11	00.11	01.02		00.12	00.12	00.12	01.02		00.12		00.11
T	01.09	01.09	01.11		01.12	01.12	01.11	01.07		-		01.12
P	02.04			02.04	02.06		02.07		02.06		02.07	
T	-			-	-		-		-		-	

Appendix B

Table B (cont.). Classical business cycle chronologies of other European and non-European countries.

	DK	SD	UK	CN	NW	JP	US	NBER
60's								
P			66.03	69.03	68.05	-	69.08	69.12
T			66.11	70.10	69.04	62.12	70.11	70.11
70's								
P		71.01	70.10		71.07			
T		71.09	72.02		72.03			
P	-	74.06	74.06	74.03	76.08	74.01	73.11	73.11
T	75.03	78.06	75.08	75.05	77.05	75.03	75.05	75.03
P	78.04							
T	79.01							
P	79.10	79.12	79.06	79.07				
T	80.11	82.11	81.05	80.06				
80's								
P				81.04	80.02	80.02	80.01	80.01
T				82.10	80.07	80.08	80.07	80.07
P					81.07	81.10	81.07	81.07
T					82.10	82.10	82.12	82.11
P	86.09	85.09	84.01	86.01		85.05		
T	87.10	86.04	84.08	86.08		86.08		
P	88.12						89.01	
T	89.08						89.07	
90's								
P	92.06	90.04	90.06	89.04		91.05	90.09	90.07
T	93.05	92.12	91.08	91.02		94.01	91.03	91.03
P				95.02				
T				95.12				
P	98.07		98.06		97.10	97.05		
T	98.12		99.02		99.04	98.08		
00's								
P		00.11	00.06	00.10	00.10	00.12	00.06	01.03
T		02.01	-	01.12	01.05	01.11	01.12	-
P	02.05				02.02			
T	-				-			

Appendix B

Table B (cont.). Classical business cycle chronologies of acceding countries.

	CY	CZ	ET	HN	LA	LI	PO	SK	SL	RO	TK
90's											
P	-	90.12		-			-			-	
T	91.02	91.09		91.12			91.11			92.07	
P	92.08	92.09			-			-	-		93.12
T	93.10	93.07			95.06			93.07	93.06		94.05
P	95.08				96.01	-					
T	96.12				96.12	96.06					
P		98.02	98.03		98.05	98.11	98.02	98.03	98.02	97.01	98.03
T		99.01	99.01		99.05	99.08	98.11	99.02	99.04	99.07	99.08
00's											
P	00.02			01.01			00.12				00.10
T	00.12			01.09			01.06				01.03
P	02.04								02.07		
T	-								-		

Appendix C

Can distances be explained?

Table C1 *Dependant variable:*
VAR Distances of Business Cycles

	OLS	IV
Constant	0.557	0.555
	(0.0288)	*(0.0360)*
%Industry	1.214	1.218
	(0.211)	*(0.2153)*
%Agriculture	1.704	1.704
	(0.2993)	*(0.2995)*
Saving Ratio	0.372	0.374
	(0.1925)	*(0.1941)*
Labor Productivity	0.053	0.054
	(0.051)	*(0.0516)*
Public Balance	0.625	0.630
	(0.2723)	*(0.2787)*
Trade (%Exports)	-0.477	-0.455
	(0.1585)	*(0.3069)*
R squared	28%	

Table C2 *Dependant variable:*
Spectral Distances of Business Cycles

	OLS	IV
Constant	0.503	0.523
	(0.0296)	*(0.0371)*
%Industry	0.698	0.658
	(0.217)	*(0.2221)*
%Agriculture	2.042	2.050
	(0.3079)	*(0.3088)*
Saving Ratio	0.420	0.397
	(0.1980)	*(0.2002)*
Labor Productivity	0.001	-0.006
	(0.0524)	*(0.0532)*
Public Balance	0.956	0.901
	(0.2801)	*(0.2874)*
Trade (%Exports)	-0.685	-0.929
	(0.163)	*(0.3165)*
R squared	28%	

Table C3 *Dependant variable:*
Harding Pagan Distances of Business Cycles

	OLS	IV
Constant	0.708	0.704
	(0.0314)	*(0.0393)*
%Industry	0.536	0.544
	(0.2306)	*(0.2353)*
%Agriculture	0.779	0.777
	(0.3271)	*(0.3273)*
Saving Ratio	0.349	0.354
	(0.2103)	*(0.2122)*
Labor Productivity	0.175	0.177
	(0.0557)	*(0.0564)*
Public Balance	-0.024	-0.013
	(0.2976)	*(0.3046)*
Trade (%Exports)	-0.461	-0.411
	(0.1732)	*(0.3354)*
R squared	16%	

Notes: The tables C1, C2 and C3 show the estimated coefficients for the OLS and instrumental variables (IV)
regression of the distances across business cycles in different economies and distances of those economies
in each of the macroeconomic variables.The instruments employed to solve the possible endogeneity problem
of trade variable are: log of the geographical distance between countries, border dummy, euro dummy, EU
dummy and the absolute differences between the logs of population.
All the explanatory variables are explained in Appendix D.
Standard errors are in parenthesis.

Appendix D

Countries and data availability

Industrial Production Index (S.A.)

Euro-area

Country		Sample	Source
Austria	OE	62.01-02.12	OECD -MEI
Belgium	BG	62.01-03.01	OECD -MEI
Germany	BD	62.01-03.01	OECD -MEI
Greece	BR	62.01-03.01	OECD -MEI
Finland	FN	62.01-03.01	OECD -MEI
France	FR	62.01-03.01	OECD -MEI
Italy	IT	62.01-03.01	OECD -MEI
Ireland	IR	75.07-03.01	OECD -MEI
Luxembourg	LX	62.01-03.01	OECD -MEI
Netherlands	NL	62.01-03.01	OECD -MEI
Portugal	PT	62.01-03.01	OECD -MEI
Spain	ES	65.01-03.01	OECD -MEI

European Union

Country		Sample	Source
Denmark	DK	74.01-03.01	OECD - MEI
Sweden	SD	62.01-03.01	OECD - MEI
United Kingdom	UK	62.01-03.01	OECD - MEI

Acceding (by 2007)

Country		Sample	Source
Bulgaria	--	--	--
Romania	RO	90.05-03.01*	OECD - MEI

Negotiating

Country		Sample	Source
Turkey	TK	90.01-03.01	OECD - MEI

Candidates (1st May 2004)

Country		Sample	Source
Cyprus	CY	90.01-03.01	IMF - IFS
Czech Republic	CZ	90.01-03.01*	OECD - MEI
Estonia	ET	95.01-03.01	OECD - MEI
Hungary	HN	90.01-03.01*	OECD - MEI
Latvia	LA	90.01-03.01*	OECD - MEI
Lithuania	LI	96.01-03.01	OECD - MEI
Malta	--	--	--
Poland	PO	90.01-03.01*	OECD - MEI
Slovak Republic	SK	93.01-03.01	IMF - IFS
Slovenia	SL	90.01-03.01*	OECD - MEI

Other countries

Country		Sample	Source
Canada	CN	62.01-03.01	OECD - MEI
Norway	NW	62.01-03.01	OECD - MEI
Japan	JP	62.01-03.01	OECD - MEI
USA	US	62.01-03.01	OECD - MEI

Macro variables

Variable	Smp Aver [1]	Source	Observation
Trade Variable	1989-1998	IMF, Dir Trade	Explained in text.
Saving Ratio	1995	Penn World Table	
%Public Sector	1998-2002	Eurostat	[2]
Inflation	1998-2002	Eurostat	[3]
Labor productiv.	1995-1999	Eurostat	[4]
%Industry	1996-2000	World Devel Report	
%Agriculture	1996-2000	World Devel Report	

[1] The sample average is, in all cases, the maximum allowed by the data

[2] Public balance - Net borrowing/lending of consolidated general government sector as a percentage of GDP

[3] Inflation rate - Annual average rate of change in Harmonized Indices of Consumer Prices (HICPs)

[4] Labour productivity - GDP in PPS per person employed relative to EU-15 (EU-15=100)

* The sample used in the estimation starts in 1992.01.

Dating the European Business Cycle:
Euro area and US recessions 1970-2003

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November 16, 2004

1 Introduction

Many papers have analyzed differences and similarities between the Euro area and the US business cycles (e.g. Artis et al., 1997, Artis and Zhang, 1997, Canova and Ciccarelli, 2003, Del Negro and Otorok, 2003, Monfort et al. 2002, Stock and Watson, 2003). Moreover, the CEPR has recently produced dates of recessions in the Euro area aggregate cycle since 1970 and these dates can now be compared with those established by the NBER on the US cycle. Knowledge on the Euro area cycle is building up and times are perhaps mature to model the interaction between the US and the Euro area cycle and to try understand differences and similarities between business fluctuations in the two economies.

The literature has focused on a variety of concepts of business cycle and stressed similarities rather than differences with the US. The comparison shows that Euro area and US recessions are mostly synchronous, in both cases they are rare events and shorter than expansions which are the "normal state" of both economies.

This paper starts from the observation that although level cycles are strikingly similar in the two economies, the growth rate of output in the Euro area is less volatile than in the US and more persistent. Persistence implies that the effect of an exogenous shock in the Euro area is longer than in the US and, as a consequence, the ratio between long-run variance to total variance of output growth is larger.

How can differences between growth cycles be reconciled with the similarities in level cycles?

We argue that a simple statistical model of joint US - Euro output behavior that is able to produce these characteristics has the following features: (i) Euro area and US output have a common trend, but US output grows at an average rate one fourth higher than Euro area output; (ii) the Euro-US output gap, defined as the difference between the Euro output and the common Euro-US output trend, does not Granger cause (and it is not Granger caused by) the US output growth; (iii) the shock generating the common trend has larger contemporaneous impact but less persistence effect on US output than on the Euro area output.

By definition, the shock generating the common trend has long-run effects on the output of both economies and can therefore be interpreted as a technology shock. The model described above then implies that, in the US, the technology shock is rapidly absorbed while it takes longer time to work its effect throughout European economies. The shock can be interpreted either as the world shock, immediately absorbed in the US, or as a shock originating in the US which spread to the Euro area with a lag. The two hypotheses are empirically indistinguishable.

The immediate effect of the shock is a divergence between the level of economic activity in the US and the Euro area. The divergence seems to reach its maximum in the middle of the cycle (roughly five years). Europe eventually catches up, but the catching up lasts about 10 years.

The model suggests that the leading-lagging relation between the two cycles is explained by the different rates of absorption of the technology shock. This feature also explains the different profile of output volatility in the two economies, with the US showing larger volatility at high than at low frequencies and the Euro area showing

more persistence.

Beside estimating the model testing for cointegration and Granger causality, we use the constraints implied by characteristics (i) to (iii) to define an hypothetical data generating process that we then use to generate artificial data. When using standard techniques to identify peaks and troughs in the cycles of the generated data, we find features which are insignificantly different than those identified on output data. These features are also very similar to those implied by the CEPR and the NBER dating. This suggests that our simple model is able to capture the essential characteristics of cyclical output in the two economies.

The same model fits consumption data.

The model and the CEPR-NBER "fact" that classical recessions are rare events while expansions are the normal state of the economy can be assembled to draw some conclusions on the welfare implications of fluctuations in both economies. Even assuming that there are no long-run differences in trend, Europe loses welfare because, after a technology shock, reaches its steady state later than in the US. In other words, the US enjoys all advantages of growth immediately while Europe has to wait much longer. In Europe, losses in terms of both output and consumption during recessions are not as drastic as in the US and they are distributed over a long period of time. Recessions are less sharp, but recoveries are very slow. Given that expansions are the normal state of affairs in the economy (the mean of the shock is positive) while recessions are rare events, at realistic real interest rate values, the larger loss of welfare that the US incurs on impact is more than compensated by the rapid recovery.

2 Stylized Facts

2.1 Classical cycles: NBER and CEPR dating

The National Bureau of Economic Research (NBER) and the Center for Economic Policy Research (CEPR) provide a chronology for, respectively, the US and the Euro area business cycle. In both cases the chronology is established by informal inspection of a variety of key macroeconomic time series and it is not just based on GDP. The dates refer to what is typically called the classical cycle, i.e. the turning points in the *level* of economic activity. Figure 1 plots quarterly US and Euro area GDP since 1970 (the first date for which aggregate euro statistics are available) and dates established by CEPR and NBER.

NBER and CEPR dating illustrate striking similarities between the cyclical characteristics of the two economies. In both economies, recessions are rare and of short duration if compared with expansions and they are roughly synchronized.

The dates produced by CEPR and NBER, based on informal data analysis, can also be compared by dates for peaks and troughs identified by the automatic algorithm designed by Bry and Boschan, 1971 (BB from now on). The latter is a non-parametric procedure deviced to identify local maxima and minima and it is widely used in business cycle analysis.[1]. Table 1 reports results.

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[1] For the BB algorithm, we have applied the parameterization suggested by Harding and Pagan, 2002a

Figure 1: GDP since 1970
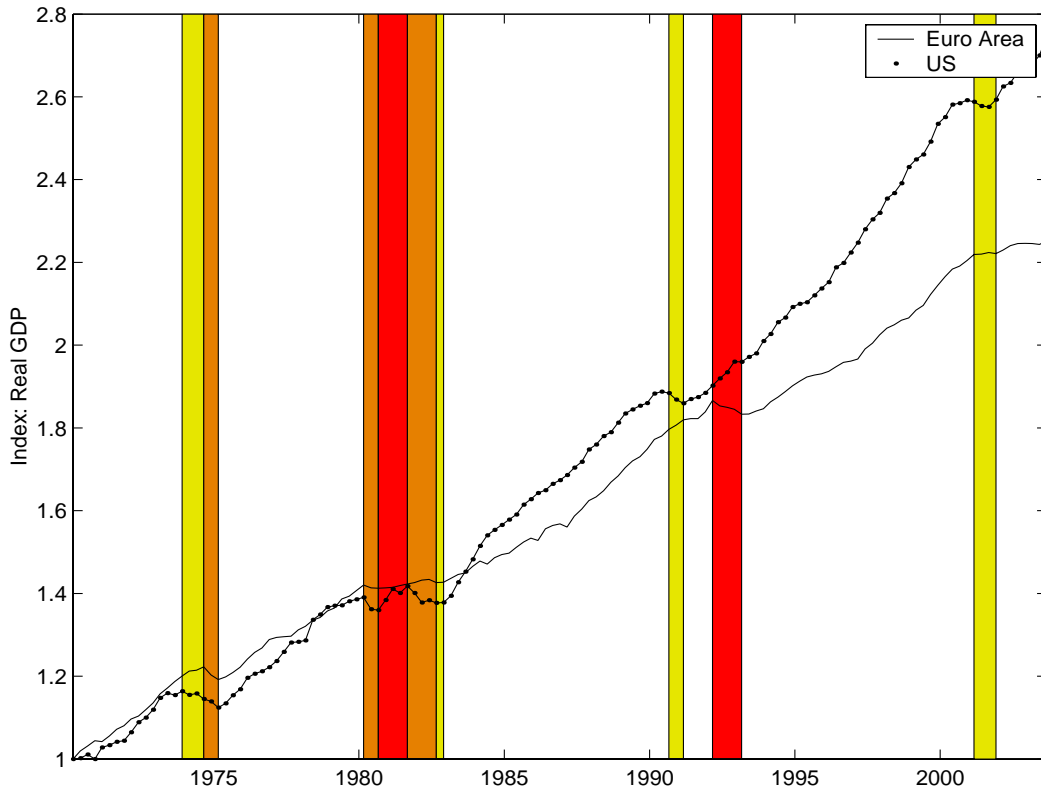
The light shadow corresponds to a recession in the US, the dark one to a recession in the Euro Area and overlapping recessions show with an intermediate shade

Notice that the informal CEPR and NBER procedures give similar results to the BB procedure. There are two exceptions, both pertaining to the Euro area: the early eighties and the recent slowdown. The differences are explained by the fact that CEPR (as NBER) dating is not exclusively based on GDP and both in the eighties and in the recent slow-down, Euro area GDP dynamics is not clearly correlated to labor market variables, industrial production and investment (on this point, see the discussion by the CEPR dating committee on www.cepr.org).

We will now compute some descriptive statistics on duration, amplitude and synchronization of cycles to document further similarities and differences between the two business cycles. Table 2 reports statistics for the two classifications of peaks and troughs: the informal CEPR and NBER classification (bold figures) and the dating resulting from the application of the BB algorithm to quarterly GDP (in parenthesis). Amplitude is measured as the quarterly average growth rate of GDP during the sub-period, duration is measured in quarters while the concordance index is a measure of synchronization developed by Harding and Pagan, 2002b. Calling the log of US GDP

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Table 1: Dating Algorithm

EURO ZONE		US	
P^{EU}	T^{EU}	P^{US}	T^{US}
1974 q3	**1975 q1**	**1973 q4**	**1975 q1**
(1974 q3)	(1975 q1)	(1973 q4)	(1975 q1)
		1980 q1	**1980 q3**
1980 q1	**1982 q3**	(1980 q1)	(1980 q3)
(1980 q1)	(1980 q3)+8q	———————	———————
		1981 q3	**1982 q4**
		(1981 q3)	(1982 q3)+1q
1992 q1	**1993 q1**	**1990 q3**	**1991 q1**
(1992 q1)	(1993 q1)	(1990 q2)+1q	(1991 q1)
?	?	**2001 q1**	**2001 q4**
(2002 q4)+?q	(2003 q2)+?q	(2000 q4)+1q	(2001 q3)+1q

Both the CEPR and NBER dates for the Peaks and the Troughs appear in bold. We show between parentheses the date computed by the Dating Algorithm and finally the number of quarters of mismatch

as y_t^{US} and the log of Euro area output as y_t^{EU}, the concordance index is defined as:

$$C_{ij} = \frac{1}{T} \sum_{t=1}^{T} [S_{y_t^{US}} S_{y_t^{EU}} + (1 - S_{y_t^{US}})(1 - S_{y_t^{EU}})]$$

where $S_{y_t^j}$ is a binary random variable that takes the values unity during recessions and zero during expansions. The concordance index ranges between 0 and 1.

The Table shows that, as suspected by inspection of Fig. 1, there is high concordance between the two cycles. However, cyclical amplitude in the US is larger than in the Euro area while recessions are shorter. In general, the Euro area cycle seems to be smoother than the US one.

2.2 Growth cycles

The problem with the definition of the cycle in terms of level of economic activity is that it depends on the underlying trend growth rate so that in period of sustained growth, one may be led to never detect a business cycle. An alternative is to refer to the growth cycle and define a recession as a period of deceleration of the growth rate, an event which may occur even when the GDP growth rate is positive (clearly, growth cycles exhibit more frequent turning points than classical cycles).

The analysis in terms of growth rates brings further insights on differences and similarities between business cycles. Since the growth of output is typically stationary, growth cycle characteristics can be illustrated by looking at volatility, persistence and dynamic correlations.

Volatility is typically measured by the variance of the growth rate of the series. This is an average of the variance at all frequencies and therefore captures short-run, long-run and business cycle variance. Persistence can be measured in different ways.

Table 2: Business Cycle Statistics

	US	Euro Area
peak to trough amplitude	**-0.5658**	**-0.2433**
	(-0.6294)	(-0.4979)
trough to peak amplitude	**0.9445**	**0.7653**
	(0.9589)	(0.6254)
peak to trough duration	**3.4000**	**5.3333**
	(3.4000)	(2.5000)
trough to peak duration	**23.25**	**29**
	(23.500)	(35.00)
n. of recessions	**5.00**	**3.00**
	(5.00)	(4.00)
Concordance Index	**0.8593**	
	(0.8222)	

The business cycle statistics corresponding to the NBER and CEPR dating are in bold. We show in parentheses the same statistics, produced by the Bry-Boschan Dating Algorithm.

We will here define it as the variance of that component of the growth rate of output corresponding to cycles eight years or longer. This roughly corresponds to the variance of the Hodrick and Prescott trend with smoothing parameter equal to 1600 (HP-trend). Table 3 reports the variance of the growth rates of output, the variance of the HP-trend and the ratio between the latter and the former for both the Euro and the US economy. We can observe the following characteristics:

1. Output volatility is higher in the US than in the Euro area.

2. Persistence, as measured by the ratio between the variance of the HP trend and the total variance, is larger in the Euro area.

Table 3: Standard Deviation of the growth rate of output and of the HP trend

	US	Euro Area
$std(\Delta y)$	0.88	0.60
$std(\Delta HP)$	0.14	0.19
$\frac{std(\Delta HP)}{std(\Delta y)}$	0.16	0.31

Differences in volatility and persistence characteristics of growth cycles between the US and the Euro area are the same as what observed for level cycles based on amplitude and duration statistics. Larger persistence in the Euro area is not surprising, since recessions, as we have seen, are less pronounced, but last longer than in the US.

What about synchronization?

Figure 3 plots quarterly growth rates of GDP (upper quadrant) and Hodrick and Prescott cycles (lower quadrant) corresponding, as we have seen, to cycles 8 years or longer. The plot shows that the persistent component of output growth in the Euro area is lagging the US analog.

Figure 2: growth rates and HP trends
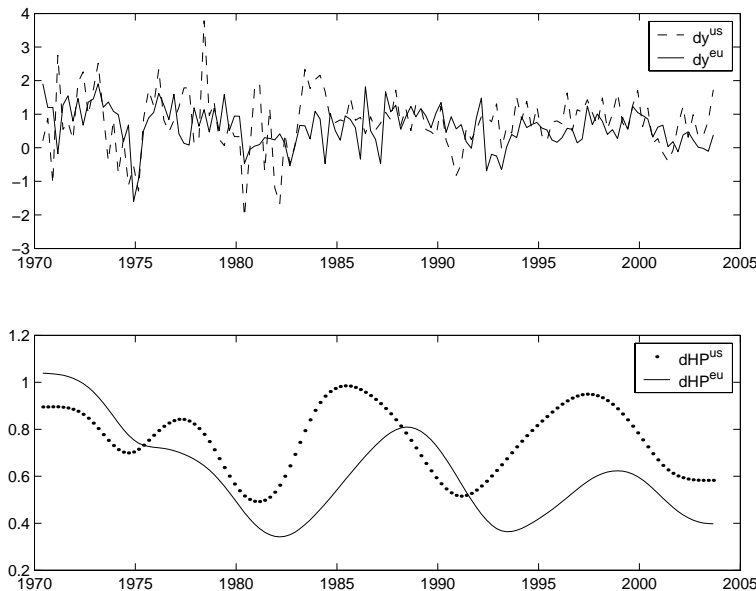
3   Classical and growth cycles: reconciling the evidence

The descriptive statistics reported in the previous Section show that, although level cycles are similar in the Euro and US economies, the Euro area is characterized by lower volatility of output growth and larger persistence. This implies that shocks have a larger impact effect on the US economy but they are absorbed faster than in the Euro area [2]. Moreover, the US growth cycle seems to lead the Euro area cycle at medium to long term frequencies.

In this Section we identify a statistical model of joint US-Euro area output dynamics which can account for these characteristics.

We will proceed as follows. We first test for cointegration to determine whether the two economies have a common trend. Then, we apply Granger causality tests to determine whether the Euro area growth adjusts to the US's as suggested by the lagging relation of its HP cycle illustrated in Figure 3.

Results from Johansen cointegration test are illustrated in Table 4. They show that, at the 1 % level, the hypothesis of cointegration cannot be rejected and that with

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[2]On this point, see also Forni and Reichlin, 2001

cointegration coefficients are estimated to be $[1, -3/4]$. This implies that, during the sample period, the average rate of growth in the US has been three fourth higher than in the Euro area and that there is only one shock driving output in the long-run in both countries (the world shock).

Let us now define

$$X_t = \begin{pmatrix} \Delta y_t^{\text{US}} \\ y_t^{\text{EU}} - 3/4 y_t^{\text{US}} \end{pmatrix}$$

where $\text{GAP}_t = y_t^{\text{EU}} - 3/4 y_t^{\text{US}}$ is the output gap between the Euro and the US. The VAR augmented by an error correction term can be written as:

$$B(L)X_t = \epsilon_t.$$

The F-test rejects the hypothesis of the significance of GAP_t on Δy_t^{US} implying that the gap does not Granger-cause (and it is not Granger-caused by) the US rate of output growth (results are reported in Table 5).

Table 4: Unrestricted Cointegration Rank Test

No. of Coint. vectors	eigenvalue value	trace statistics	5% cv	1% cv
None *	0.111818	15.56124	15.41	20.04
At most 1	0.001123	0.146078	3.76	6.65
cointegrating equation		$y^{eu} - 0.72 y^{us}$ (0.01931)		

Table 5: Granger Causality Tests

Null Hypothesis	F-Statistic	Probability
GAP does not Granger-Cause y^{EU}	9.84170	0.00011
y^{EU} does not Granger-Cause GAP	2.74502	0.06806
GAP does not Granger-Cause y^{US}	0.43504	0.64820
y^{US} does not Granger-Cause GAP	0.00992	0.99013

The restricted form of the model is:

$$\Delta y_t^{\text{US}} = \alpha + \beta_1 \Delta y_{t-1}^{\text{US}} + \cdots + \beta_4 \Delta y_{t-4}^{\text{US}} + \epsilon_{t1}$$
$$\text{GAP}_t = \rho_1 \text{GAP}_{t-1} \cdots + \rho_4 \text{GAP}_{t-4} + \epsilon_{t2}.$$

This triangular form implies that the Euro area rate of growth adjusts itself to the US growth while the US does not respond to shocks specific to the Euro area.

On the basis of the constrained model we can now compute impulse response functions to the non-neutral (world) shock (Figure 3 reports impulse responses and bootstrapped confidence intervals).

Notice that a given shock has a larger impact in the US, but it takes longer to get absorbed in the Euro area than in the US. This is a consequence of the higher persistence in European output noticed above.

If the non-neutral common shock is interpreted as the world technology shock this result implies that the US economy has a higher ability to absorb technology faster

Figure 3: Impulse Response Functions
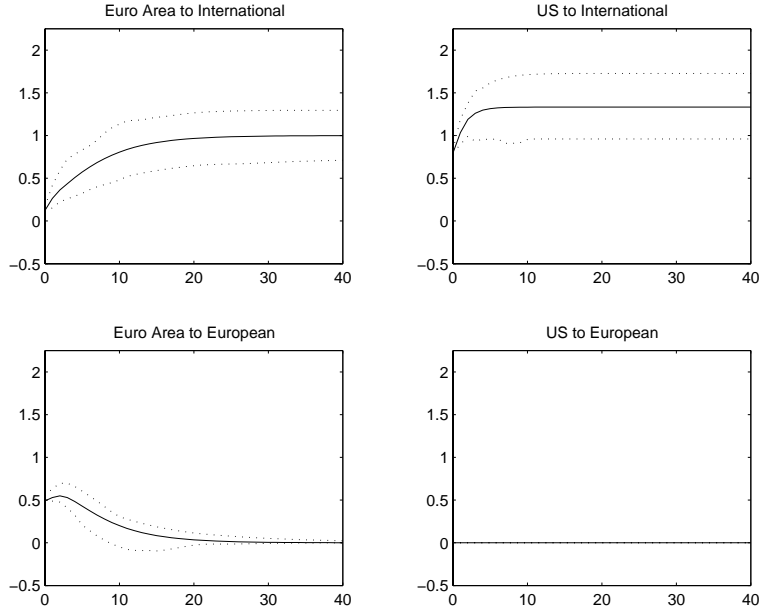
than the Euro economy. The high rapidity with which technology is absorbed in the US seems to induce high short-term volatility. In the Euro area, on the other hand, the bulk of the variance is in the long-run because it takes longer to absorb shocks. An alternative interpretation is that the world shock is in fact the US shock. The two hypotheses cannot be distinguished statistically, but the economic implication of the two alternative interpretations is the same.

The result on Granger causality indicates that the world growth is led by the US with the Euro area following with a lag. This should explain why turning points of the Euro cycle lag those of the US cycle.

The restricted model can now be used to simulate levels of output to verify whether we can reproduce the BB dating described in Section 1.

The model is simulated using 2000 drawings. On the generated output series we apply the BB algorithm and compute the same statistics on duration and amplitude as in Table 2. Table 6 reports true values and simulated values with bands and shows that true values are in the bands in all cases.

Table 7 reports the simulated and true concordance statistics for US and Euro area GDP log levels. They are strikingly similar.

It is interesting to note that in order to generate the empirical characteristics of Euro area and US cycles, with rare recessions and prolongues phases of expansions, we do not need to simulate out of a complicated non-linear model: our simple linear model does the job. This has already been documented by Harding and Pagan (2002a) and stressed in their discussion with Hamilton, 2001 (see also Harding and Pagan, 2003a-b).

Notice that the model implies that the second shock, which is neutral on output, is

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Table 6: Simulation results

peak to trough amplitude				
	True	Lower Bound	Simulated	Upper Bound
Euro	**0.4979**	0.0937	0.3324	0.5744
US	**0.6294**	0.2163	0.5306	0.8851

trough to peak amplitude				
	True	Lower Bound	Simulated	Upper Bound
Euro	**0.6254**	0.4038	0.6065	0.7781
US	**0.9589**	0.6441	0.8621	1.0612

peak to trough duration				
	True	Lower Bound	Simulated	Upper Bound
Euro	**2.5000**	2.0000	3.0921	5.6667
US	**3.4000**	2.0000	3.1397	6.0000

trough to peak duration				
	True	Lower Bound	Simulated	Upper Bound
Euro	**35.0000**	10.0000	36.9428	95.0000
US	**23.5000**	11.2500	29.5700	65.5000

n. of recessions				
	True	Lower Bound	Simulated	Upper Bound
Euro	**4.0000**	1.0000	3.2033	6.0000
US	**5.0000**	2.0000	4.0433	7.0000

Table 7: Concordance Index

Real	Lower Bound	Simul	Upper Bound
0.8222	0.7463	0.8427	0.9254

European specific so that to explain Euro area cyclical output we need more than technological shocks while for the US, technology explains the bulk of cyclical fluctuations.

4   The costs of business cycles: consumption

The statistical model we have defined is very simple, but, to a first approximation, is able to characterize the basic features of the cycles in the US and the Euro economies. A proper multivariate analysis goes beyond the scope of this paper. Rather than fully going in that direction we perform, on consumption, the same analysis we did for output to obtain a first rough estimate of the welfare costs of business cycle.

Table 8 shows standard deviations of consumption in the short and long-run.

Table 8: Standard Deviation of the growth rate of consumption and of the HP trend

	US	Euro Area
$std(\Delta c)$	0.70	0.59
$std(\Delta HP)$	0.16	0.23
$\frac{std(\Delta HP)}{std(\Delta c)}$	0.23	0.39

Comparing these results with those for GDP, we can see that, in Europe, the standard deviation of consumption is larger than the standard deviation of output. This implies that there is less consumption smoothing in Europe than in the US, probably as a consequence of less efficient capital markets. A first observation is then that, although in the US, output volatility is more pronounced than in the US, the relative effect on welfare is mitigated by a relatively high degree of consumption smoothing.

There is another aspect of fluctuations that indicate that the welfare losses associated to output volatility are less pronounced in the US. This can bee seen from the impulse response functions of consumption in response to the technology shocks.

Figure 3 reports the impulse response functions to the non-neutral shock to consumption. The impulses are computed from a model which has the same parameterization of that estimated for GDP: autoregressive order equal to four and cointegrating vector $[1 \quad -3/4]$. This parameterization is justified by the fact that tests for cointegration and Granger causality tests give the same results (results available on request). Note that the result on cointegration is consistent with stationarity of savings in both economies.

The impulses do not take into account differences in trend. We are imposing the same long-run value of consumption which implies to multiply the Euro area impulses by 4/3.

The differences in persistence noticed for GDP also emerge for consumption. Even assuming that there are no long-run differences in variance and no differences in trend, Europe loses welfare because, after a technology shock, reaches its steady state later than in the US. In other words, the US enjoys all advantages of growth immediately

Figure 4: Impulse Response Functions of Consumption to International Shocks
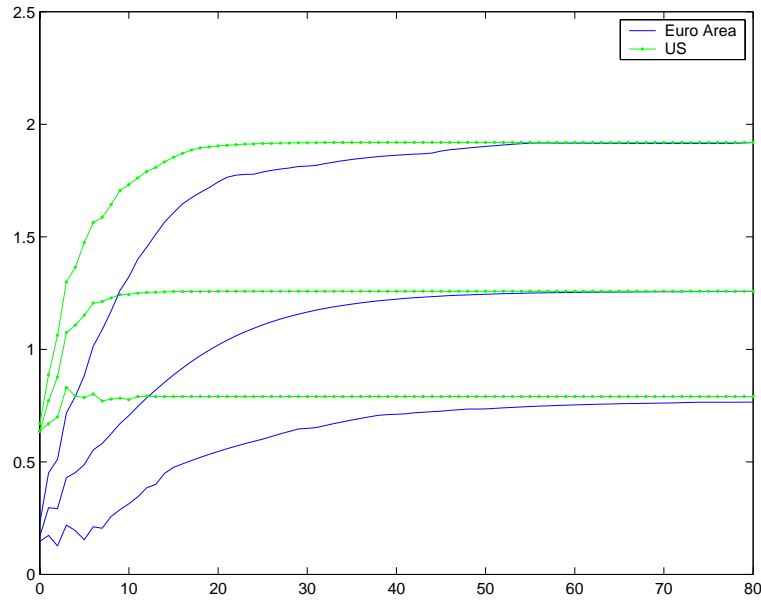
while Europe has to wait much longer. Notice, however, that this also implies that losses, during recessions, are not as drastic as in the US and they are distributed over a long period of time. Given that expansions are the normal state of affairs in the economy (the mean of the shock is positive) while recessions are rare events, at realistic real interest rate values, the larger loss of welfare that the US incurs on impact is more than compensated by the rapid recovery.

5   Conclusions

This paper argues that a model of the joint behavior of US output and Euro area output that can account for stylized facts on business cycle in the two economies has one common trend with a larger drift in the US than in the Euro area. We also find that the Euro-US output gap, defined as the differences between the Euro output and the common Euro-US trend, does not Granger cause (and it is not Granger caused by) the US output growth.

The model implies that there is one technology shock originating in the US (world shock). We show that this shock has larger contemporaneous impact but less persistence effect on US output than on the Euro area output where it is absorbed at a slower rate. Fast absorption in the US induce large short-run variance of US output while slow absorption in Europe induce high long-run volatility of Euro area output.

A similar pattern is found in consumption data. The technology shock affects long-run volatility of the two economies by the same amount, but, after the long-run shock, it takes longer for Europe to reach the steady state. Since the shocks have positive drift and recessions are rare event, this implies that the Euro area incurs a larger welfare loss due to business cycle fluctuations.

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7   Appendix: Data Sources

US GDP and consumption: OECD, Main Economic Indicators

Euro Area GDP and consumption: Fagan et al., 2001 for sample 1970-1997 and Eurostat starting in 1998, first quarter.

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November 2004

Comments on

Dating the European Business Cycle

by Lucrezia Reichlin, ECARES, Université Libre de Bruxelles and CEPR

The presentation by Lucrezia Reichlin gives a glimpse into her research program over the last few years, albeit a perhaps rather surprising glimpse. While her research on dynamic factor models utilizing large numbers of data series is probably by consensus among the most important in all of recent empirical macroeconomics, the current presentation on Euro area and U.S. business cycles is based on methodologically altogether different approaches: informal assessment of Euro area business cycle dynamics based on summary statistics and a restricted bivariate VAR model for Euro area and U.S. GDP to capture key features of the U.S. and Euro area business cycles as well as business cycle interaction.

The presentation touches on a great many issues, but in light of time constraints my comments will be restricted to two of the issues addressed in the presentation: the formation and initial work of the CEPR business cycle dating committee (chaired by Lucrezia Reichlin), and the comparison of U.S. and Euro area business cycle dynamics using a restricted bivariate VAR.

The CEPR Business Cycle Dating Committee

Some essentials to know about the CEPR business cycle dating committee:

- According to the CEPR's announcement of the formation of the committee, "the committee is to establish the chronology of recessions and expansions, not to forecast, nor even to characterize the current conjuncture".

- The committee's methodology to dating business cycles is to by and large follow that of the NBER's business cycle committee's work for the U.S.; in particular, the dating of peaks and troughs is to occur in an informal, non-rule based manner.

- In some of the specifics of its work the CEPR committee will differ from the work of its counterpart at the NBER. For example, the CEPR committee will not go back beyond 1970 in its analysis; its dating of business cycle turning points will be at quarterly rather than monthly frequency as at the NBER; both Euro area aggregated and country-specific data series are to be considered (without public specification of the relative weight of the area-wide and country-specific series); the number of countries to be considered is larger from 1999 onwards than before 1999 (the whole Euro area is considered from 1999 onwards, whereas only the eleven original Euro member countries plus Greece are considered before 1999).

While the CEPR obviously is to be commended for forming a business cycle dating committee, it is difficult not to be concerned about some of the choices the committee has made:

- It may be misleading to date a Euro area-wide business cycle in the pre-EMU era.
  When business cycle dynamics differ markedly across countries, then the interpretation of a Euro area-wide business cycle is unclear.

  To develop this critique a little further, consider a dynamic heterogeneous panel data model for some variable y:

  $$y_{it} = \alpha_i \left(1 - \lambda_i\right) + \lambda_i y_{i,t-1} + \varepsilon_{it}, \quad \varepsilon_{it} \sim \left(0, \sigma_i^2\right)$$

  Suppose that a researcher ignores the heterogeneity of the slope coefficient (λ_i) and instead estimates the homogeneous slope model:

  $$y_{it} = \alpha_i \left(1 - \lambda\right) + \lambda y_{i,t-1} + \varepsilon_{it}, \quad \varepsilon_{it} \sim \left(0, \sigma_i^2\right)$$

  What we know from the econometrics literature (Pesaran and Smith, *Journal of Econometrics*, 1995) is that in this case

  $$\hat{\lambda}_{ML} \overset{N,T \to \infty}{\neq} E\left(\lambda_i\right)$$

  That is, the slope coefficient estimated by the researcher does not only improperly suppress the existing heterogeneity, but also does not have an interpretation of being the average slope coefficient.

  An implication of this point is that if business cycle dynamics do differ markedly across European countries, then the dynamics of the Euro area-wide business cycle are most unlikely to be the average of country-specific business cycles, and its interpretation is not clear, which seems particularly troublesome for the pre-EMU era: An example at hand for heterogeneity prevailing in the pre-EMU era

being strong is that the CEPR business cycle dating committee has dated a recession for 1980:Q1 to 1982:Q3, even though GDP for example for Italy and France was growing during this time period.

- It does not seem clear what the advantages of a non-rule based, informal methodology to date business cycles are; rather such an approach seems costly for the timely work of the committee itself (take as an example the fact that the NBER business cycle dating committee in its announcement of October 2003 of a trough in U.S. economic activity occurring in November 2001 writes: "Why did the committee wait so long before identifying a trough? … The committee felt it was important … to study the NBER's past practices carefully to ensure that its decision in this episode was consistent with the dating of earlier turning points."), and even more so seems costly for the transparency of the work of the committee towards the public.

- Except for historical studies of business cycles and their determinants, it is not clear how useful business cycle dating announcements are that involve quarterly (rather than monthly) frequencies and that occur with a sizeable lag. The perspective of policy makers for example was summarized by Klaus Regling in his opening remarks at this conference: "We would like to date cycles in real time, not with a long lag." The choice of methodology by the CEPR's business cycle dating committee seems thus surprising, given that strong alternatives to a non-rule based, significantly lagging business cycle dating procedure are available: for example, one might make use of the EuroCOIN coincident monthly indicator of Euro area-wide economic activity ("EuroCOIN: A Real Time

Coincident Indicator of the Euro Area Business Cycle, Altissimo, Bassanetti, Cristadoro, Forni, Lippi, Reichlin and Veronese, CEPR Working Paper, December 2001) coupled with a modified Bry-Boschan business cycle dating algorithm (for example, Harding and Pagan, 2001). Invoking such a latter probabilistic framework as the core piece of information for business cycle dating decisions would of course not rule out simultaneous visual inspection of and illustration of decisions by means of graphs.

Finally, even if a non-rule based procedure for dating business cycle turning points was to be maintained, it would still seem desirable to achieve more timely announcements by means of using the most recently available data and then revising the dating of turning points as revised data do become available. Such a revision of turning points due to data revision surely would not involve a loss of reputation for the CEPR business cycle dating committee.

Comparison of U.S. and Euro Area Business Cycle Dynamics

The second part of Lucrezia Reichlin's presentation is based on work in progress with Domenico Giannone. Analyzing quarterly data for the U.S. and for the aggregated Euro area since 1970, the main findings and arguments advanced by Giannone and Reichlin are:

- Output growth in Europe is less volatile but more persistent that U.S. output growth. The persistent component of U.S. output growth leads that of the Euro area.

- These dynamics may be captured using a bivariate VAR model in U.S. output growth and a Euro area/U.S. output gap (which is also the cointegrating relationship between U.S. and Euro area output). The argument that the model matches up well with the actual data is mainly made by means of matching up the model's Bry-Boschan dated business cycles with those observed for the actual data.

While there is no doubt that the bivariate VAR model of Giannone and Reichlin is an interesting demonstration of how far a simple low-dimensional model can go in capturing U.S. and Euro area business cycled dynamics as well their interaction, some of the analysis in the present version of the paper by Giannone and Reichlin may warrant further scrutiny and reflection:

- As noted above, inclusion of pre-EMU era data for the analysis of an aggregated Euro area business cycle may be rather problematic. In the work of Giannone and Reichlin this problem manifests itself through the results delivered by the Bry-Boschan dating algorithm that is being used by the authors to date business cycle turning points. While Giannone and Reichlin argue that the Bry-Boschan dating algorithm "does not work" for the Euro area in that it would deliver turning points different from those set by the CEPR business cycle dating committee, it actually works very well (even by this definition of working well) except for the CEPR dated recession of the early 1980's. That recession, however, features a very strong degree of heterogeneity across Euro area countries, as noted above.

- As far as I can tell, the current analysis of the paper seems to pre-suppose (without providing any empirical evidence for it) that Euro-area and U.S. data are

co-trending, and in any case does not separate the phenomena of two series being co-trended vs. two series being co-integrated, even though these are actually conceptually distinct phenomena. A proper specification of a bivariate VAR of the type considered by Giannone and Reichlin would be

$$\Phi(L)\left[\begin{pmatrix} y_t^{US} \\ y_t^{EU} \end{pmatrix} - \begin{pmatrix} \mu^{US} \\ \mu^{EU} \end{pmatrix} - \begin{pmatrix} \gamma^{US} \\ \gamma^{EU} \end{pmatrix}t\right] = \begin{pmatrix} \varepsilon_t^{US} \\ \varepsilon_t^{EU} \end{pmatrix}$$

$$\Leftrightarrow \begin{pmatrix} \Delta y_t^{US} \\ \Delta y_t^{EU} \end{pmatrix} = a_0 + \underbrace{\left[\Phi(1) - I_2\right]}_{=\Pi = \alpha\beta'}\left[\begin{pmatrix} y_t^{US} \\ y_t^{EU} \end{pmatrix} - \begin{pmatrix} \gamma^{US} \\ \gamma^{EU} \end{pmatrix}t\right] + \Theta(L)\begin{pmatrix} \Delta y_{t-1}^{US} \\ \Delta y_{t-1}^{EU} \end{pmatrix} + \begin{pmatrix} \varepsilon_t^{US} \\ \varepsilon_t^{EU} \end{pmatrix}$$

For such a bivariate VAR cointegration occurs when the matrix Π is rank deficient. Co-trending, on the other hand, occurs when

$$\Pi\begin{pmatrix} \gamma^{US} \\ \gamma^{EU} \end{pmatrix} = 0$$

My experience working with output data for the U.S. and individual Euro area countries has been that there is quite strong empirical evidence that output in the U.S. and individual Euro area countries is not co-trended; thus my prior for the present analysis would have been:

$$\Pi\begin{pmatrix} \gamma^{US} \\ \gamma^{EU} \end{pmatrix} \neq 0; \quad \gamma^{US} \neq \gamma^{EU}$$

It would seem strongly desirable that the authors provided evidence in favor of the co-trending hypothesis of Euro area and U.S. data, should they wish to maintain thus hypothesis.

- I am not clear about the interpretation of the cointegrating vector between U.S. and Euro area output provided by Giannone and Reichlin. They seem to argue that the cointegrating vector

$$y_t^{EU} - .75 y_t^{US}$$

would imply that the "average rate of growth in the U.S. has been three fourths higher than in the Euro area". The cointegrating relationship between U.S. and Euro area output seems to measure a long-run levels relationship, however, which may also be driven by initial conditions, and not just average past growth.

- There is a growing literature that the nature of international business cycle dynamics has changed over the time period since 1970. Stock and Watson (2004) in particular argue that these changing dynamics are for the U.S. data best captured by a single break in 1984 (mostly due to subsequent moderation of shocks), but for European data are best captured by a drawn-out pattern of moderation of the volatility of output growth. Under such asymmetry of the change of business cycle dynamics in the U.S. versus the Euro area, Giannone and Reichlin are likely to overestimate the size of shocks in the U.S. relative to those in the Euro area for sizeable parts of their sample period. This in turn would cast doubt on various of their empirical findings.

- Finally, it does not seem a particularly challenging hurdle for a time-series model to do well in terms of its Bry-Boschan dated business cycles matching up well with those in the actual data. Even early generation Real Business Cycle models did quite well on this count, but are now well understood to perform rather poorly in terms of capturing the conditional dynamics of U.S. and Euro area output data.

Thus, to make the argument that the Giannone and Reichlin captures well the dynamics of U.S. and Euro area business cycles (as well as their interaction), it would seem necessary to present model evaluation criteria that provide an adequate measurement of conditional dynamics in time series.

Is Poland the Next Spain?

Francesco Caselli and Silvana Tenreyro[*]

March 2005

Abstract

We revisit Western Europe's record with labor-productivity convergence, and tentatively extrapolate its implications for the future path of Eastern Europe. The poorer Western European countries caught up with the richer ones through both higher rates of physical capital accumulation and greater total factor productivity gains. These (relatively) high rates of capital accumulation and TFP growth reflect convergence along two margins. One margin (between industry) is a massive reallocation of labor from agriculture to manufacturing and services, which have higher capital intensity and use resources more efficiently. The other margin (within industry) reflects capital deepening and technology catch-up at the industry level. In Eastern Europe the employment share of agriculture is typically quite large, and agriculture is particularly unproductive. Hence, there are potential gains from sectoral reallocation. However, quantitatively the between-industry component of the East's income gap is quite small. Hence, the East seems to have only one real margin to exploit: the within-industry one. Coupled with the fact that within-industry productivity gaps are enormous, this suggests that convergence will take a long time. On the positive side, however, Eastern Europe already has levels of human capital similar to those of Western Europe. This is good news because human capital gaps have proved very persistent in Western Europe's experience. Hence, Eastern Europe does start out without the handicap that is harder to overcome. JEL Classification numbers: F15, F43, N10, O11, O14, O47. Keywords: Convergence, Capital accumulation, technology catch-up, Structural transformation.

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1 Introduction

Western Europe is the quintessential convergence club. In 1950, real labor productivity in some of its richest countries was more than three times that of some of its poorest. By the end of the century, all Western European labor-productivity ratios were well below two. One aspect of this decline in cross-country European inequality is, of course, the catch-up by the Southerners: Italy first, then Spain, Greece, Portugal, and eventually Ireland (a Southerner in spirit) all had their spurts of above-average productivity growth. Spain's experience is emblematic and inspiring: In less than 15 years between the late 1950s and the early 1970s, its labor productivity relative to France's (our benchmark for the "average" European experience) went from roughly 65 percent to over 90 percent.

On May 1, 2004, the European Union (EU) admitted 10 new members, primarily from Eastern Europe. To varying degrees, the Easterners' current relative labor productivities are similar to the relative labor productivities of the Southerners before their convergence spurts. For example, Hungary today is almost exactly as productive relative to France as Greece was in 1950, while Poland is roughly as productive – always relative to France – as Portugal was then. This widely noted analogy has naturally given rise to hopes that the Easterners will be the new Southerners, and Poland, the new Spain. Indeed, this hope is one of the very reasons why these countries have wanted to join (and several others hope to join) the club.

Given that so many people are pinning so many hopes on the continued ability of the European club to generate convergence among its members, this seems a useful time to revisit the data on the relative growth performance of European countries in the second half of the 20th century. Our main aim is to look behind the aggregate labor productivity numbers and present a couple of different approaches to "decompose" the overall convergence experience into more disaggregated processes. We make no claim of methodological or conceptual innovation: Our goal is to organize all the data "under one roof" and take stock.

We organize the discussion around four views or hypotheses potentially explaining the convergence process. The first view is grounded in the Solovian-neoclassical hypothesis, according to which initially capital-poor countries have higher marginal productivity of capital, and hence faster growth. The second hypothesis, motivated in part by endogenous growth models, explains the convergence process as the result of technological catch-up. Backward countries converge to the technological leaders mainly through a process of imitation (which is presumably cheaper than innovation). The third hypothesis interprets the convergence process as driven mainly by gains from trade from European integration, which may have been disproportionately larger for the poor economies (as a proportion of GDP) both because of their initially more autarchic status and because of their relatively smaller size. The fourth and final hypothesis views the convergence process as a by-product of the

structural transformation, which is partially a process of reallocation of resources from low-productivity to high-productivity sectors. If initially poorer countries had a longer way to go in this transformation, this process may itself have been a source of convergence.

With respect to the relative contributions of capital deepening and technological change to the reduction of European inequality we find that physical capital accumulation and total factor productivity (TFP) growth were roughly equally important. However, somewhat surprisingly, we also find virtually no role for human capital accumulation: Differences in human capital per worker – at least, as measured by years of schooling – are both substantial and persistent. Another somewhat surprising result is that TFP was not always initially lower in poor countries, a fact that is hard to reconcile with catch-up theories of technological diffusion.

As an explanation for regional convergence the trade view runs into some problems. For example, countries with a comparative disadvantage (or no advantage) in agriculture invariably show larger shares of agriculture, while countries with a comparative advantage in agriculture tend to show systematically lower shares. The structural-transformation approach fares better. For example, we find that Southerners converged to the rest mainly through a faster rate of reallocation of the labor force from low-productivity agriculture into high-productivity manufacturing and services. However, in other cases within-industry productivity catch-up was also quite important.

When we turn our attention to 13 (mostly) Eastern European countries that have either recently joined the EU, or are in line to join, we tend to find very large labor productivity gaps vis-à-vis Western Europe. In accounting for these gaps, we find substantial roles for physical capital and TFP gaps, but no role whatsoever for human capital gaps. This is in a sense good news for the Easterners, because the Western European experience suggests that human capital gaps are the hardest to bridge.

Like Portugal, Spain, Italy, and Greece 50 years ago, the new and forthcoming EU members exhibit substantially larger shares of workers employed in agriculture, which tends to be the least productive sector. Manufacturing and services are also less productive in the East than in Western Europe, though the gaps are not as large as in agriculture. There is, therefore, some scope for large productivity gains through both labor reallocation out of agriculture and within-industry catch-up. However, quantitatively, in Eastern Europe the distribution of employment among sectors is much less important as a source of income gaps vis-à-vis the rest of Europe than it was in Southern Europe in 1960. Hence, in a way, the Easterners have only one margin to exploit in their quest for convergence – the within-industry productivity gap. In contrast, the South was also able to exploit the between-industry margin.

There are, of course, several other authors who have looked at Western European con-

vergence from various angles. These include Barro and Sala-i-Martin (1991), Quah (1996), and Boldrin and Canova (2001). There are also several excellent studies of individual countries' convergence experiences, such as Honohan and Walsh (2002) and Oltheten, Pinteris, and Sougiannis (2003). Finally, the idea of using the experience of other countries/regions to speculate on the convergence prospects of Eastern Europe is also not new: see, among others, Fisher, Sahay, and Vegh (1998a, 1998b) and Boldrin and Canova (2003). Our contribution, however, looks at the data from a different perspective and is thus complementary to the existing ones.

The remainder of this paper is organized as follows. In Section 2, we review the European experience with labor-productivity convergence in the second half of the 20th century. In Section 3, we discuss various possible views one can advance to explain the convergence process. In Sections 4 and 5, we take a look at more disaggregated data to try to shed light on the explanatory power of the various approaches. In Section 6, we introduce the Easterners, and compare their characteristics with those of the Southerners before their catch-up. We summarize and conclude in Section 7.

2   European Convergence 1950-2000

The point of this section is to refresh our memories on the basic fact of European convergence. This is done in Figure 2.1, where we plot, for each of 14 Western European countries, per worker GDP in purchasing power parity (PPP) relative to France. We choose France as a benchmark because its growth experience between 1950 and 2000 is virtually identical to that of the average European country. In fact, the ratio of per-worker GDP (in PPP) of France relative to the European (population-weighted) average is practically 1 throughout the whole period. The 14 countries are the other members of the European Union (pre-May 1), less Luxembourg plus Norway.[1] The data for Figure 2.1 come directly from the Penn World Table, Version 6.1 (PWT) and measure GDP per worker [via the variable GDPWOK. See Heston, Summers, and Aten (2002)].[2]

In order to highlight the convergence outcomes we draw horizontal lines in each graph through 0.9 and 1.1. Note that 13 of the 14 countries start out outside this range, and 10 out of 14 end up inside (or right at the threshold). Furthermore, in three of the four cases in which relative GDP is still outside our "convergence band," the distance from the band has nevertheless declined considerably. The overall reduction in inequality is dramatic. To cap it

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[1]Hence, other than city-states, we are missing only Iceland and Switzerland, for which there were too many gaps in some of the data we use later in the paper.

[2]For Germany we actually use the series on Western Germany from Version 5.6 of PWT up to 1990 and the series on Germany from Version 6.1 thereafter.

all, the only case in which the absolute distance from France has increased rather than fallen is not so much a case of failed convergence but one of, so to speak, "excessive convergence": Ireland started out poor, converged from below, and then forgot to stop – ending up the most productive in Europe. It is now well above the upper bound of the convergence band.

The geographical patterns are also well known but nonetheless striking. Note that the country graphs are arranged in increasing order of latitude (using the countries' capitals as the reference points). The Southerners (Greece, Portugal, Spain, Italy, and Austria) all start out poorer and experience various degrees of catching up. Spain, Italy, and Austria fully make it; Greece has virtually made it by 1975, but then slips and loses some (but by no means all) of the gains between 1975 and 1995; Portugal's progress is slower, but it seems on track to reach the lower edge of the band in the not-too-distant future. Then there are most of the "Northerners" (Belgium, the United Kingdom, the Netherlands, Denmark, Sweden, and Norway), which start out richer than France and converge "from above" to within 90 percent and 110 percent of France's labor productivity -- with the minor exception of Belgium, which ends up slightly above the upper boundary. Germany is the geographical and economic "in-betweener," starting and ending within the 90 to 110 band. The only two serious deviations from the geographical-economic pattern are Finland, which converges from below instead of from above like the other high-latitude countries; and Ireland, which is exceptional both because it converges from below instead of from above, and because – as we have already seen – it fails to stop after converging.

Of course, convergence from above by the Northerners really means that France has caught up with them. Hence, what Figure 2.1 truly tells us is that there has been a generalized catching up from South to North or that the growth rate has been, on average, decreasing with latitude fairly smoothly.

As mentioned in the Introduction, the rest of this paper explores a couple of ways of peering into the black box of the convergence processes depicted in Figure 2.1 in the hope of shedding some light on some of its mechanics.

Before proceeding, we quickly dispose of a secondary issue having to do with entering into formal membership in the EU. Figure 2.2 is identical to Figure 2.1, except that it adds a vertical line for the date at which each country joined the European Community. Visual inspection suggests that it is extremely hard to argue for an important role for formal EC (later, EU) membership *per se* in facilitating convergence. Italy, Spain, Greece, and Austria all had their convergence spurts before formally joining European institutions, and the Northerners lost ground whether or not they were in the EC/EU. One can squint at the behavior of the relative income series around the dates of accession, but no systematic "kink" up or down seems to be associated with that date. What seems to matter for convergence is

not so much entry into formal membership in European institutions, but rather – if anything – participation in a generalized trend towards greater economic integration at the European level. This integration would probably have occurred with or without the EC.[3]

3   Four Ways to Converge

Depending on one's background and tastes, there are at least four possible reactions to the graphs in Figure 2.1 and to the convergence processes they describe. In this section we briefly outline these four possible responses, and in the rest of the paper we query the available data for the corresponding supporting evidence. We stress at the outset that the four views are not mutually exclusive.

1) Solovian convergence. If you are steeped in neoclassical growth theory [Ramsey (1928), Solow (1956), and subsequent developments] you will be strongly tempted to interpret Figure 2.1 in terms of capital deepening. The idea, of course, is that initially capital-poor countries have higher marginal productivities of capital. This leads them to grow faster than initially capital-rich countries. This argument still works if you take a broader view of capital, to include human capital [Mankiw, Romer, and Weil (1992)]. It is also independent of whether one thinks the capital is generated by domestic savings or flows in from abroad – though that may affect the speed of convergence [Barro, Mankiw, and Sala-i-Martin (1995)]. This Solovian interpretation of convergence processes motivates much of the growth-regression literature of the 1990s [Barro (1991), Barro and Sala-i-Martin (1992), and all the rest]. It also finds strong support in growth accounting exercises for East-Asian miracle economies [Young (1995)].

2) Technological catch-up. If instead you have been captivated by so-called "endogenous-growth" models [Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992)], you may tend to read in the graphs of Figure 2.1 the effects of technological catch-up by initially backward countries. In particular, you will have in mind models where imitation is less costly than innovation, so that countries initially behind the world technology frontier experience faster improvements in technology than the leaders [for example, Nelson and Phelps (1966), Krugman (1979), Barro and Sala-i-Martin (1997), Howitt (2000)]. Empirical work on cross-country TFP growth is generally motivated by this view [for example, Coe and Helpman (1995), Coe, Helpman, and Hoffmaister (1997)]. Evidence that cross-country income differences are largely due to differences in TFP is also consistent with this view [for example, Klenow and Rodriguez-Clare (1997), Hall and Jones (1999)].

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[3]Some authors use growth regression techniques to estimate the coefficient of an "EC-dummy." Results are mixed. Even if it were more strongly in favor of a positive EC-effect, however, this type of evidence does not bear directly on the issue of the sources of convergence. A positive coefficient on the EC-membership dummy means that EC members grow faster than non-EC members, not that they should converge to one another.

3) Gains from trade. If you are a trade theorist your instinct may be to interpret the graphs in terms of gains from trade. In particular, suppose (realistically) that initially the richer European countries were more integrated among themselves and with the rest of the world than the poorer ones. Suppose further (and also realistically) that over the second half of the century the poorer countries gradually became more integrated with the rest. Then not only should they have experienced gains from trade but also – due to their initially more autarchic status – their gains from trade should have been larger as a proportion of GDP than those of the richer economies: Hence, the convergence. The fact that poorer countries have tended to be smaller is another reason to expect disproportionate gains by these countries and ultimately convergence.

It is customary to object to trade-based interpretations of rapid growth that the theory predicts higher income levels, not higher growth rates. But looking again at Figure 2.1, one cannot reject outright the hypothesis that convergence was the result of one-off, discrete jumps in income levels. Consider again the fewer than 15 years it took Spain to recover from a 25-percent productivity handicap, or the 10 years or so it took Greece to bridge an even larger gap. Furthermore, it is actually possible – exploiting the idea of a "ladder of comparative advantage" – to turn the static gains-from-trade theory into a dynamic one [Jones (1974), Findlay (1973), Kruger (1977), and Ventura (1997)].[4]

4) Structural transformation. If you are an old-fashioned macro-development economist, you are used to thinking about the growth process as inextricably linked with structural transformation: vast reallocation of resources from one industry to another. The early classics include Clark (1940), Nurske (1953), and Lewis (1954), among others. There is more systematic recent work by Imbs and Wacziarg (2003) and Koren and Tenreyro (2004). If resources are reallocated from low-productivity to high-productivity sectors, this structural transformation is itself a source of growth. If Southern countries – as is likely – underwent a more radical structural transformation than Northern countries during the 1950 to 2000 period, then this is also a source of convergence.

This reasoning is best illustrated by recent work on another South-to-North convergence, that of the southern United States to the rest of the United States over the 20th century [Caselli and Coleman (2001)]. At the beginning of the century, the South was overwhelmingly agricultural, while the rest of the United States was predominantly specialized in manufacturing and services. Since agriculture had much lower output per worker, the South

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[4]Not all trade theorists will look at Figure 2.1 with comparative advantage in mind. Readers of Helpman and Krugman (1989) may view increased integration as allowing for increasing returns in the presence of intra-industry trade. We do not attempt to assess this view in the present draft (except for a brief remark in footnote 16), but perhaps in the future we can explore this by seeing whether there have been particular gains in labor productivity in sectors experiencing the biggest increases in trade.

also had much lower aggregate labor productivity. Over the decades, the U.S.-wide cost of migrating from the agricultural sector to the non-agricultural ones declined sharply, mainly as a result of improved access to schooling for rural children. In turn, the lower cost of migration to the more productive sectors led to overall aggregate productivity gains. However, these productivity gains were disproportionately concentrated in the South, which had the largest share of workers initially trapped in agriculture. Perhaps the Southern Europeans also had their labor force initially disproportionately concentrated in low-productivity industries?

We should stress that the mapping between the accounting exercise that follows and the four convergence hypotheses we study is not perfect. The accounting analysis is aimed at providing guidance as to the main forces behind convergence, and hence the results should be taken as suggestive indications rather than as conclusive verdicts.

4 Solovian Convergence and Technological Catch-Up

In this section we tackle the first two of the possible views of convergence we listed in the previous section: the capital deepening explanation associated with the Solow and other neoclassical models of growth, and the technology-diffusion explanation, which would be emphasized by endogenous growth theories.

Our approach will be to decompose the convergence series plotted in Figure 2.1 into three components: convergence in physical capital, convergence in human capital, and convergence in Total Factor Productivity. The sum of the first two may be seen as the contribution of Solovian convergence, while the third may capture the contribution of technology catch-up. Plainly, this approach is a hybrid of *growth accounting*, which decomposes growth rates into capital growth and TFP growth, and *development accounting*, which decomposes cross-country differences in income *levels* into capital and TFP. Here, since we decompose *relative* growth rates, we have both the time and the cross-country dimension. Hence, we may term the exercise we perform *convergence accounting*.

More specifically, we will use the following familiar-looking expression:

$$\Delta \log y_{it}^R = \alpha \Delta \log k_{it}^R + (1 - \alpha)\Delta \log h_{it}^R + \Delta \log A_{it}^R, \tag{1}$$

where α is the capital share in output, and Δ is a first-difference operator. The only slightly unusual aspect is that output, inputs, and total factor productivity are measured relative to those of France. Hence, y_{it}^R is aggregate labor productivity in country i relative to aggregate labor productivity in France, k_{it}^R and h_{it}^R are relative physical and human capital, and A_{it}^R is relative TFP.[5]

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[5]Of course, equation (1) can be interpreted as an approximation for the growth rate of relative labor productivity when the production function (per worker) is $y = Ak^\alpha h^{1-\alpha}$.

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Data on y_{it}^R are of course the data we plotted in Figure 2.1. For k_{it}^R and h_{it}^R we need to construct time series for each country's physical and human capital stocks. We construct physical capital stocks from the Penn World Tables (PWT) series on real investment. Investment data start in 1950. To initialize the capital stock we assume that the growth rate of investment up to 1950 has been the same as the observed growth rate of investment between 1950 and 1955.[6] In order to minimize the bias arising from this arbitrary choice of initial value of the capital stock we begin our convergence decomposition in 1960. Little is lost by this curtailing of the time series as most of the important convergence spurts (with the exception of Italy) begin right around, or after, this date.

To construct data on h_{it}^R we mostly use the De La Fuente and Domenech (2002) data set on average years of schooling in the OECD. However, De La Fuente and Domenech data stop in 1990 or 1995, depending on the country. To extend the series to 2000 we use the growth rates (over the relevant periods) of the corresponding series in the Barro and Lee (2001) data set – in combination with the latest level reported by De La Fuente and Domenech.[7] With these data at hand, we follow the development-accounting literature and estimate each country's human capital as $h_{it} = \exp(\beta s_{it})$, where s_{it} is the average years of schooling in the labor force, and β is the Mincerian rate of return to one extra year of schooling. We set $\beta = 0.10$, which reflects a broad consensus on the average returns to schooling around the world. Finally, following yet again the development-accounting literature, we set $\alpha = 0.33$. We report later on how results change when using country-specific capital shares.[8]

Before proceeding to the formal results, we spend a minute looking at the time series in Figure 4.1, where we plot the time paths of k^R, h^R, and A^R for all countries. For physical capital we see patterns of convergence that broadly resemble those in Figure 2.1: Poor countries started out with lower physical capital levels than France and accumulated faster over time, while rich countries started out with more capital and accumulated more slowly than France. This is very Solovian. The only exceptions are Italy, which by 1960 already had a level of capital intensity very close to France's (and kept it that way thereafter), and the

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[6]Hence, $K_{1950} = I_{1950}/(g + \delta)$, where g is the investment growth rate between 1950 and 1955, and δ is the depreciation rate. Young (1995) follows a similar approach. Following the development-accounting literature we set $\delta = 0.06$.

[7]An alternative would have been to use Barro and Lee throughout, but the De La Fuente and Domenech data are supposed to constitute an improvement over Barro and Lee for this set of countries. In the Appendix we compare the average years of schooling variable from the two data sets (Figure A.1). It does appear that the Barro and Lee numbers contain some surprising jumps in their series. The country rankings of attainment are also more consistent with our priors. In footnote 10 we report on the results of the convergence-accounting exercise when using the Barro and Lee data.

[8]For a survey of development-accounting methods see Caselli (2003). We will not bore the reader with the obvious list of caveats and disclaimers about the very rough and tentative nature of the exercise just described.

U.K., which in 1960 had lower capital intensity than France – despite being richer. Relative human capital in 1960 was also generally lower in poor countries and higher – or about the same as in France – in rich countries. However, unlike what we see for physical capital, relative human capital levels are extremely persistent, so that relatively human-capital-poor countries remain that way throughout the period. This is not very "augmented-Solovian" at all, and it implies that human capital accumulation cannot have contributed much to aggregate convergence. Two exceptions are perhaps Denmark and Norway, which have lost some of their human-capital advantage relative to the rest.

Initial relative TFP levels were lower in Greece, Portugal, and Austria, but rose after 1960, so technology catch-up contributed to these countries' convergence. In Spain and Italy, however, TFP was already at the same level as in France, or higher, in 1960. Still, after that date these two countries continued to outpace France in efficiency gains, so that technological change did contribute to their overall convergence. Basically, these countries used faster technological change (and Spain also faster capital deepening) to bridge the gap caused by their persistently lower human capital. For the initially rich countries, the expected pattern of initially higher and subsequently falling relative TFP is observed in the U.K., the Netherlands, and Sweden. However, Denmark's TFP is roughly at France's level throughout the period, so that its relative loss is entirely due to slower rates of physical and human capital accumulation. Norway actually starts out with lower TFP and converges to France from below, so that France's convergence to Norway occurs despite technological catch-up from Norway to France. One objection to the use of years of schooling as a measure of human capital is, of course, that it does not take into account the differences in the quality of education across countries. Caselli (2003) performs a development accounting exercise using quality-adjusted measures of human capital based on international tests and schooling inputs (pupil/teacher ratios and education spending) and finds that these differences are relatively immaterial. While level comparisons might be different from growth comparisons, Caselli's findings are somewhat reassuring.

The casual observations described before are made more precise in Table 4.1, which reports the formal results of the decomposition in equation (1). The first panel shows changes over the entire 1960 to 2000 period. Formally, this means that the Δ operator in equation (1) represents the 40-year difference. The first column reports the value of $\Delta \log y_{it}^R$ for each country. This is basically the same information already reported in Figure 2.1. Hence, for example, Greece's productivity relative to that of France increased by almost one-fourth, or roughly equivalently; over these 40 years Greece's average annual growth rate exceeded France's by little more than one-half percentage point. The biggest gain, of course, was posted by Ireland, whose productivity grew by 60 percentage points more than France's, followed

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by Portugal. Italy's gain looks slightly more modest than those of the other Southerners because most of its convergence spurt took place in the 1950s. The biggest comparative losses were experienced by Sweden and the Netherlands, against which France gained about 30 percentage points of relative income.

The remaining three columns show how relative physical and human capital accumulation and TFP growth contributed to these changes in relative income. These numbers are illustrated in Figure 4.2, where the bars show the contribution of the three terms. (The sum of the bars corresponds to the total convergence to France.) The clearest indication to emerge from the table (as from the figure) is that in nearly all cases – despite substantial differences in levels, and aside from the already-noted two exceptions – convergence in human capital played a nearly insignificant role in driving aggregate productivity convergence.

This leaves it to physical capital and total factor productivity to share the role of proximate sources of convergence. Broadly speaking, in most cases relative TFP growth appears to have contributed slightly more to convergence than capital deepening, but the orders of magnitude of the two contributions are similar.[9] In view of the noisy nature of the data, it seems warranted to conclude that – as a general rule – Western European convergence is attributable in roughly equal parts to faster capital accumulation and technological improvement by the poorer countries. The only clear exceptions are Italy and Ireland, both of which converged overwhelmingly through relative efficiency gains, and Denmark, whose slowdown relative to France we have already noted to be entirely due to slower human and physical capital accumulation.

In sum, the glass is half full both for neoclassical and endogenous growth theorists: Poorer countries experienced faster physical capital deepening, and this explains about 50 percent of their relative gains; and they experienced faster TFP growth, accounting for the remaining 50 percent. But the glass is also half empty for both. Neoclassical growth theorists may be puzzled by the lack of convergence in human capital. And endogenous growth theorists may be disoriented by the fact that not all initially poorer countries lagged the rest technologically, so that their continued faster TFP growth does not square well with the technology catch-up story that these theorists would probably favor.

Inspection of Figure 2.1 reveals in many cases what may loosely be termed a "structural break" around 1975 (that fateful year!). Indeed, 1975 looks like the year of accomplished convergence for several countries. After that year, relative incomes tend to look much more stable. In the case of Greece there is actually a convergence reversal around 1975. For these reasons, it seems useful to present additional decomposition results for the 1960 to 1975 pe-

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[9]This may seem puzzling given the apparently bigger swings of physical capital shown in Figure 4.1, but recall that k^R in equation (1) gets weighted by 0.33.

riod. This is done in Table 4.2, which is otherwise an exact replica of Table 4.1. Notable in this table are the truly exceptional relative performances of Greece and Spain during this sub-period, driven in equal parts by physical capital accumulation and TFP growth in the former and about two-fifths by capital and three-fifths by TFP in the latter. For completeness, in Table 4.3 we also show the convergence decomposition for the 1975 to 2000 period. Here we see with dismay the reversal of much of Greece's gains of the previous sub-period, driven once again in equal parts by a slowdown in capital accumulation and a (relative) technological falling-back; the solid gains that Portugal keeps posting, again attributable to both physical capital and TFP growth; and the TFP-driven explosion of Ireland.[10]

As a robustness check on our conclusions we repeated the capital-TFP convergence decomposition using country-specific capital shares instead of the common value of 0.33. Country-specific capital shares have recently been estimated by Gollin (2002) and by Bernanke and Gurkaynak (2001). Using figures from the latter paper, we found our main conclusion – that human-capital convergence played a very small role in cross-country productivity convergence – to be very robust. More specifically, the numbers for the contribution of human capital to convergence change very little. However, for some countries the relative contributions of physical capital accumulation and technology catch-up do change. In particular, for Greece in 1960 to 2000, convergence becomes overwhelmingly a matter of TFP convergence, while for Spain most of the action becomes concentrated on physical capital. Most of France's catch-up to the Netherlands becomes technological, while its physical-capital catch-up to Denmark and Norway becomes more pronounced (so that, correspondingly, these countries no longer vastly outpace it in TFP growth). The detailed results using country-specific capital shares are presented in Tables 4.4 to 4.7.

5 Trade and Structural Transformation

In this section we turn to interpretations (3) and (4) of the European convergence experience. According to explanation (3), gains from trade following European economic integration disproportionately benefited the (initially less integrated) poor economies. Explanation (4)

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[10]There are some important differences in results when using the Barro and Lee (2001) data on years of schooling instead of those of De La Fuente and Domenech (2002). In particular, convergence in human capital becomes an important source of overall convergence for Greece and Spain. In the former, convergence in human capital almost entirely displaces convergence in TFP as a source of overall convergence, while in the latter it grabs half of TFP's contribution. (Of course, the contribution of physical capital is insensitive to measurement of human capital.) There are also several changes in the results for the Northerners. In particular, according to the Barro and Lee data, the Netherlands, Sweden, and Norway greatly outpace France in human capital accumulation, so that their convergence from above takes place despite strong divergence in human capital. Also, Finland's convergence from below becomes primarily a matter of human capital accumulation.

is that the initially poorer countries had the productive structure most distorted towards low-productivity sectors and that they therefore benefited proportionately the most from the gradual removal of barriers to inter-sectoral mobility.

It is easy to see why these two views can be assessed jointly: They have broadly opposite predictions on the patterns of structural change we should see across countries. In particular, by emphasizing specialization according to comparative advantage, the traditional trade view implies that productivity convergence should be associated with structural *divergence.* On the other hand, by envisioning a world in which all countries gradually shift resources to the greatest value-added sectors, the structural-transformation view predicts that productivity convergence should be accompanied by convergence in industrial composition as well.

In order to investigate these two convergence hypotheses we have put together a data set on the evolution of the industrial composition of output and employment in our 15 countries. Specifically, we have data on the value-added and number of workers employed in the following six sectors: (1) agriculture, hunting, and fishing (henceforth agriculture); (2) manufacturing, mining, and quarrying (henceforth manufacturing); (3) utilities; (4) construction; (5) transportation; and (6) everything else (henceforth, services). We would, of course, have preferred to work with more finely disaggregated data, but this is the best we have been able to do. We observe these data at five-year intervals, starting for most countries in 1955 (but in some cases in 1950 and in some others in 1960). We have assembled these data through a laborious process of parsing from many different sources, both international and national. We give details in the appendix.[11]

We begin the exploration of these data by looking at a series of graphs. Figure 5.1 shows for each country the evolution over time of the employment shares of agriculture, manufacturing, and services. (The other three industries together invariably account for a very small proportion of overall employment.) The textbook pattern of declining employment share of agriculture, increasing employment share of services, and inverted-U-shaped employment share of manufacturing is clearly visible in the graphs for most countries.[12] This is little more than a check on the basic reasonableness of our data. Still, it is useful to be reminded of the sheer magnitude of the differences in industrial composition among Western European countries in the 1950s. For example, all of the Southerners have employment shares of agriculture between 40 and 60 percent (roughly the level of the United States in 1880), while the Northerners have agricultural shares well below 30 percent – and in a few cases well below 10 percent. Fittingly, our "middle-of-the-road" benchmark, France, is in between,

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[11]Given the paucity of organized information on this subject, especially for the early (and more interesting) period, the creation of this data set may well be the most important contribution of the present paper.

[12]See Ngai and Pissarides (2004) for a recent model that matches these empirical regularities.

with 35 percent. For completeness, Figure 5.2 shows the shares of the three "small" sectors. They jointly account, on average, for less than 15 percent of total employment.

That all of the club members have been steadily moving out of agriculture and (eventually) into services is neither surprising nor conclusive with respect to which interpretation of European convergence has more explanatory power. The more important question is whether the various countries are converging towards similar industrial structures – as predicted by a theory in which all countries shift resources towards the highest value-added sectors – or towards permanently different ones – as would be more consistent with a comparative-advantage explanation for convergence. To try to get a handle on this question, we plot in Figure 5.3 the sectoral employment shares in Figure 5.1 minus the corresponding shares in France. We also plot a horizontal line at 0 to better gauge whether the general movement is towards convergence in employment shares.[13]

The data show a general tendency towards structural convergence. The Southerners, together with Ireland and Finland, all start out with higher-than-average agricultural labor shares, but experience a substantial decline in these shares relative to France. Greece, Portugal, and Austria, though, have not yet closed the gap. The Northerners, in contrast, experience a significant increase in agricultural shares relative to France. Manufacturing shares also show remarkable convergence, with some overshooting in the cases of Portugal, Ireland, and Italy. The share of labor in services converges quickly for the Northerners, but less so for the Southerners.

Obviously, if we had all the sectors in the economy, the sum of all the lines would be zero. The persisting differences between the services shares in Greece and Austria and the services share in France are the mirror image of the persisting differences between the corresponding agricultural shares. For Italy, the services gap is made up by a symmetric gap in manufacturing. For Portugal, Ireland, and Finland, the services difference is partly compensated for by the overshooting in manufacturing, partly by a persistent gap in agricultural shares, and partly by an increase in these countries' shares of construction relative to France's, which is shown in Figure 5.4, together with the shares of the remaining (small) sectors relative to the corresponding ones in France.

In sum, at least judging by the coarse evidence of Figure 5.3, the conclusion seems to be that Western European countries did grow closer in industrial structure over the second half of the 20th century – as in the "structural-transformation" view of convergence – but there remain some potentially permanent differences in industrial composition – as in the "comparative advantage" view.

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[13]The analytics in the next sub-section justify using employment-share differences instead of employment share ratios.

Another way to think about trade is to look at the relative labor productivities in the various sectors. In particular, under a comparative-advantage interpretation we would expect non-convergence to occur in those sectors in which labor productivity relative to the "average country" is relatively higher. For this reason, and also because it is interesting in and of itself, we plot in Figure 5.5 each sector's output per worker as a ratio of France's output per worker in the same sector. (We continue to choose France as a plausible stand-in for the average country).

We draw two lessons from these graphs. First, over time there has been significant convergence in the labor productivities of the various sectors towards French sectoral labor productivity levels. We will return to this important *within-industry* productivity convergence process shortly. Second, and more directly relevant to the discussion at hand, it actually does not look as if the remaining differences in industrial structure that seem to emerge from Figure 5.3 are dictated by comparative advantage. For example, looking at recent years, Italy seems to have a comparative advantage in services and a comparative disadvantage in manufacturing. Yet, as we have seen, its pattern of specialization has tilted towards manufacturing. Greece, which specializes in agriculture, has a comparative advantage in everything but.[14,15] An alternative way to look at this is through the plot of differences in sectoral shares with France against relative productivity.

Clearly, this reading of the data relies on all sectors being tradable. One may object, however, that services are very likely less tradable than both manufacturing and agriculture. Restricting the analysis to these two sectors, Greece does not exhibit any clear pattern of comparative advantage vis-à-vis France. Austria and Portugal seem to have a comparative advantage in manufacturing. But then it is certainly difficult for the comparative-advantage view to explain why Greece, Austria, and Portugal have larger shares of agriculture than France. Ignoring services, Italy and Spain exhibit a comparative advantage in agriculture with respect to France until 1970, when the comparative advantage shifts in favor of manufacturing. A similar pattern emerges for Ireland, although the shift occurs more than two decades later. Throughout most of the period, and again at odds with the comparative-advantage view, the shares of agriculture in Spain, Italy, and Ireland, although declining, have been systematically larger than that in France.

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[14]Comparative advantage should be judged against all trading partners and not only France. So, for example, if other trading partners had significantly higher productivity in all sectors relative to agriculture when compared with Greece, we could rationalize the fact that Greece specializes in agriculture. However, looking at the figures we see that this criterion would imply that all other EU members (except for Austria, Germany, and perhaps Norway) should also specialize in agriculture! Note also that Austria, which should not, according to this view, specialize in agriculture, has a relatively large agricultural labor force.

[15]For completeness, Figure 5.6 shows the sectoral labor productivities of the three small sectors.

We now turn the focus to the structuralist interpretation of the data. Let us recapitulate that story. First, there are some sectors that are intrinsically more productive than others. Second, there are labor-market distortions that prevent the flow of resources to the more productive sectors, with the result that even in equilibrium one observes differences in value-added per worker. Third, these imperfections notwithstanding, resources do gradually flow toward the more productive sectors, leading to catch-up by the countries whose industrial structure was initially most distorted.

As a first step to evaluating this view, we plot, for each country, the levels of sectoral labor productivity relative to agricultural productivity. These plots are displayed in Figure 5.7. It is clear from this figure that, for all countries, and throughout the entire period, agriculture is the least productive sector. The (weak) exceptions are the U.K. before 1975, for which the productivity levels of the three sectors are very close, the Netherlands before 1970, and Sweden between 1975 and 1990, for which the productivity gap of services over agriculture is nil. To the extent that poorer countries experience flows of labor away from agriculture larger than the Northerners, these productivity gaps should be a source of overall productivity convergence. As we saw above, this has indeed been the case: Greece, Portugal, Spain, Ireland, and Italy have experienced substantial declines in their shares of agriculture relative to France, whereas the Northerners, having started out with relatively small shares of agriculture, experienced a relative increase in agricultural shares (always with respect to France).

While the inter-sectoral productivity gaps are generally large, there are few clear general trends in their behavior over time. In several countries the gap between the high-productivity sectors (services and manufacturing) and the low-productivity sectors (agriculture) has been slowly closing over the period. This is the case for Greece, Spain, Italy, Germany, Denmark, Sweden, Finland, and our reference country, France. However, in all these cases, the inter-sectoral productivity gaps remain well above 50 percent. For Portugal, the productivity gap in favor of manufacturing declines until 1980, stabilizes during the eighties, and then shoots up decisively, together with the productivity advantage of the services sector, which shows no trend in the earlier period. In the U.K., the Netherlands, and Norway, we see a sizeable increase in the productivity premium of manufacturing starting in the mid seventies. Ireland shows a similar pattern, although the increase starts in 1980. Austria exhibits significant increases in the productivity advantage of both services and manufacturing relative to agriculture in the sixties. Belgium's experience is an attenuated and more gradual version of Austria's.

For the sake of completeness, Figure 5.8 shows the labor productivity of the remaining (small) sectors relative to agriculture. Again there are no uniform trends across countries.

What strikes the eye is that the utilities sector is substantially more productive than the two other sectors and agriculture, although this is neither very surprising (given that the utility sector is not labor-intensive), nor very relevant (as utilities account on average for less than 2 percent of the labor force). Far below utilities, the next sector in this B-league ranking is transportation and the third and last is construction (although in some countries – such as Greece – and in some sporadic years, the ranking between these two is reversed).[16]

      This discussion so far suggests the following tentative conclusion. Initially poorer Western European countries converged to France because: (i) The productivity of the sectors in which they specialized converged to the productivity of the same sectors in France – this is the *within industry productivity convergence* documented in Figure 5.5; (ii) They moved a larger share of their workforce towards the higher productivity sectors – this is the pattern of *convergence in sectoral composition* of the labor force documented in Figure 5.3; and (iii) (For some of these countries) there was a generalized convergence of the productivity of the sectors in which they had a disproportionate share of the labor force to the productivity of the sectors in which France was specialized – when and where this *inter-sectoral productivity convergence* occurred can be seen in Figure 5.7. We turn now to a quantitative assessment of these three channels.

5.1   Convergence Decomposition: Analytics

      Let us call y_{jt}^i the per worker value added in country i, sector j, at time t. Denote by a_{jt}^i the share of employment in country i, sector j, at time t. Total value added per worker in country i at time t, y_t^i, can then be expressed as the weighted sum of sectoral labor productivities,

$$y_t^i = \sum_{j=1}^{J} a_{jt}^i y_{jt}^i. \tag{2}$$

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[16]As we mentioned, new trade theories not grounded on comparative advantage are harder to differentiate from the structural-transformation view in that they do not necessarily predict that integration leads to structural *divergence*. We observe, however, that if trade-induced scale economies had been an important source of catch-up for the Southerners we should see their tradable sectors (agriculture and/or manufacturing) systematicaly outpace their non-tradable sectors (services, utilities, construction, and electricity) in productivity gains. It is hard to discern any such systematic pattern in Figures 5.7 and 5.8.

As always, we use France, $i = F$, as the numeraire for our convergence analysis. We thus measure overall productivity convergence to France by the quantity[17]

$$\Delta \frac{y_t^i - y_t^F}{y_t^F} = \frac{y_t^i - y_t^F}{y_t^F} - \frac{y_{t-1}^i - y_{t-1}^F}{y_{t-1}^F}.$$

This measure of convergence is convenient because it can be *exactly* decomposed into the three channels mentioned in our previous discussion: *i*) within-industry convergence, *ii*) convergence due to labor reallocation, and *iii*) inter-sectoral, or between-industry convergence. To see this, add and subtract the term $\sum_{j=1}^{J} a_{jt}^i y_{jt}^F$ to equation (2):

$$y_t^i = \sum_{j=1}^{J} a_{jt}^i (y_{jt}^i - y_{jt}^F) + \sum_{j=1}^{J} a_{jt}^i y_{jt}^F.$$

Then:

$$y_t^i - y_t^F = \sum_{j=1}^{J} a_{jt}^i (y_{jt}^i - y_{jt}^F) + \sum_{j=1}^{J} (a_{jt}^i - a_{jt}^F) y_{jt}^F$$

$$\frac{y_t^i - y_t^F}{y_t^F} = \sum_{j=1}^{J} a_{jt}^i \left(\frac{y_{jt}^i - y_{jt}^F}{y_t^F} \right) + \sum_{j=1}^{J} (a_{jt}^i - a_{jt}^F) \frac{y_{jt}^F}{y_t^F}.$$

Taking first differences, and grouping terms conveniently, we obtain:

$$\Delta \frac{y_t^i - y_t^F}{y_t^F} = \sum_{j=1}^{J} \bar{a}_{jt}^i \Delta \left(\frac{y_{jt}^i - y_{jt}^F}{y_t^F} \right) + \tag{3}$$

$$+ \sum_{j=1}^{J} \overline{\left(\frac{y_{jt}^i}{y_t^F} \right)} \Delta a_{jt}^i - \sum_{j=1}^{J} \overline{\left(\frac{y_{jt}^F}{y_t^F} \right)} \Delta a_{jt}^F$$

$$+ \sum_{j=1}^{J} \left(\bar{a}_{jt}^i - \bar{a}_{jt}^F \right) \Delta \left(\frac{y_{jt}^F}{y_t^F} \right)$$

where $\Delta x_{jt} = x_{jt} - x_{jt-1}$ and $\bar{x}_{jt}^i = \frac{x_{jt}^i + x_{jt-1}^i}{2}$.

In the tables that follow, we call "Total convergence" the quantity on the left-hand side in equation (3). "Within-industry convergence" is the quantity on the first line of the right-hand side; this captures the productivity catch-up of each sector with the corresponding one in France, weighted by the average labor share in that sector. "Labor reallocation" is

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[17]Note that the two expressions we study in our convergence decomposition exercises are, to a first-order approximation, equivalent; that is, $\frac{y_t^i - y_t^F}{y_t^F} \approx \ln y_t^i - \ln y_t^F$. To see this, notice that log-linearizing $\frac{y_t^i - y_t^F}{y_t^F} = \frac{y_t^i}{y_t^F} - 1$ around $\frac{y_t^i}{y_t^F} = 1$ leads to $\ln \frac{y_t^i}{y_t^F} (= \ln y_t^i - \ln y_t^F)$. Or, alternatively, $\frac{y_t^i - y_t^F}{y_t^F}$ can be seen as the first-order Taylor approximation of $\ln \frac{y_t^i}{y_t^F}$ around $\frac{y_t^i}{y_t^F} = 1$.

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the quantity in the second line that quantifies the part of convergence due to inter-sectoral workforce movements; it is appropriately weighted by the relative productivity of the sector. In particular, in the special case where there are no within-industry labor productivity gaps $(y_{jt}^i = y_{jt}^F)$, labor reallocation contributes to convergence if and only if country i transfers a larger share of the labor force than does France towards the high-productivity industries. If there are within-industry productivity gaps, this effect may be attenuated. Specifically, if sector j is much more productive in France than in country i, labor reallocation may lead to divergence even if France is moving fewer workers towards this sector. Finally, "between-industry convergence" is the quantity in the third line; it measures the contribution to convergence of inter-sectoral productivity convergence. In particular, if the productivity of the sectors in which a country had a disproportionate share of the labor force converges to the overall productivity of France, we will see convergence.

We perform this decomposition for the whole period, 1960 through 2000, for which sectoral data are available in all countries (except for Ireland, which has data beginning in 1970). The results are summarized in Table 5.1. Panel A shows the convergence decomposition in absolute terms. The first column shows the total productivity convergence to France from 1960 through 2000 (for Ireland, we report the figures for 1970 to 2000). These are the same numbers underlying the plots in Figure 2.1, and the first column of Table 4.1 to a first-order approximation $(\frac{y_t^i - y_t^F}{y_t^F} \approx \ln y_t^i - \ln y_t^F$, as noted before). As we already know, six countries experienced substantial convergence from below: Ireland, Spain, Portugal, Austria, Italy, and Greece. The other countries converged from above or remained at roughly the same level as France.

The three following columns in Panel A show the quantitative magnitudes of the three sources of convergence. The corresponding columns in Panel B show the contribution of each source as a percent of total convergence. These numbers are illustrated in Figure 5.10, which shows graphically the contribution to convergence of the different components. Interestingly, the true Southerners – Greece, Italy, Spain, and Portugal – achieved convergence mainly by reallocation of the labor force from low- to high-productivity sectors (at a faster rate than France, as always). Labor reallocation accounts for about 60 percent of total convergence in Spain and Portugal, 100 percent in Italy, and more than 100 percent in Greece (other elements played against convergence in this country). Hence, for the true Southerners, we find a lot of support for what we called the "structuralist" view of convergence. Labor reallocation is also quite important for the convergence of France to the U.K., as it accounts for about 50 percent of it. (An important part of the story here is that agricultural shares declined much more slowly in the U.K. than in France.)

Austria and Ireland, instead, converged mainly through within-industry productivity

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catch-up. The within-industry mechanism is also behind the convergence of the Northerners, accounting in all cases for more than 60 percent of the total convergence. Within-industry productivity convergence is not well accounted for by either the trade view or the structural-transformation view. Rather, it probably has more to do with the capital deepening and technology catch-up processes highlighted in the previous section.

Given the qualitative evidence from Figure 5.7 it is not surprising that the third component of the sectoral decomposition of convergence, between-industry productivity convergence, is never the most important factor. Indeed, in most cases it is the least important source of convergence – and in some cases it even operates in the direction of divergence. Nevertheless, in the case of Greece, inter-sectoral productivity convergence has been fairly important. In particular, Greece benefited from the productivity gains of agriculture, given its large share in this sector. Portugal and Spain also gained some ground thanks to this between-industry catch-up, although the quantitative contribution of this source has not been as substantial.

Before concluding and summarizing this section we take a brief look at the role of sectoral developments in shaping convergence dynamics in different sub-periods. Hence, we decompose each of the terms in (3) into the two sub-periods 1960 through 1975 (60-75) and 1975 through 2000 (75-00). We now introduce sub-indices to indicate the period to which the difference operator Δ applies. So, within-industry convergence 1960-2000 is decomposed as:

$$
\begin{aligned}
\begin{array}{c} Within\text{-}industry \\ convergence \end{array} \quad &= \quad \sum_{j=1}^{J} \bar{a}_{j00}^{i} \Delta_{60-00} \left(\frac{y_{j00}^{i} - y_{j00}^{F}}{y_{00}^{F}} \right) \\
&= \quad \sum_{j=1}^{J} \bar{a}_{j00}^{i} \left(\frac{y_{j00}^{i} - y_{j00}^{F}}{y_{00}^{F}} - \frac{y_{j60}^{i} - y_{j60}^{F}}{y_{60}^{F}} \right) \\
&= \quad \sum_{j=1}^{J} \bar{a}_{j00}^{i} \left(\underbrace{\frac{y_{j00}^{i} - y_{j00}^{F}}{y_{00}^{F}} - \frac{y_{j75}^{i} - y_{j75}^{F}}{y_{75}^{F}}}_{\Delta_{75-00} \left(\frac{y_{jt}^{i} - y_{jt}^{F}}{y_{t}^{F}} \right)} + \underbrace{\frac{y_{j75}^{i} - y_{j75}^{F}}{y_{75}^{F}} - \frac{y_{j60}^{i} - y_{j60}^{F}}{y_{60}^{F}}}_{\Delta_{60-75} \left(\frac{y_{jt}^{i} - y_{jt}^{F}}{y_{t}^{F}} \right)} \right) \\
&= \quad \underbrace{\sum_{j=1}^{J} \bar{a}_{j00}^{i} \Delta_{75-00} \left(\frac{y_{jt}^{i} - y_{jt}^{F}}{y_{t}^{F}} \right)}_{\text{within-industry conv. 75-00}} + \underbrace{\sum_{j=1}^{J} \bar{a}_{j00}^{i} \Delta_{60-75} \left(\frac{y_{jt}^{i} - y_{jt}^{F}}{y_{t}^{F}} \right)}_{\text{within-industry conv. 60-75}},
\end{aligned}
$$

where $\bar{a}_{j00}^{i} = \frac{a_{j00}^{i} + a_{j60}^{i}}{2}$.

Similarly, labor reallocation is decomposed as

$$
\begin{aligned}
\text{\textit{Labor reallocation}} \atop \text{\textit{convergence}} \quad &= \quad \sum_{j=1}^{J} \left[\left(\overline{\frac{y_{j00}^i}{y_{00}^F}} \right) \Delta_{60-00} a_{00}^i - \left(\overline{\frac{y_{j00}^F}{y_{00}^F}} \right) \Delta_{60-00} a_{j00}^F \right] \\
&= \quad \sum_{j=1}^{J} \left[\left(\overline{\frac{y_{j00}^i}{y_{00}^F}} \right) (a_{j00}^i - a_{j60}^i) - \left(\overline{\frac{y_{j00}^F}{y_{00}^F}} \right) (a_{j00}^F - a_{j60}^F) \right] \\
&= \quad \sum_{j=1}^{J} \left[\left(\overline{\frac{y_{j00}^i}{y_{00}^F}} \right) (a_{j00}^i - a_{j75}^i + a_{j75}^i - a_{j60}^i) - \left(\overline{\frac{y_{j00}^F}{y_{00}^F}} \right) (a_{j00}^F - a_{j75}^F + a_{j75}^F - a_{j60}^F) \right] \\
&= \quad \sum_{j=1}^{J} \left[\left(\overline{\frac{y_{j00}^i}{y_{00}^F}} \right) (\Delta_{75-00} a_{j00}^i + \Delta_{60-75} a_{j75}^i) - \left(\overline{\frac{y_{j00}^F}{y_{00}^F}} \right) (\Delta_{75-00} a_{j00}^F + \Delta_{60-75} a_{j75}^F) \right] \\
&= \quad \underbrace{\sum_{j=1}^{J} \left[\left(\overline{\frac{y_{j00}^i}{y_{00}^F}} \right) \Delta_{75-00} a_{j00}^i - \left(\overline{\frac{y_{j00}^F}{y_{00}^F}} \right) \Delta_{75-00} a_{j00}^F \right]}_{\text{labor reallocation 75-00}} + \\
&\qquad + \underbrace{\sum_{j=1}^{J} \left[\left(\overline{\frac{y_{j00}^i}{y_{00}^F}} \right) \Delta_{60-75} a_{j75}^i - \left(\overline{\frac{y_{j00}^F}{y_{00}^F}} \right) \Delta_{60-75} a_{j75}^F \right]}_{\text{labor reallocation 60-75}}
\end{aligned}
$$

where $\overline{\dfrac{y_{j00}^i}{y_{00}^F}} = \dfrac{1}{2} \left(\dfrac{y_{j00}^i}{y_{00}^F} + \dfrac{y_{j60}^i}{y_{60}^F} \right)$.

Finally, between-industry convergence is decomposed by sub-periods as:

$$
\begin{aligned}
\text{\textit{Between-industry}} \atop \text{\textit{convergence}} \quad &= \quad \sum_{j=1}^{J} \left(\bar{a}_{j00}^i - \bar{a}_{j00}^F \right) \Delta_{60-00} \left(\frac{y_{jt}^F}{y_t^F} \right) \\
&= \quad \sum_{j=1}^{J} \left(\bar{a}_{j00}^i - \bar{a}_{j00}^F \right) \left(\frac{y_{j00}^F}{y_{00}^F} - \frac{y_{j60}^F}{y_{60}^F} \right) \\
&= \quad \sum_{j=1}^{J} \left(\bar{a}_{j00}^i - \bar{a}_{j00}^F \right) \left(\frac{y_{j00}^F}{y_{00}^F} - \frac{y_{j75}^F}{y_{75}^F} + \frac{y_{j75}^F}{y_{75}^F} - \frac{y_{j60}^F}{y_{60}^F} \right) \\
&= \quad \sum_{j=1}^{J} \left(\bar{a}_{j00}^i - \bar{a}_{j00}^F \right) \left[\Delta_{75-00} \left(\frac{y_{j00}^F}{y_{00}^F} \right) + \Delta_{60-75} \left(\frac{y_{j75}^F}{y_{75}^F} \right) \right] \\
&= \quad \underbrace{\sum_{j=1}^{J} \left(\bar{a}_{j00}^i - \bar{a}_{j00}^F \right) \Delta_{75-00} \left(\frac{y_{j00}^F}{y_{00}^F} \right)}_{\text{Between-industry conv. 75-00}} + \underbrace{\sum_{j=1}^{J} \left(\bar{a}_{j00}^i - \bar{a}_{j00}^F \right) \Delta_{60-75} \left(\frac{y_{j75}^F}{y_{75}^F} \right)}_{\text{Between-industry conv. 60-75}}
\end{aligned}
$$

Table 5.2 looks at the within-industry convergence in the two sub-periods 1960 through 1975 and 1975 through 2000. As mentioned before, Austria and Ireland converged mainly through within-industry catch-up. However, in the case of Austria, this catching up took

place very early: More than 90 percent of the within-industry productivity gain took place in the first sub-period, whereas in the case of Ireland, more than 90 percent of the catch-up took place in the second sub-period. As for the Northerners, typically more than two thirds of the within-industry convergence took place in the first sub-period. The only exception is Germany, which exhibits significant convergence in the second sub-period, clearly due to the addition of East Germany. An interesting case is Greece, which lost significant ground in terms of within-industry productivity in the second period. This source of divergence is behind the reversal in relative overall productivity noted in Figure 2.1.

Table 5.3 shows the part of the convergence due to labor reallocation in each of the sub-periods. About 50 percent of the labor-reallocation-induced convergence experienced by the Southerners took place in the first 15 years. This fraction is even larger for Greece in this sub-period (65 percent), so we can conclude that Greece converged through labor reallocation in the 1960s and early 1970s and subsequently diverged by losing within-industry relative productivity. For the Northerners, more than 50 percent of the convergence due to labor reallocation appears to have taken place in the first sub-period, except for Norway, where the contribution of the early period's reallocation was 20 percent. All in all, then, these 15 years witness substantial convergence induced by labor reallocation. As discussed early on, this is primarily driven by the relatively faster decline in agricultural shares experienced by the deep Southerners. Recall that Austria, in contrast with the deep Southerners, started with a relatively low share of agriculture, and hence there was little action on this margin. Ireland started out with a somewhat higher agricultural share than Austria, but a share still well below the corresponding ones of the true Southerners.[18]

Summing up to here, the deep Southerners – Greece, Portugal, Spain, and Italy – converged mainly through labor reallocation, with about half of it taking place between 1960 and 1975. In the case of Greece, this effect was counterbalanced in 1975 by significant losses in within-industry productivity. The other (real or honorary) Southerners, Austria and Ireland, converged mainly through within-industry productivity gains, most of which occurred in the first 15 years for Austria and in the second sub-period for Ireland. France converged to the Northerners mainly through the within-industry channel, although in the U.K. labor reallocation also played an important role.

Our tentative overall conclusion on the Western European convergence experience is as follows. First, at least by the admittedly coarse standards we have applied, sectoral specialization according to comparative advantage has not been a critical source of catching up by the initially poorer countries. Instead, disproportionately large labor reallocation towards

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[18]For completeness Table 5.4 shows the between-industry catch-up in the two sub-periods. We do not linger on this table because we saw in Table 5.1 that this mechanism did not play a prominent role for most countries.

more productive sectors has contributed substantially to the convergence of Portugal, Spain, Greece, and Italy towards average Western European levels of labor productivity. Second, we also see substantial within-industry labor productivity convergence, and this was especially important in the catching up of Austria and Ireland. This within-industry labor productivity convergence is probably best understood in the light of the substantial relative gains in physical capital per worker and total factor productivity by poorer countries documented in the previous section. It is probably not linked to human-capital deepening.[19]

6   The Easterners

Enough with latitude: Let's turn to longitude. As mentioned in the Introduction, relative to France, labor productivity in Eastern Europe is roughly where it was in Southern Europe before the South staged its catch-up. Given what we have learned about some of the mechanics of this catch-up, we can try to speculate about the Easterners' prospects. In particular, we can ask two sets of questions. The first set of questions is based on the analysis of Section 4. How much do gaps in physical capital per worker, human capital, and TFP account for the overall productivity gap of the Easterners relative to France? How do these three gaps compare with the corresponding gaps prevailing in Southern Europe in 1960? The second set of questions is linked to the analysis in Section 5. How does the industrial structure of the Easterners differ from France's? How do these differences compare to the corresponding differences in Southern Europe before the catch-up?

We begin, however, by briefly reviewing the aggregate picture. Figure 6.1 plots current levels of labor productivity relative to France in 13 "Eastern-European" countries: the 10 admitted into the EU in May 2004, plus three candidates, Bulgaria, Romania, and Turkey. For comparison, we also plot the corresponding relative productivities in the five Southerners in 1960. (For these aggregate GDP comparisons we could have plotted the 1950 values for the Southerners, but – for reasons already discussed above – the earliest available date for the disaggregated comparisons we present later is typically 1960. Hence, we chose to write this section with 1960 as the benchmark). To continue with the geographic theme, these relative productivities are plotted in increasing order of longitude. As before, these productivity data come from PWT.

The Easterners are very unproductive relative to France. In fact, their real produc-

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[19]Needless to say, intersectoral reallocation of labor also contributes to overall capital deepening and TFP gains if labor flows towards more capital-intensive and efficient sectors. It would indeed be very interesting to be able to decompose the capital and TFP convergence of the previous section into a within-industry relative capital deepening and TFP growth component and a component linked to sectoral reallocation. At the moment we do not have the data to do this.

tivity gap with France is on average substantially larger than the Southerners' productivity gap in 1960. The exceptions are Malta (which is where Austria was then), Cyprus (between Spain and Austria), Slovenia (similar to Spain in 1960), and Hungary, the Czech Republic, and Slovakia (at about Portugal's level back then). Some of the other countries are far below these levels and indeed considerably poorer (in relative terms) than the Southerners were even in 1950. Romania's relative productivity, 15 percent, is especially low.

What are the sources of these large productivity gaps? One way to answer this question is presented in Figure 6.2, which shows physical capital gaps, that is, levels of physical capital per worker relative to France (first panel); human capital gaps (second panel); TFP gaps (third panel); and investment gaps (fourth panel). The physical capital stocks and TFPs of the Easterners are constructed in the same way as the corresponding variables for Western European countries in Section 4. Unfortunately, we have long time series on real investment rates for only five of the Easterners, which explains the thinner data clouds in the first and third panels. The human capital stocks are also constructed as in Section 4, except that now we must use the Barro and Lee (2001) data as the De La Fuente and Domenech (2002) data set does not cover these countries. Relative capital stocks and relative TFPs are plotted against relative labor productivities. The solid line in each graph is the 45-degree line.

Once again, the most striking feature of this decomposition seems to pertain to human capital: Most of the Easterners have current levels of human capital *above* those of France. Only Slovenia, Malta, and Turkey have fewer average years of schooling than France, and only the last one substantially so. Hence, one conclusion is that among the Easterners, Turkey is the only country whose productivity gap with France is partially explained by a human-capital gap. This was not generally true for the Southerners in 1960: Portugal, Greece, Spain, and Italy all had significantly lower human capital than France. Since human capital gaps seem to be very persistent (see Section 4), this may be viewed as very good news for the Easterners: The handicap that is toughest to overcome is one they do not have.

For the countries with available long investment series, physical capital gaps are large. Indeed, by checking relative physical capital levels against the 45-degree line, we can see that in most cases physical capital gaps are even larger (though not by much) than real productivity gaps. The same was true in 1960 of Portugal, Greece, and Spain. Not surprisingly, for the same countries we also see TFP gaps that are large, but not as large as the labor productivity gaps. The Southerners had smaller TFP gaps, even controlling for the level of relative income. (This makes up for their lower relative human capital.) In sum, it would appear that for the Easterners to converge, what is required is a combination of capital deepening faster than that of the West and technological catch-up. This is exactly what the

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Southerners did. However, the Southerners' initial disadvantage was not as large, so it may be presumed that the Easterners' convergence will take somewhat longer.

One way to see whether the Easterners appear to be on the path to catch up in physical capital levels is to look at investment shares of GDP. These are shown in the fourth panel of Figure 6.2. (Examining these shares is a way of extending the assessment of the physical capital position of a larger number of Eastern European countries.) Judging from the position of relative investment vis-à-vis the 45-degree line, in 1960 the Southerners had investment shares relative to France somewhat higher than their labor productivities relative to France. The same seems to be broadly true today of the Easterners. This is reassuring.

We now turn to industrial structure. The discussion that follows is based on the data reported in Table 6.1 or shown in its graphical equivalent, Figure 6.3, which plots against total productivity (i) the difference in sectoral shares (resh) of each country with respect to France, (ii) the relative sectoral productivity (rely) of each country with respect to France, and (iii) the relative productivity of manufacturing and services vis-à-vis agriculture for each country (secty). Table 6.1 begins by reporting differences in employment shares of the three main sectors vis-à-vis France – in 1960 for the Southerners and in 2000 for the Easterners. Once again, sectoral data construction is described in the Appendix.

There is significant variance in the relative shares of agriculture both within the group of Southerners and within the group of Easterners. Romania and Turkey exhibit the highest agricultural share relative to France. The agricultural share in Romania is 40 percentage points higher than that in France; in Turkey it is 30 percentage points higher. The closest parallel in 1960 is Greece, with roughly a 35-percentage-point difference over France. Poland and Bulgaria are closer to Spain, with a difference in shares vis-à-vis France of about 20 percentage points. Latvia and Lithuania resemble Italy in 1960. If the historical experience of their Southern counterparts is any guide, there seems to be a substantial margin for convergence through labor reallocation for all these countries. In Hungary, Estonia, the Slovak Republic, and Slovenia, differences in labor shares in agriculture with respect to France are lower (somewhere between the corresponding share differentials in Austria and Italy in 1960), while Malta, Cyprus, and the Czech Republic have agricultural labor shares that are very close to those in France (as was the case for Austria in 1960).

Labor shares in manufacturing are larger than France's for all Easterners, except Cyprus, which exhibits approximately the same share as France. On these dimensions, then, the situation is quite different from the Southerners' in 1960, when manufacturing shares were systematically below those in France (except for Austria, whose share was very close to France's).

Services, broadly speaking, take up the slack between these sectors. Romania, Turkey,

Poland, the Czech Republic, the Slovak Republic, and Bulgaria have services shares that are well below the corresponding shares in France in 2000, and the differences are remarkably higher (in absolute terms) than those exhibited by the Southerners in 1960. Continuing with the parallel between the two years, Hungary looks like Greece, Slovenia like Portugal, Lithuania like Spain, and Estonia and Latvia like Italy.

Turning to sectoral productivity (fourth to seventh columns of Table 6.1, second row of Figure 6.3), the Easterners in 1960 are on average significantly less productive vis-à-vis France than the Southerners were in 1960. In particular, with three exceptions, agricultural productivity relative to France is lower for all Easterners than it was for Greece – the country with the lowest relative agricultural productivity in 1960. The exceptions are the Czech Republic, whose relative agricultural productivity is comparable to that in Portugal in 1960; Cyprus, with relative productivity comparable to Spain's; and a big outlier, Malta, whose agricultural productivity is well above France's in 2000.

There are also big contrasts in manufacturing productivity. The Easterners' productivity is remarkably lower than that in France, and the productivity gap is again higher than that exhibited by the Southerners in 1960. Ten out of the 13 Easterners show productivity levels well below 50 percent of France's. The relative productivities for these 10 countries range from 19 percent in Romania to 43 percent in Hungary. In 1960, even Greece, the least productive country in manufacturing, was in a better position, with a productivity equal to 53 percent of France's. This is quite remarkable, given that – as we just mentioned – the industrial production of the Easterners is tilted towards manufacturing. The productivity gaps for Slovenia, Cyprus, and Malta find some counterparts in the Southerners in 1960. Slovenia's relative productivity is similar to that of Portugal. Cyprus's relative productivity falls between that in Spain and Italy, and Malta's compares with Austria's.

A similar picture emerges in services. With the three small exceptions – Cyprus, Malta, and Slovenia – the Easterners' productivity in services is much lower than France's, and productivity gaps are larger than those shown by the Southerners in 1960. Labor productivity relative to France's ranges from 32 percent to 57 percent for the Easterners—without counting the three exceptions—whereas the lowest value for the Southerners in 1960 was 70 percent (in Portugal). Slovenia's relative productivity (77 percent) falls between those of Portugal and Austria, while Cyprus's and Malta's productivities fall between the corresponding ones in Austria and Spain

The last two columns of Table 6.1 (and the last row of Figure 6.3) take up intersectoral productivity differentials. For the Southerners in 1960 manufacturing was between two to three times as productive as agriculture. The corresponding range for services was about two to five. In the East we find more variation. At one extreme, Malta's agriculture

is (slightly) more productive than are the other sectors. At the other, Polish manufacturing is eight times as productive as agriculture, and services ten times! Romania also has an extraordinarily unproductive agriculture, vis-à-vis the other sectors. On balance, and weighted by population, we can conclude that inter-sectoral productivity differentials in the East are at least as large as they were in the South in 1960.

In sum, there are some broad qualitative similarities between the Easterners today and the Southerners in 1960. First, both groups have large shares of their workforce in their least productive sectors. Poland's large share of agriculture illustrates this massive failure of comparative advantage particularly strikingly. But Malta and Estonia also appear to have manufacturing shares that are too big.[20] Second, there is a component of the productivity gap that is not due to sectoral structure but to within-industry productivity differentials. We briefly turn now to a quantitative assessment of these similarities.

Simple algebra along the lines of the previous section allows us to write

$$\frac{y_t^F - y_t^i}{y_t^i} = \sum_{j=1}^{J} a_{jt}^i \left(\frac{y_{jt}^F - y_{jt}^i}{y_t^i} \right) + \sum_{j=1}^{J} (a_{jt}^F - a_{jt}^i) \frac{y_{jt}^i}{y_t^i} + \sum_{j=1}^{J} (a_{jt}^F - a_{jt}^i) \left(\frac{y_{jt}^F - y_{jt}^i}{y_t^i} \right). \quad (4)$$

The left-hand side is the aggregate productivity gap between France and country i, as a percentage of country i's income. The right-hand side decomposes this gap into three components. The first term is the "within-industry" component. Holding constant country i's sectoral employment shares, it answers the question by how much would country i's income increase if its sectoral labor productivities converged to the productivities of the corresponding sectors in France? The second term is the "between-industry component." Holding constant country i's sectoral labor productivities, it asks by how much would country i's output per worker increase if its employment shares were the same as France's. The third component is a "covariance" term.

The results of this decomposition are reported in Table 6.2. The first column is the productivity gap on the left-hand side of equation (4), while columns 2 to 4 report the three pieces on the right-hand side. The top panel, reserved to the Southerners in 1960, shows that broadly speaking within-industry productivity gaps and sectoral composition were both important determinants of the productivity gaps of these countries. The between component was larger than the within component for Italy and Greece, while the within component dominated for Austria, Spain, and Portugal.

The bottom panel reports decomposition results for the Easterners. Consistent with our previous discussion, we find enormous within-industry productivity differences. For some

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[20]This failure of comparative advantage has been noted more broadly. For example, developing countries have huge employment shares of agriculture and much lower relative labor productivity in this sector than in the rest of the economy. For example, Gollin, Parente, and Rogerson (2001).

of the poorest countries, within-industry productivity convergence (holding constant employment shares) would lead to a four-fold increase in aggregate labor productivity. Also, as expected, the within-industry component of the income gap with France is much larger than was the case for the Southerners in 1960.

What is new and somewhat unexpected in Table 6.2 is the relatively limited role of the between-industry component. Despite their large employment shares in the relatively unproductive industries, for 8 out of the 18 Eastern European countries the income gap due to the structure of employment is less than 10 percent (that is, moving to French employment shares holding constant labor productivities would increase output by less than 10 percent). As a result, the between component explains a relatively modest fraction of the overall productivity gap with France. In comparison, except for Austria, the Southerners had substantially larger between components, both in absolute terms and as a percent of the overall income gap. The smaller role of the between component is particularly evident if one compares South and North at similar levels of the income gap with France.

Nevertheless, for some of the largest and poorest countries, labor reallocation towards the more productive sectors would make a substantial difference. In the case of Poland it would raise income by 27 percent – hardly enough to bridge the gap with France, but certainly important in absolute terms. Similarly, attaining French sectoral employment shares would increase income per worker by 32 percent in Turkey, 19 percent in Bulgaria, and 68 percent in Romania.

To summarize, then, we could say the following. In the South, structural imbalances towards the low-productivity sectors were important determinants of their initial income gaps vis-à-vis France, and a big part of their convergence experience is associated with the reallocation of resources towards greater value-added industries. These structural distortions are also present today in the East. Indeed, some of the poorest and largest countries can look forward to meaningful labor productivity gains from inter-sectoral labor reallocation. However, in contrast with the story in the South, these potential gains constitute a relatively small share of their overall income gap. Hence, to the extent that productivity gains through structural reshuffling are a relatively low-hanging fruit, one comes away from this evidence somewhat less bullish about the prospects of fast convergence by the Easterners.

Nevertheless, the news is not all bad. The South also had sizable within-industry productivity gaps – as well as between-industry ones – and was able to bridge most of these gaps through physical capital accumulation and TFP growth. One can only presume that the East will be able to replicate this experience. Furthermore, whatever gaps remain in the South are due to a failure to catch up in human capital. If anything, then, the Easterners should do even better in the long run, as they face no permanent handicap arising from human

capital differentials. But the fact that the within-industry gaps are much larger, coupled with having to rely exclusively on the "within" margin (and not also on the "between" margin), suggests that the long run may take a long time to arrive.

7 Conclusions

In 1950, the average Spanish worker generated goods and services worth little more than 60 percent of the goods and services generated by the average French worker. By 1970, the ratio was 90 percent. How did this happen? The data suggest that a critical mechanism for Spain's explosive catch-up has been a vast redeployment of labor out of agriculture and towards higher value-added sectors. This redeployment was going on in France as well, but because Spain started out with a much larger agricultural sector, it benefited disproportionately. The sectors receiving these labor flows are presumably more productive because they are characterized by higher capital intensity and higher total factor productivity. Consistent with this conjecture, we see Spain's overall capital-labor ratio and TFP catching up strongly with France's. However, a secondary but not trivial part of Spain's convergence to France is the catch-up of labor productivity within sectors: For example, Spanish manufacturing was 60 percent as productive as French manufacturing in 1960, but by 1970 this ratio had increased to 87 percent. Hence, presumably, not all of the overall convergence in physical capital and TFP is linked to the structural transformation: Some of it is driven by relative productivity trends within industries. Despite substantial convergence in sectoral structure, physical capital per worker, and TFP, Spanish average labor productivity has hovered at around 90 percent of French average labor productivity since the mid-1970s . Our data indicate that this persistent remaining gap is due mostly to an equally persistent gap in human capital per worker.

In 2000, the average Polish worker generated goods and services worth 41 percent of those produced by the average French worker. Various elements contribute to this low productivity. As was true for Spain in 1960, a substantially large fraction of workers in Poland is employed in agriculture. The difference between the labor shares of Poland and France is above 22 percentage points. As was true for Spain then, this disproportionate share of agriculture flies in the face of economic efficiency. The average worker in agriculture in Poland produces less than 9 percent of what his counterpart produces in France, while the relative productivities of manufacturing and services are, respectively 40 percent and 56 percent. There is, therefore, substantial scope for efficient labor reallocation in the country. However, these numbers also imply that – once again – as was true for Spain in 1960, there is also a big margin for within-industry productivity catch-up. Indeed, quantitatively, the case of Poland is quite different from the case of Spain, as most of the aggregate productivity gap

with France is attributable to these within-industry productivity gaps. Hence, for Poland, the road to convergence passes through physical-capital deepening and TFP gains at the industry level. This means that convergence may take quite a bit longer. On the other hand, unlike Spain, Poland could actually look forward to a complete catch-up, as it is not hobbled by a human-capital handicap.

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APPENDIX ON SECTORAL DATA

Data on PPP-adjusted real GDP per worker and total employment come from the *Penn World Tables 6.1*. Real GDP per worker is the variable RGDPWOK and total employment is computed using real GDP per capita (RGDPCH), real GDP per worker, and population (POP) as:

$$Total\ employment = \frac{RGDPCH * POP}{RGDPWOK}$$

Shares of sectoral GDP and sectoral employment were computed from the Organization for Economic Cooperation and Development (OECD)'s "*STAN Database for Industrial Analysis*," Volume 2004, release 03. This database reports the value-added at basic prices (named VALU) and employment (EMPN) by sector (ISIC Rev. 3) from 1970 to 2000. The countries covered (and used in our analysis) are: Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, and United Kingdom. There are, however, missing values for some countries/years, which we completed using the OECD's "*National Accounts of OECD Countries*" (Detailed Tables, Volume II, 1970-2001). The variables used are Valu-B (value-added at basic prices), and ETOP (number of persons employed).[21] Both *STAN* and *National Accounts* are available online through *SourceOECD*.

For data on sectoral value-added in the period 1950 through 1970, and for missing values in *SourceOECD* during 1970 through 2000, we use sectoral value-added from various printed editions of the OECD's "*National Accounts of OECD Countries*" (Volume II). In particular, for 1950-1965, we use Table 3 of the 1950-1969 Volume. For 1970-1980, we use Table 12 of the 1970-1982 Volume. For 1985-1990 we use Table 12 of the 1983-1995 Volume, and for 1995 we use Table 7 of the 1989-2000 Volume. (Note that, while available in the books, the information is not always provided by the electronic version of "*National Accounts of OECD Countries*.")[22] For Portugal, "Construction" and "Manufacturing" are aggregated in

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[21]Data for Turkey are available from this source.

[22]There are some differences in the classification across books, for which we performed the appropriate adjustments. In particular, in the first volume, some countries do not separate between "Mining and Quarrying" and "Manufacturing." We created an additional industry (Mining and Quarrying and Manufacturing) with these aggregated data. For countries that do report separately "Mining and Quarrying" and "Manufacturing," the aggregate industry is the sum of the two. An analogous rationale is behind the sectors Public administration, education, and health services, which are aggregated under Community Services. To match the categories between the first two periods in the books and the latter ones, we match "Banking etc." with "Finance etc." "Owenrship of dwellings" is always aggregated with "Finance, etc." in the latter issues. Hence we aggregate them through the whole sample. "Public administration" is matched with "Producers of Government Services." "Health and Education" is matched with "Community, Social, and Personal Services."

1955; we split them by applying the corresponding shares obtained from Bank of Portugal's "*Séries Longas para a Economia Portuguesa pós II Guerra Mundial*," available online at http://www.bportugal.pt/.

For sectoral employment information missing from *SourceOECD* during 1970 through 2000, we use employment data from the International Labor Office (ILO)'s "*LABORSTA Labour Statistics Database*," available on line at http://laborsta.ilo.org/. For the period 1950 through 1970, we use data from "*ILO Yearbook of Labor Statistics - Retrospective Edition - Population Censuses*," along with three editions (1961, 1966, and 1972) of the Book "*ILO Yearbook of Labor Statistics.*" The general strategy is to use overlapping years across different volumes to construct a consistent series. In the case of Italy, for 1965 we split some sectors that were aggregated using the corresponding shares of 1966. Still, labor share data were missing for some country-years. We completed them using Table 1, page 20*, of the "*Annuaire Statistique de la France 1972*," edited by the Institut National de la Statisque et des Etudes Economiques (INSEE). From this report, we used data for France and the United Kingdom (taking the figures in 1954 in lieu of 1955, which were missing; we also took the averages between 1958 and 1962 in lieu of 1960, and 1964 in lieu of 1965). We used these data also for Italy and Spain, in combination with the ILO's *Yearbook of Labor Statistics* data (for 1955 we used 1954; for 1960 we used the average of 1958 and 1962). Finally, we filled in data for Spain in 1965 using data from the book "*Población, Actividad y Ocupación en España: Reconstrucción de la series históricas: 1960-1978.*"

Given that part of the data are based on ISIC. Rev. 1, ISIC Rev. 2 and part are based on ISIC Rev 3., we converted the data into a maximum common denominator. The resulting sectors are 1) Agriculture, Fishing, Forestry and Hunting; 2) Manufacturing, Mining and Quarrying; 3) Construction; 4) Transport, Storage, and Communications; 5) Electricity, Gas, and Water; and 5) Services (including Trade, Restaurants and Hotels, Finance, Insurance, Real State and Business Services, and Community, Social, and Personal Services).

For a group of Easterners, *SourceOECD* has complete data in 2000. This group includes Czech Republic, Hungary, Poland, Slovakia, and Turkey. For the remaining Easterners, we took the sectoral shares of GDP and employment from the 2002 regular reports by the European Economic Commission on each country's progress towards accession. Hence, data for Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Romania, Slovenia, and Malta come from this source.

Sectoral value-added and sectoral employment are obtained by applying the sectoral shares to total real GDP and employment from the Penn World Tables.

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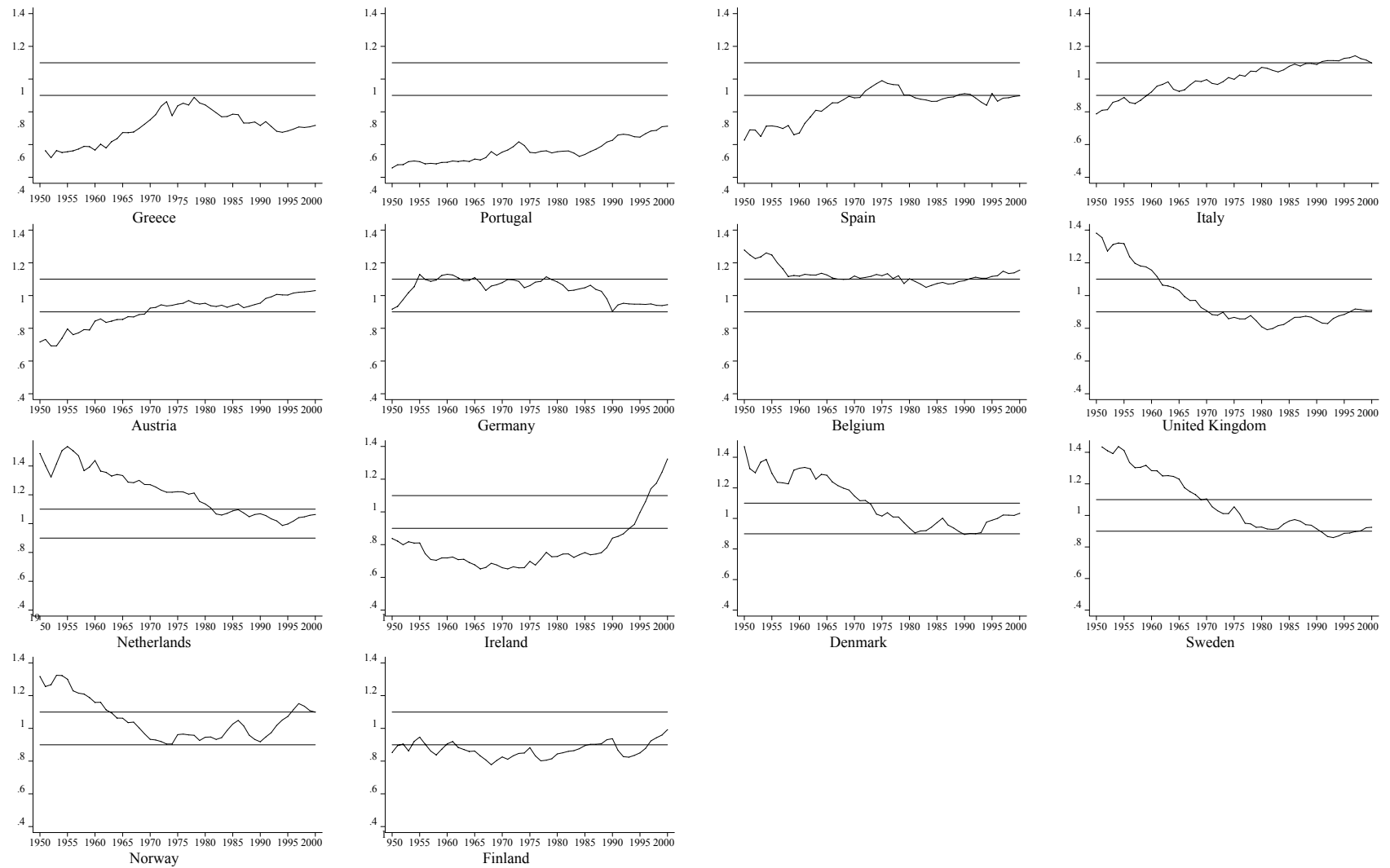
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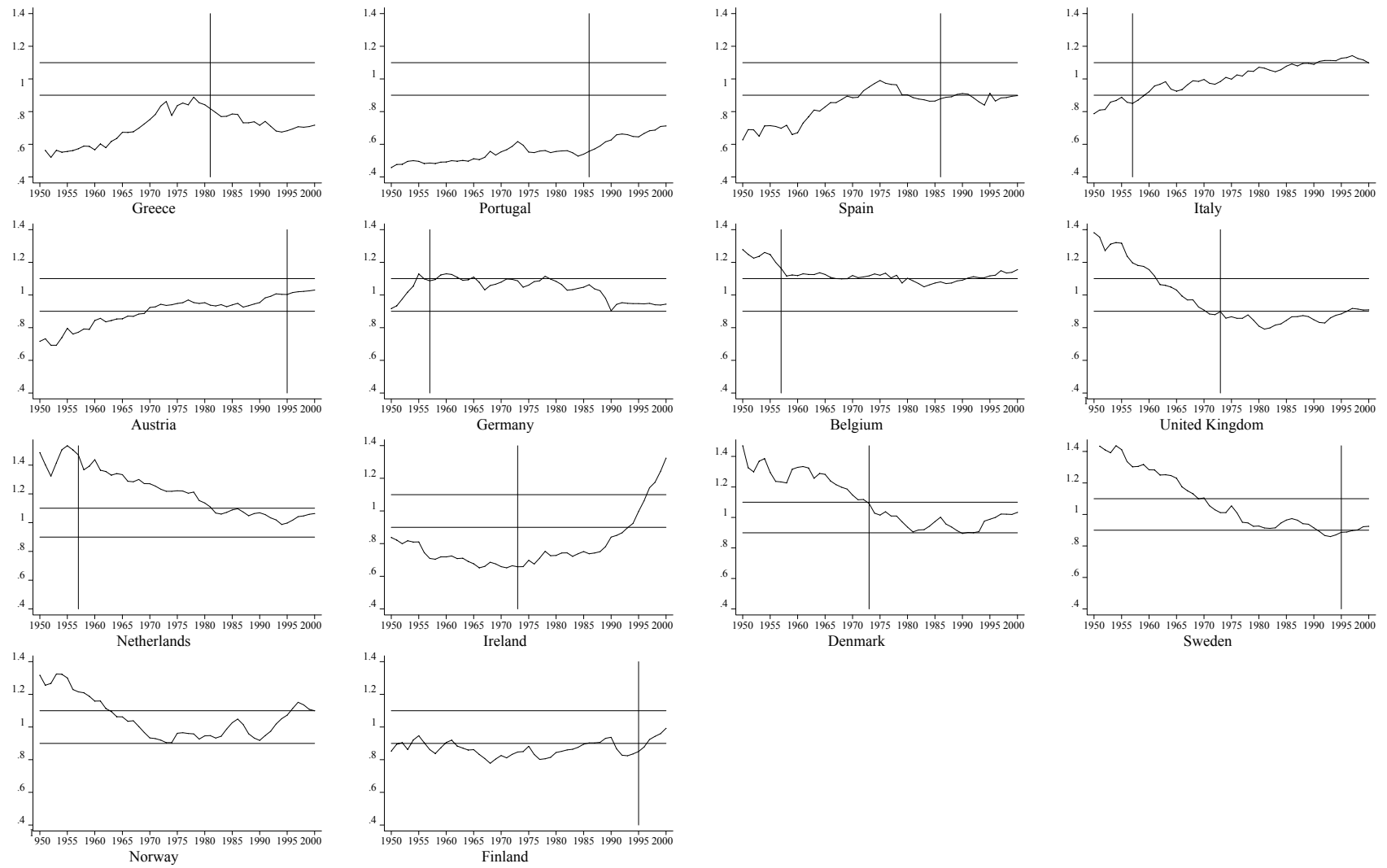
Figure 2.2: Relative GDP and Year of EC Membership

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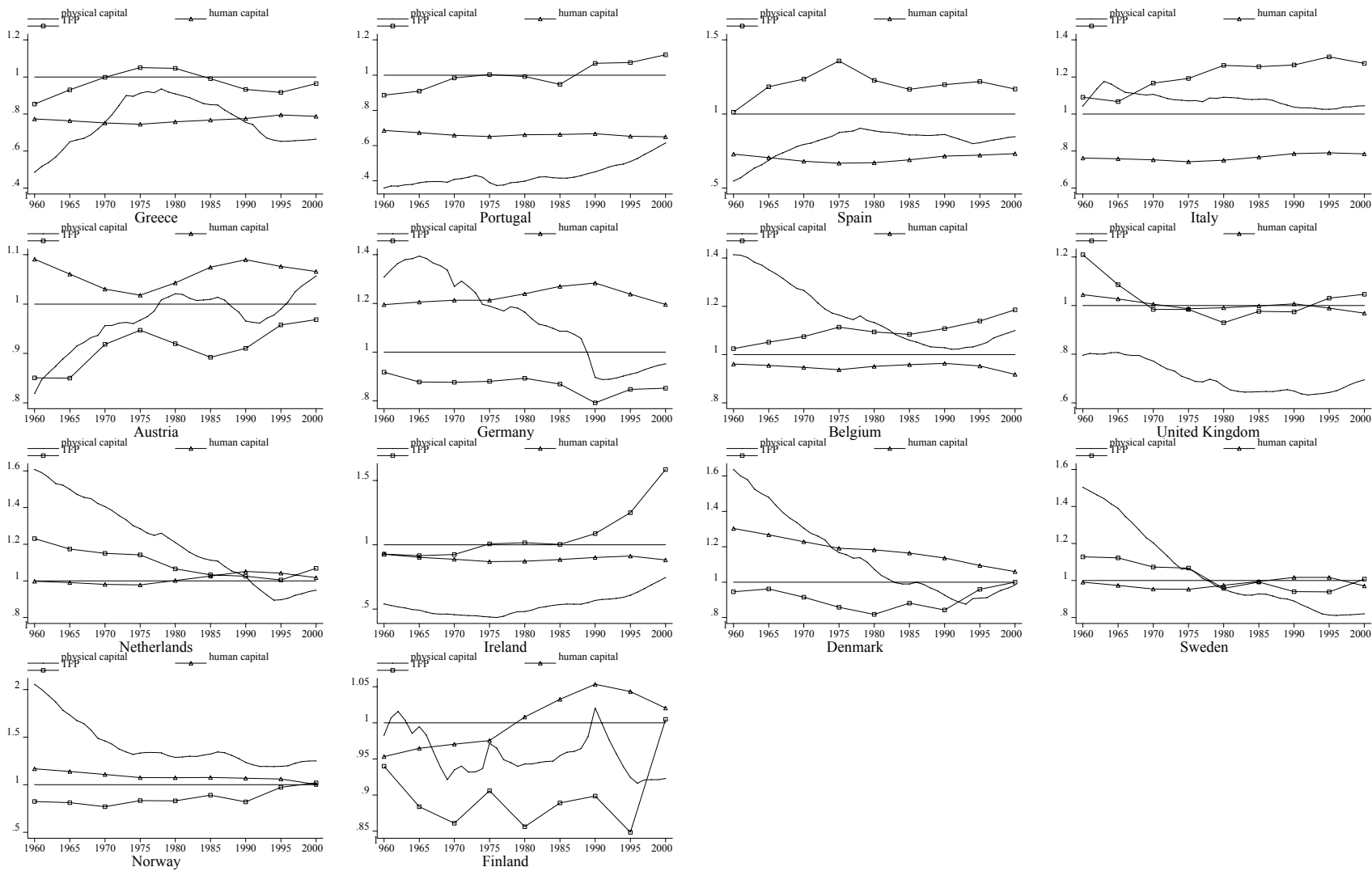
Figure 4.1: Capital Intensity and TFP Relative to France
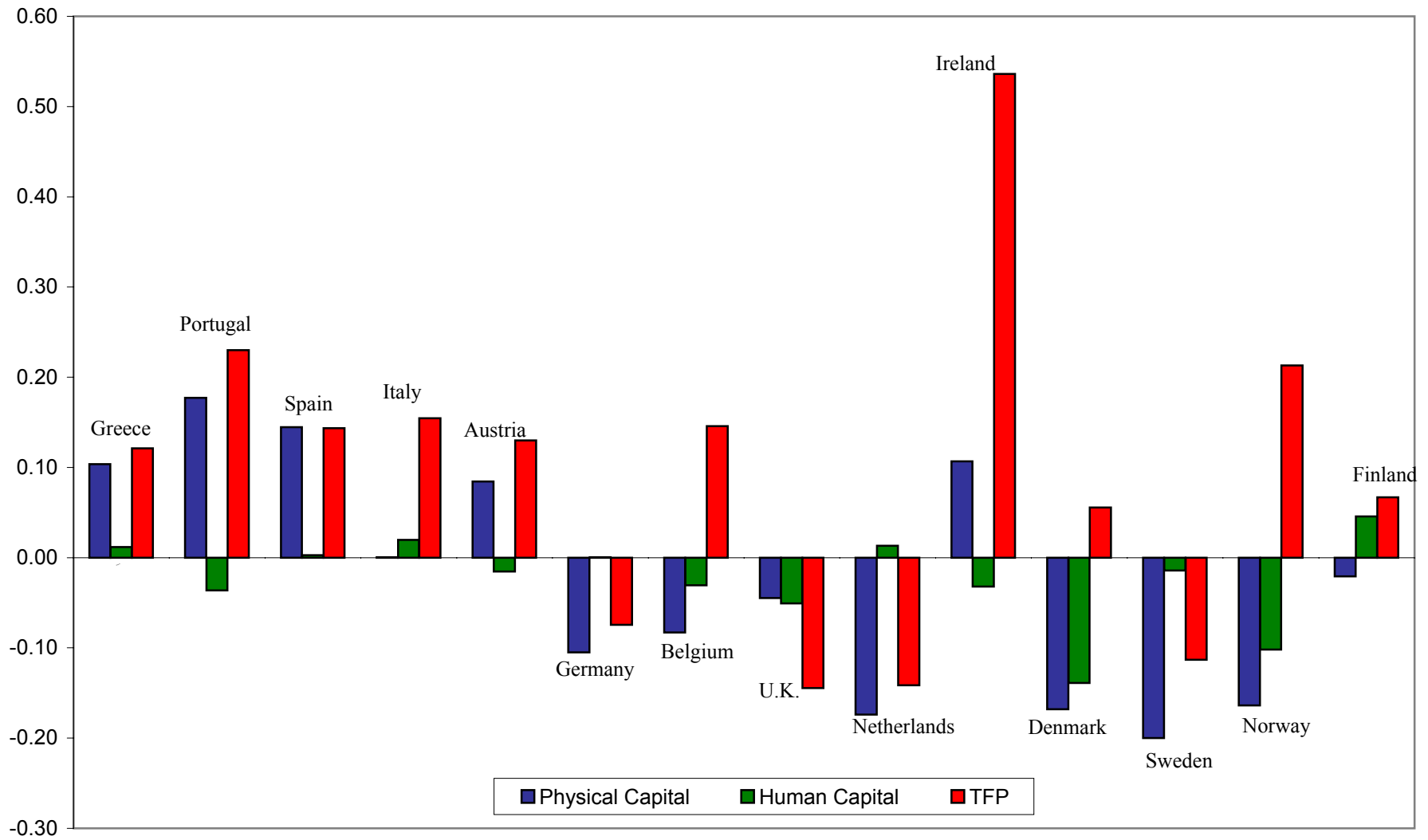
Figure 4.2. Contribution of Physical/Human Capital and TFP to Convergence

Table 4.1. Convergence Decomposition 1960-2000

Country	Total	Physical Capital	Human Capital	TFP
Greece	0.24	0.10	0.01	0.12
Portugal	0.37	0.18	-0.04	0.23
Spain	0.29	0.14	0.00	0.14
Italy	0.17	0.00	0.02	0.15
Austria	0.20	0.08	-0.02	0.13
Germany	-0.18	-0.11	0.00	-0.07
Belgium	0.03	-0.08	-0.03	0.15
United Kingdom	-0.24	-0.04	-0.05	-0.14
Netherlands	-0.30	-0.17	0.01	-0.14
Ireland	0.61	0.11	-0.03	0.54
Denmark	-0.25	-0.17	-0.14	0.06
Sweden	-0.33	-0.20	-0.01	-0.11
Norway	-0.05	-0.16	-0.10	0.21
Finland	0.09	-0.02	0.05	0.07

Table 4.2. Convergence Decomposition 1960-1975

Country	Total	Physical Capital	Human Capital	TFP
Greece	0.39	0.21	-0.03	0.21
Portugal	0.12	0.03	-0.03	0.12
Spain	0.39	0.16	-0.06	0.29
Italy	0.08	0.01	-0.02	0.09
Austria	0.12	0.06	-0.05	0.11
Germany	-0.06	-0.03	0.01	-0.04
Belgium	0.00	-0.06	-0.02	0.08
United Kingdom	-0.29	-0.04	-0.04	-0.21
Netherlands	-0.16	-0.07	-0.01	-0.08
Ireland	-0.03	-0.07	-0.04	0.08
Denmark	-0.27	-0.11	-0.06	-0.10
Sweden	-0.20	-0.11	-0.03	-0.06
Norway	-0.19	-0.14	-0.06	0.01
Finland	-0.03	0.00	0.02	-0.04

Table 4.3. Convergence Decomposition 1975-2000

Country	Total	Physical Capital	Human Capital	TFP
Greece	-0.15	-0.10	0.04	-0.09
Portugal	0.25	0.15	0.00	0.11
Spain	-0.10	-0.01	0.06	-0.15
Italy	0.10	-0.01	0.04	0.07
Austria	0.08	0.03	0.03	0.02
Germany	-0.12	-0.07	-0.01	-0.03
Belgium	0.03	-0.02	-0.01	0.06
United Kingdom	0.05	0.00	-0.01	0.06
Netherlands	-0.14	-0.10	0.03	-0.07
Ireland	0.64	0.18	0.01	0.45
Denmark	0.02	-0.06	-0.08	0.15
Sweden	-0.13	-0.09	0.01	-0.06
Norway	0.13	-0.02	-0.05	0.20
Finland	0.12	-0.02	0.03	0.10

Table 4.4. Convergence Decomposition with Country Specific Capital Shares, 1960-2000

Country	Total	Physical Capital	Human Capital	TFP
Greece	0.24	0.00	0.03	0.21
Portugal	0.37	0.18	-0.05	0.24
Spain	0.29	0.24	-0.02	0.07
Italy	0.17	0.04	0.01	0.12
Austria	0.20	0.13	-0.03	0.10
Germany	-0.18	-0.03	-0.02	-0.13
Belgium	0.03	-0.07	-0.03	0.13
United Kingdom	-0.24	-0.05	-0.05	-0.14
Netherlands	-0.30	-0.07	-0.01	-0.22
Ireland	0.61	0.10	-0.04	0.55
Denmark	-0.25	-0.11	-0.16	0.01
Sweden	-0.33	-0.18	-0.01	-0.14
Norway	-0.05	-0.01	-0.14	0.09
Finland	0.09	0.02	0.04	0.03

Table 4.5. Convergence Decomposition with Country Specific Capital Shares, 1960-1975

Country	Total	Physical Capital	Human Capital	TFP
Greece	0.39	0.09	-0.02	0.32
Portugal	0.12	0.04	-0.04	0.12
Spain	0.39	0.22	-0.07	0.24
Italy	0.08	0.03	-0.02	0.07
Austria	0.12	0.09	-0.05	0.09
Germany	-0.06	0.01	0.00	-0.08
Belgium	0.00	-0.05	-0.02	0.07
United Kingdom	-0.29	-0.04	-0.04	-0.20
Netherlands	-0.16	-0.01	-0.02	-0.13
Ireland	-0.03	-0.05	-0.05	0.07
Denmark	-0.27	-0.07	-0.07	-0.13
Sweden	-0.20	-0.11	-0.03	-0.06
Norway	-0.19	-0.06	-0.07	-0.06
Finland	-0.03	0.02	0.01	-0.06

Table 4.6. Convergence Decomposition with Country Specific Capital Shares, 1975-2000

Country	Total	Physical Capital	Human Capital	TFP
Greece	-0.15	-0.09	0.05	-0.11
Portugal	0.25	0.14	-0.01	0.12
Spain	-0.10	0.03	0.05	-0.17
Italy	0.10	0.01	0.03	0.05
Austria	0.08	0.05	0.02	0.01
Germany	-0.12	-0.04	-0.02	-0.05
Belgium	0.03	-0.01	-0.02	0.06
United Kingdom	0.05	-0.01	-0.01	0.07
Netherlands	-0.14	-0.06	0.01	-0.09
Ireland	0.64	0.15	0.01	0.48
Denmark	0.02	-0.03	-0.09	0.14
Sweden	-0.13	-0.08	0.02	-0.08
Norway	0.13	0.05	-0.07	0.16
Finland	0.12	0.00	0.03	0.09
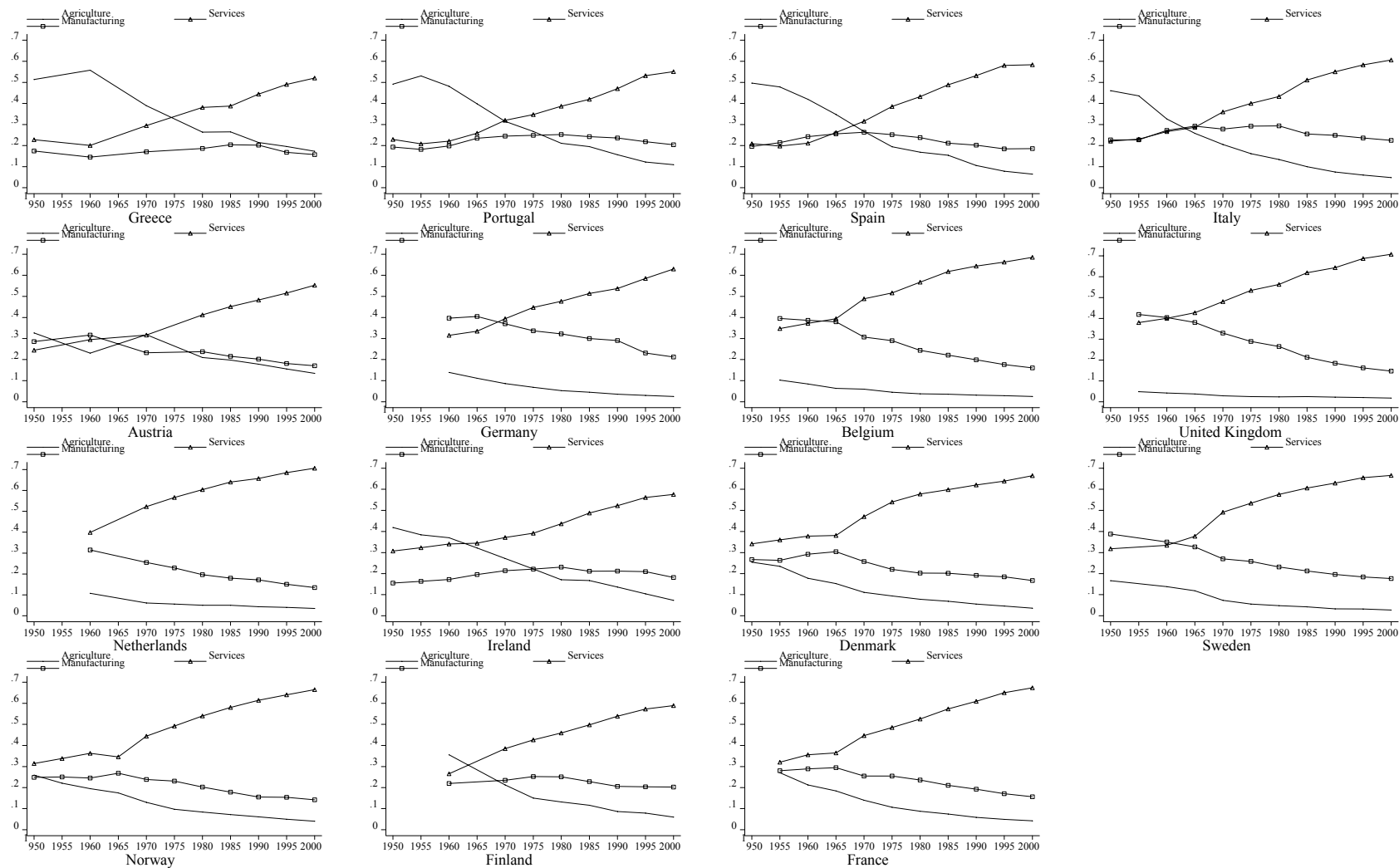
Figure 5.1: Sectoral Employment Shares, Large Sectors
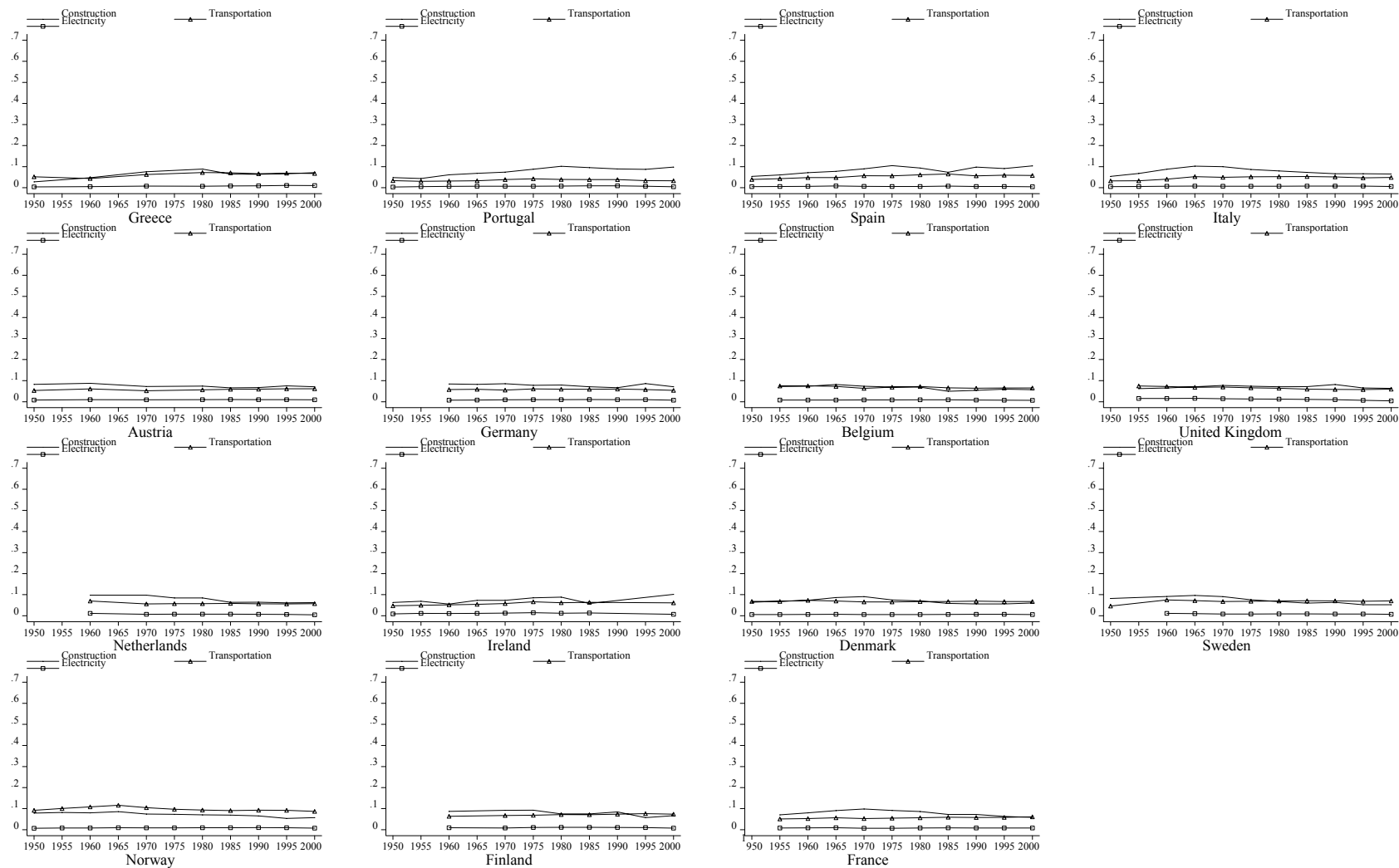
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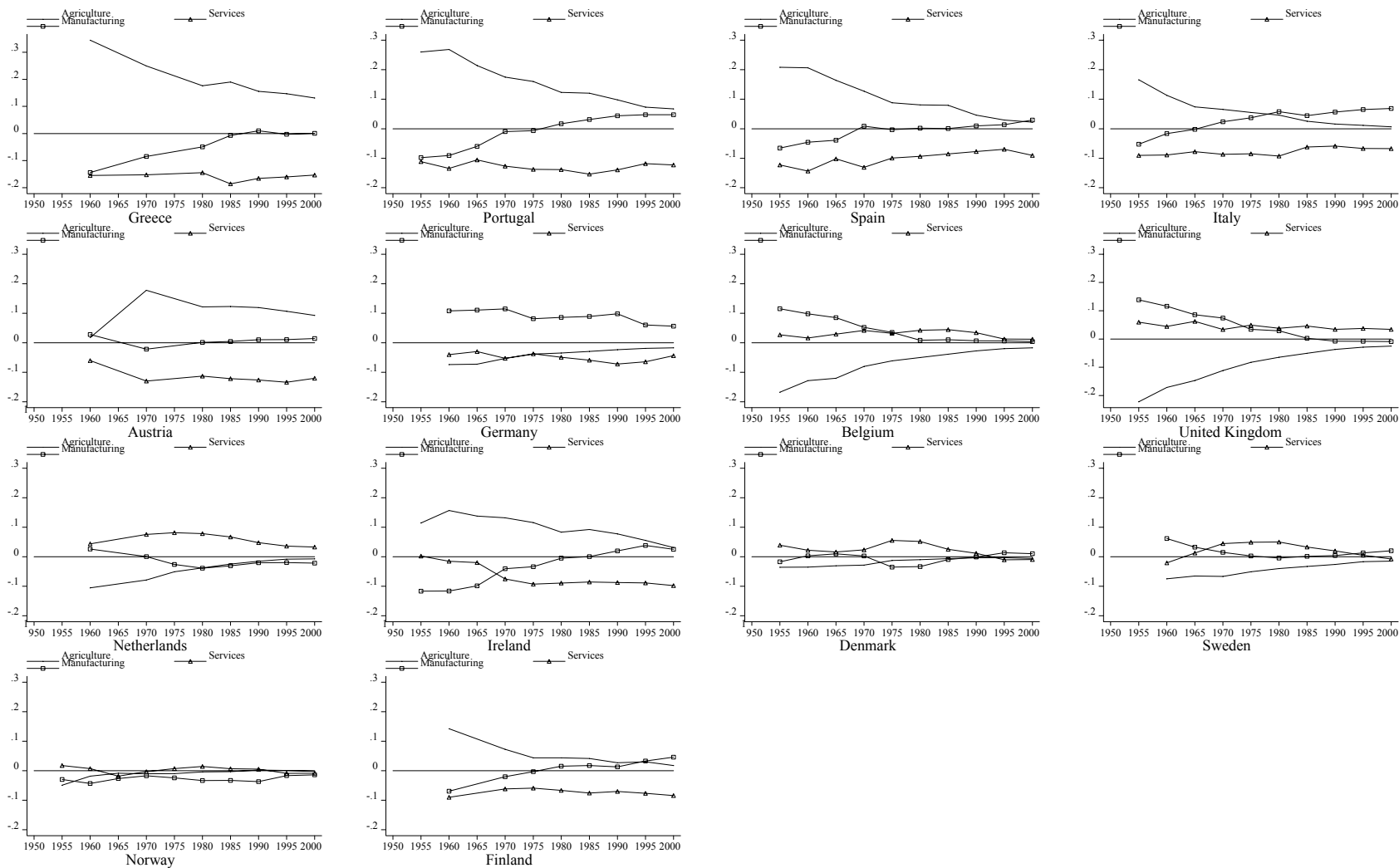
Figure 5.3: Sectoral Employment Difference with France, Large Sectors
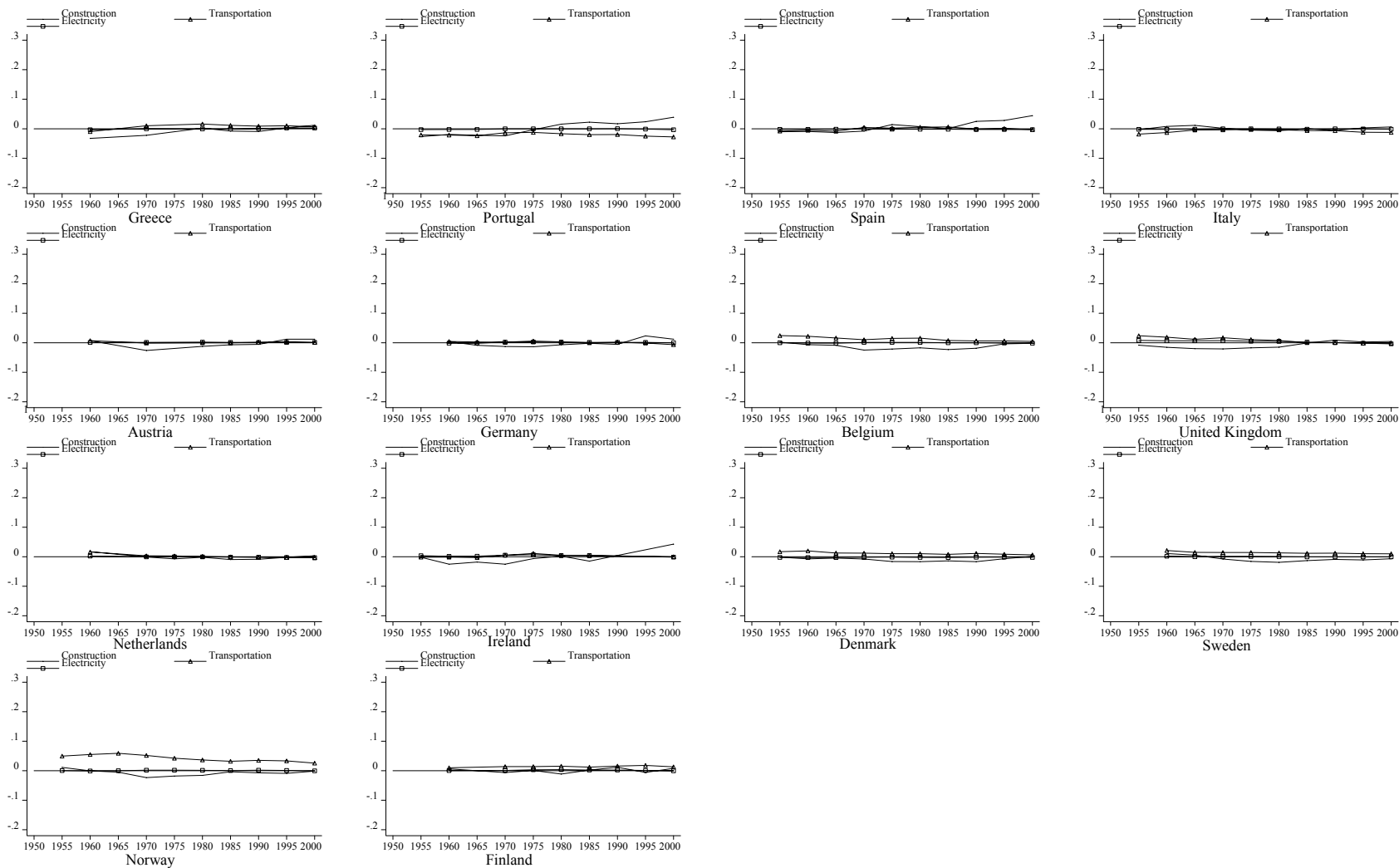
Figure 5.4: Sectoral Difference with France, Small Sectors

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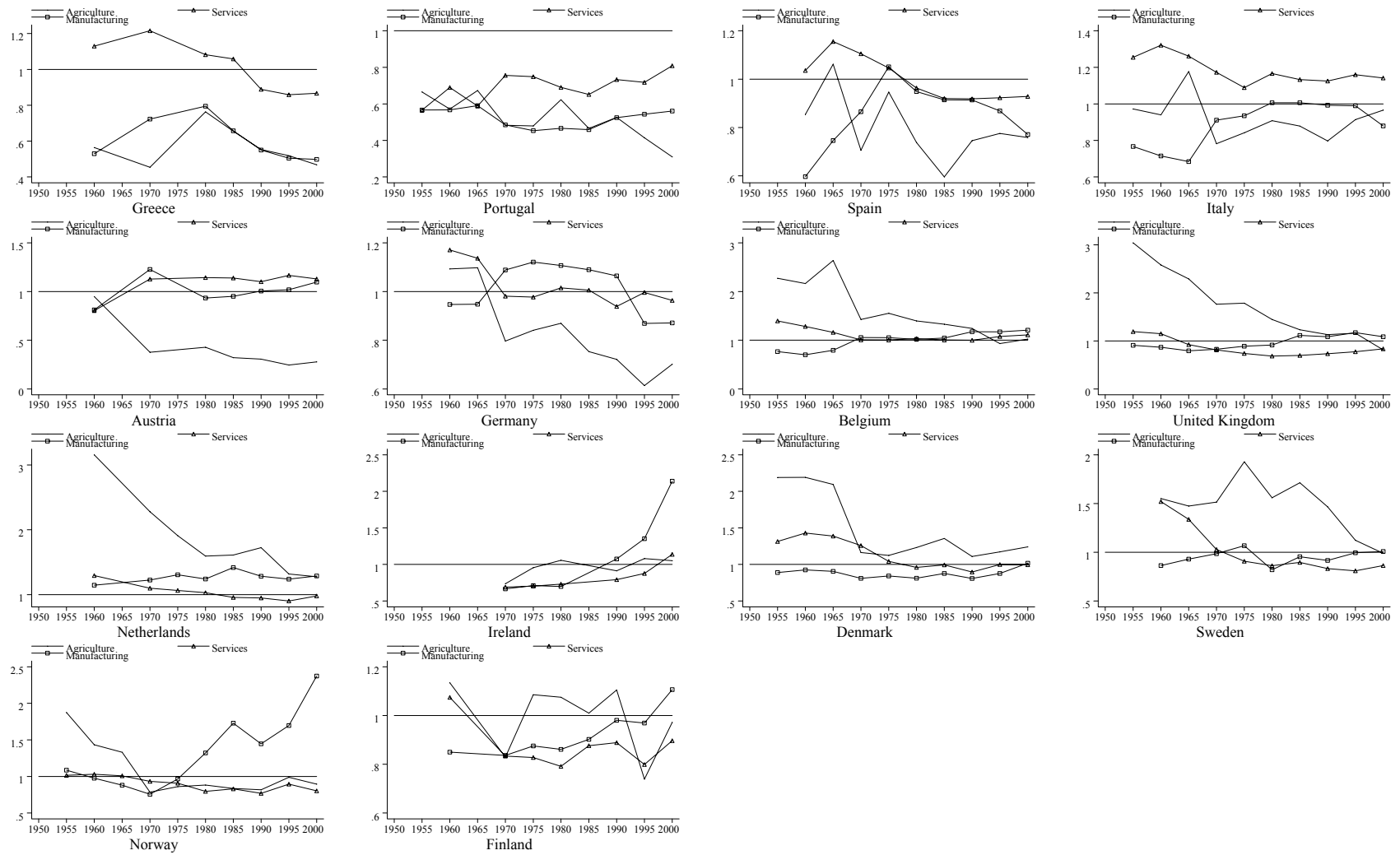
Figure 5.5: Sectoral GDP per Worker Relative to France, Large Sectors
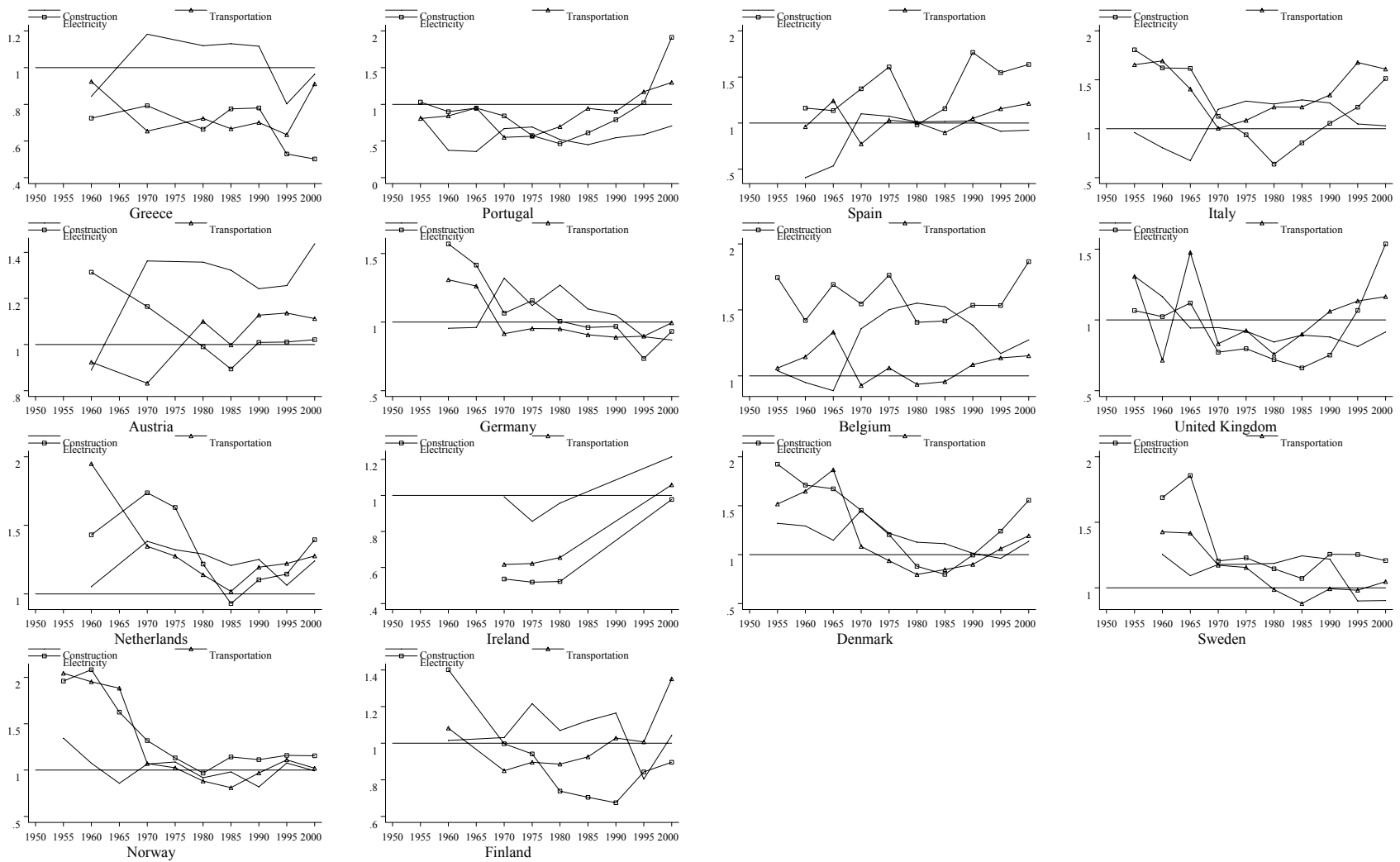
Figure 5.6: Sectoral GDP per Worker Relative to France, Small Sectors
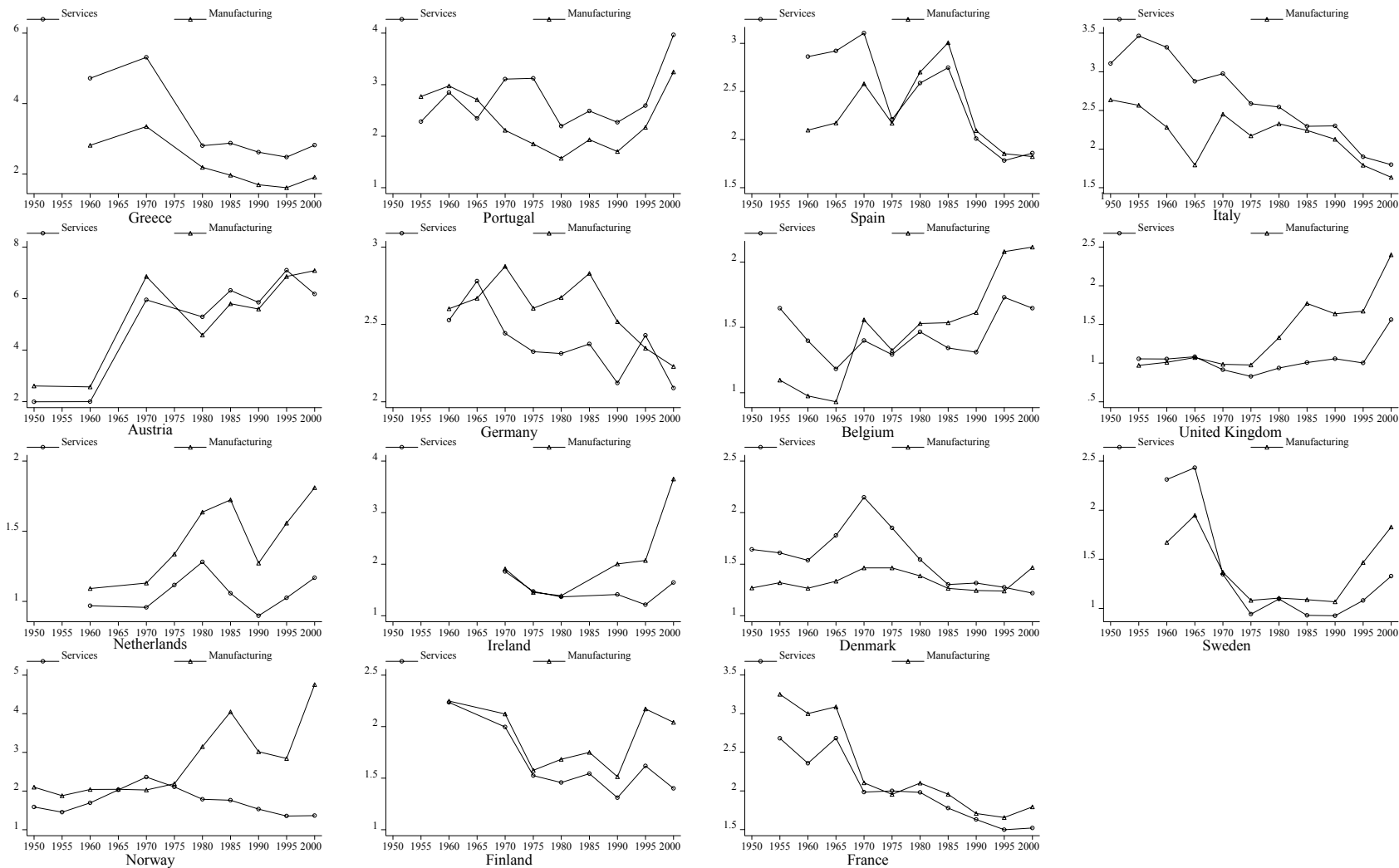
Figure 5.7: GDP per Worker Relative to Agriculture, Large Sectors
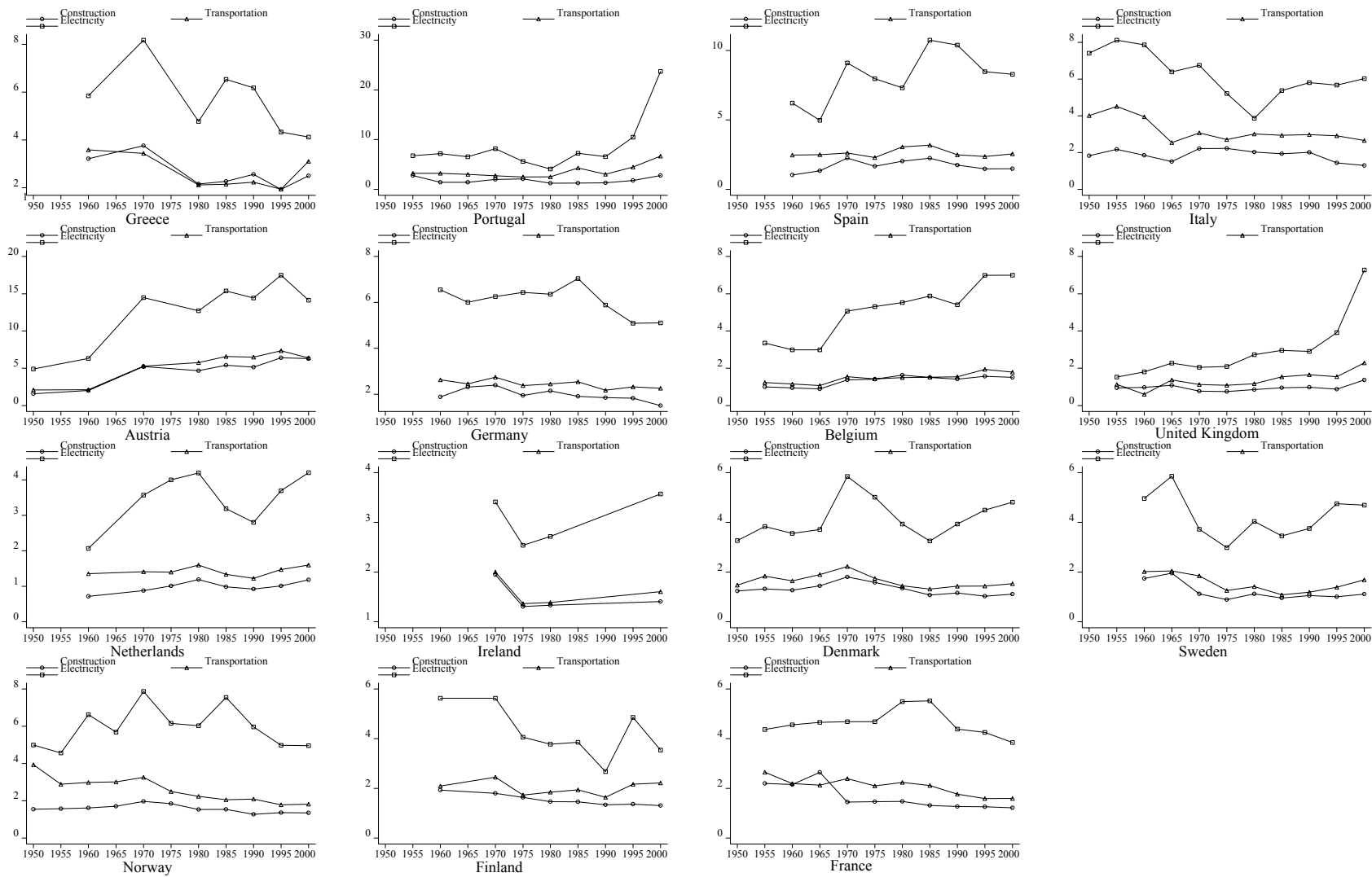
Figure 5.8: GDP per Worker Relative to Agriculture, Small Sectors
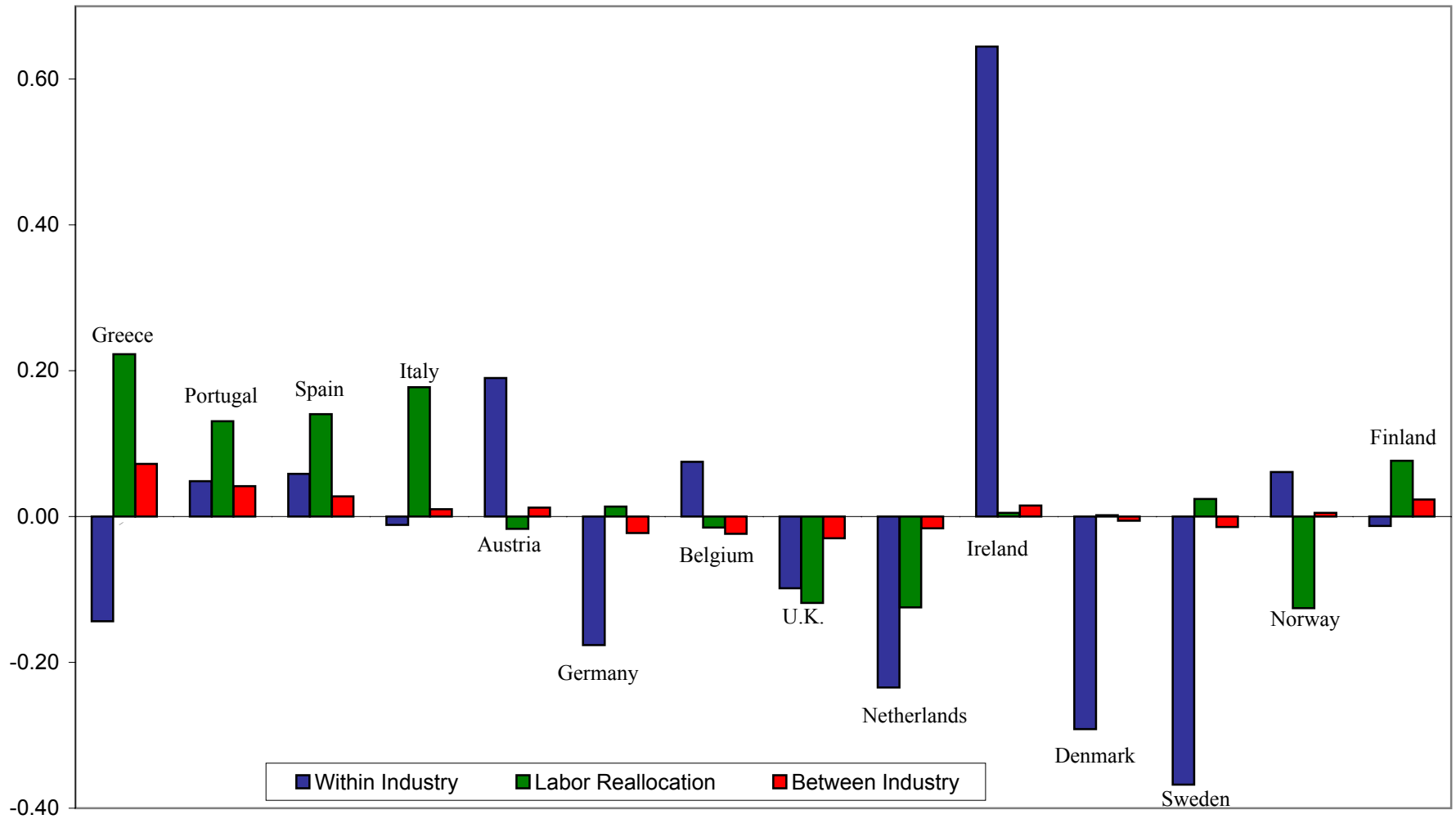
Fig 5.9. Contribution of Within/Between-Industry and Labor Reallocation to Convergence

Table 5.1. Convergence Decomposition 1960-2000

Panel A. Sources of Convergence

Country	Total	Within Industry	Labor Reallocation	Between Industry
Austria	0.18574	0.19021	-0.01690	0.01243
Belgium	0.03656	0.07528	-0.01508	-0.02364
Denmark	-0.29550	-0.29159	0.00174	-0.00566
Finland	0.08694	-0.01294	0.07648	0.02339
Germany	-0.18532	-0.17639	0.01365	-0.02259
Greece	0.15108	-0.14367	0.22265	0.07211
Ireland[a]	0.66513	0.64484	0.00509	0.01519
Italy	0.17588	-0.01138	0.17731	0.00994
Netherlands	-0.37501	-0.23461	-0.12447	-0.01593
Norway	-0.05943	0.06120	-0.12580	0.00517
Portugal	0.22085	0.04858	0.13063	0.04164
Spain	0.22670	0.05847	0.14043	0.02780
Sweden	-0.35827	-0.36782	0.02396	-0.01440
United Kingdom	-0.24639	-0.09833	-0.11848	-0.02958

Panel B. Relative Contribution of Different Sources

Country	Total	Within Industry	Labor Reallocation	Between Industry
Austria	100.00%	102.41%	-9.10%	6.69%
Belgium	100.00%	205.91%	-41.24%	-64.67%
Denmark	100.00%	98.68%	-0.59%	1.91%
Finland	100.00%	-14.88%	87.98%	26.90%
Germany	100.00%	95.18%	-7.37%	12.19%
Greece	100.00%	-95.09%	147.37%	47.73%
Ireland[a]	100.00%	96.95%	0.77%	2.28%
Italy	100.00%	-6.47%	100.81%	5.65%
Netherlands	100.00%	62.56%	33.19%	4.25%
Norway	100.00%	-102.98%	211.68%	-8.70%
Portugal	100.00%	22.00%	59.15%	18.85%
Spain	100.00%	25.79%	61.95%	12.26%
Sweden	100.00%	102.67%	-6.69%	4.02%
United Kingdom	100.00%	39.91%	48.09%	12.00%

[a] The values for Ireland correspond to 1970-2000.

Table 5.2. Within-Industry Convergence. 1960-1975 and 1975-2000.

Panel A. Within-Industry Convergence, by sub-period

Country	1960-2000	1960-1975	1975-2000
Austria[a]	0.19021	0.17845	0.01176
Belgium	0.07528	-0.01176	0.08704
Denmark	-0.29159	-0.33765	0.04606
Finland	-0.01294	-0.11098	0.09804
Germany	-0.17639	-0.06089	-0.11550
Greece[a]	-0.14367	0.06531	-0.20898
Ireland[b]	0.64484	0.03368	0.61117
Italy	-0.01138	-0.04220	0.03083
Netherlands	-0.23461	-0.15446	-0.08015
Norway	0.06120	-0.20269	0.26389
Portugal	0.04858	0.00786	0.04071
Spain	0.05847	0.20573	-0.14727
Sweden	-0.36782	-0.26671	-0.10111
United Kingdom	-0.09833	-0.24155	0.14322

Panel B. Contribution of each subperiod to Within-Industry Convergence

Country	1960-2000	1960-1975	1975-2000
Austria[a]	100.00%	93.82%	6.18%
Belgium	100.00%	-15.62%	115.62%
Denmark	100.00%	115.80%	-15.80%
Finland	100.00%	857.81%	-757.81%
Germany	100.00%	34.52%	65.48%
Greece[a]	100.00%	-45.46%	145.46%
Ireland[b]	100.00%	5.22%	94.78%
Italy	100.00%	370.99%	-270.99%
Netherlands	100.00%	65.84%	34.16%
Norway	100.00%	-331.18%	431.18%
Portugal	100.00%	16.19%	83.81%
Spain	100.00%	351.88%	-251.88%
Sweden	100.00%	72.51%	27.49%
United Kingdom	100.00%	245.66%	-145.66%

[a] Values for Austria and Greece correspond to the subperiods 1960-1980 and 1980-2000. [b] Values for Ireland correspond to the subperiods 1970-1975 and 1975-2000.

Table 5.3. Labor Realllocation. 1960-1975 and 1975-2000

Panel A. Labor Reallocation Convergence, by sub-period

Country	1960-2000	1960-1975	1975-2000
Austria[a]	-0.01690	-0.04635	0.0294519
Belgium	-0.01508	-0.01534	0.00026
Denmark	0.00174	-0.01001	0.01175
Finland	0.07648	0.06019	0.01629
Germany	0.01365	0.00791	0.00574
Greece[a]	0.22265	0.14552	0.07713
Ireland[b]	0.00509	0.00882	-0.00373
Italy	0.17731	0.08253	0.09478
Netherlands	-0.12447	-0.07747	-0.04700
Norway	-0.12580	-0.02582	-0.09999
Portugal	0.13063	0.06996	0.06067
Spain	0.14043	0.07103	0.06941
Sweden	0.02396	0.01126	0.01269
United Kingdom	-0.11848	-0.06430	-0.05418

Panel B. Contribution of each subperiod to Labor Reallocation

Country	1960-2000	1960-1975	1975-2000
Austria[a]	100.00%	101.71%	-1.71%
Belgium	100.00%	101.71%	-1.71%
Denmark	100.00%	-573.88%	673.87%
Finland	100.00%	78.70%	21.30%
Germany	100.00%	57.93%	42.07%
Greece[a]	100.00%	65.36%	34.64%
Ireland[b]	100.00%	173.15%	-73.14%
Italy	100.00%	46.55%	53.45%
Netherlands	100.00%	62.24%	37.76%
Norway	100.00%	20.52%	79.48%
Portugal	100.00%	53.55%	46.45%
Spain	100.00%	50.58%	49.42%
Sweden	100.00%	47.01%	52.99%
United Kingdom	100.00%	54.27%	45.73%

[a] Values for Austria and Greece correspond to the subperiods 1960-1980 and 1980-2000. [b] Values for Ireland correspond to the subperiods 1970-1975 and 1975-2000.

Easterners: 2000, Southerners: 1960
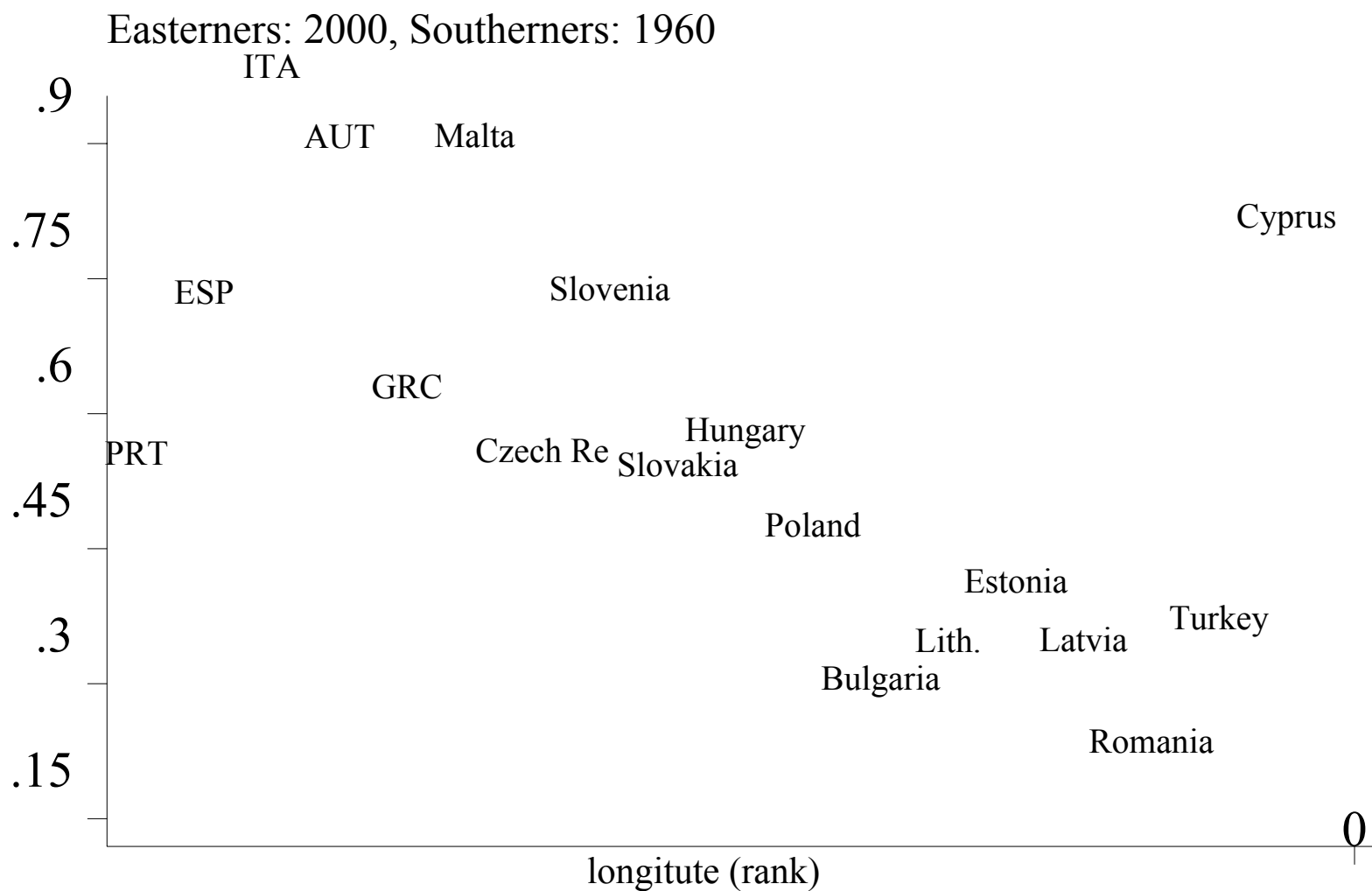
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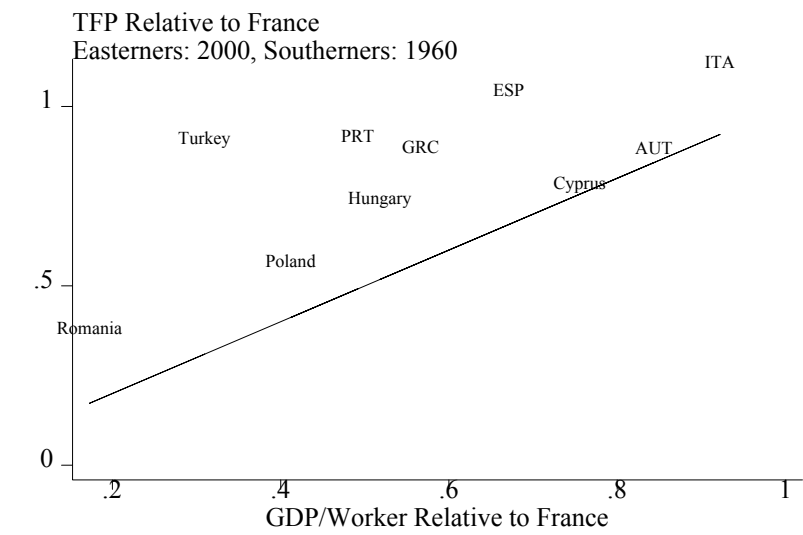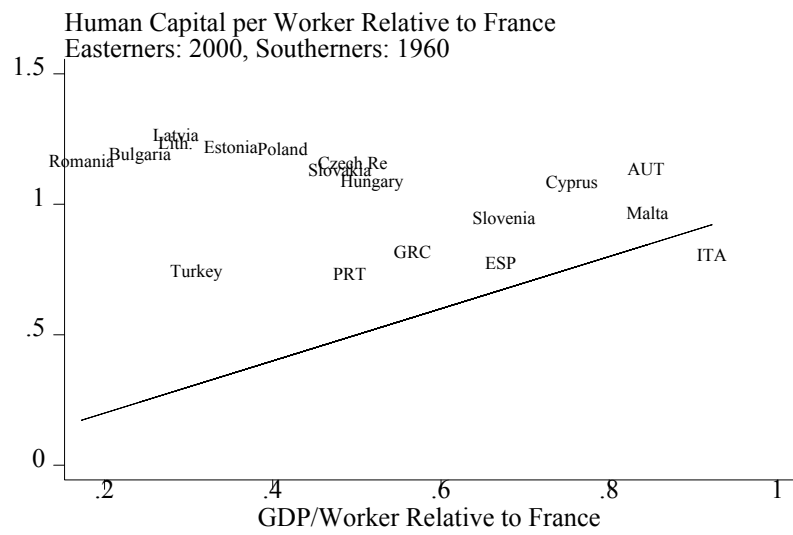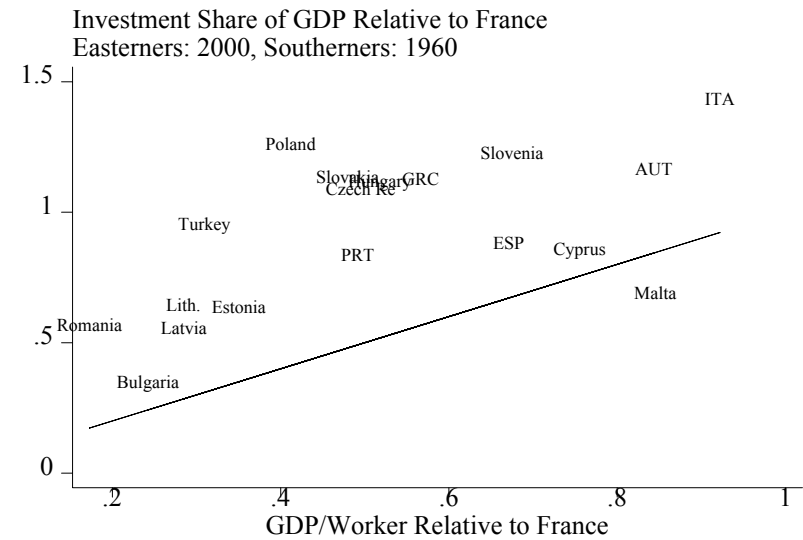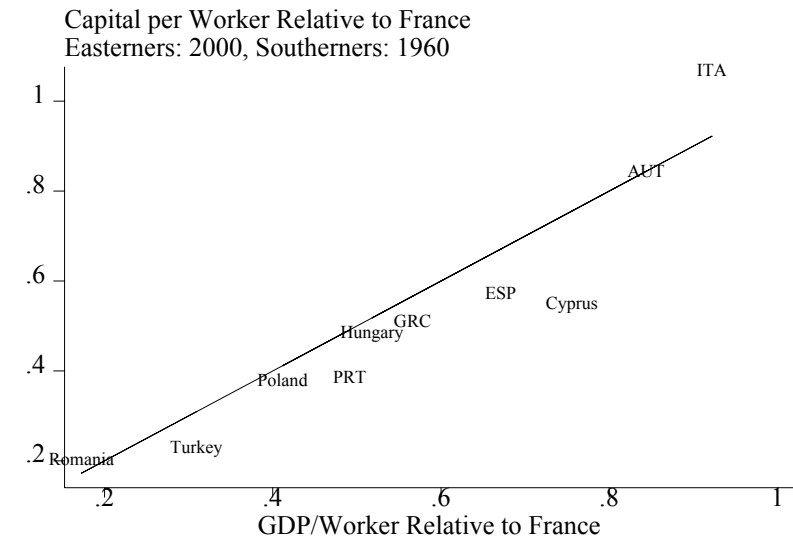
Figure 6.2: Capital Intensity and TFP Relative to France

Table 6.1. The Southerners in 1960 and the Easterners in 2000

Country	Year	Difference in Employment Shares Relative to France			Sectoral Productivity Relative to France			Sectoral Productivity Relative to Agricultural Productivity	
		Agriculture	Manufacturing	Services	Agriculture	Manufacturing	Services	Manufacturing	Services
Spain	1960	0.207	-0.046	-0.144	0.854	0.597	1.036	2.099	2.863
Italy	1960	0.113	-0.017	-0.089	0.940	0.715	1.321	2.283	3.315
Austria	1960	0.017	0.028	-0.060	0.948	0.812	0.803	2.572	1.998
Greece	1960	0.344	-0.144	-0.155	0.565	0.529	1.130	2.815	4.719
Portugal	1960	0.268	-0.091	-0.135	0.571	0.567	0.690	2.977	2.848
Malta	2000	-0.025	0.105	-0.022	1.983	0.829	1.016	0.750	0.779
Estonia	2000	0.028	0.112	-0.091	0.472	0.252	0.400	0.959	1.287
Czech Republic	2000	0.013	0.152	-0.240	0.599	0.392	0.559	1.174	1.420
Cyprus	2000	0.012	-0.015	0.031	0.852	0.644	0.869	1.356	1.551
Hungary	2000	0.024	0.092	-0.160	0.521	0.435	0.556	1.499	1.621
Slovak Republic	2000	0.050	0.098	-0.216	0.379	0.384	0.549	1.821	2.203
Bulgaria	2000	0.225	0.075	-0.213	0.194	0.208	0.320	1.926	2.510
Latvia	2000	0.102	0.052	-0.087	0.150	0.219	0.344	2.628	3.494
Slovenia	2000	0.054	0.167	-0.147	0.359	0.562	0.769	2.810	3.257
Lithuania	2000	0.142	0.059	-0.132	0.184	0.294	0.322	2.868	2.663
Turkey	2000	0.303	0.026	-0.265	0.189	0.331	0.453	3.150	3.647
Romania	2000	0.410	0.065	-0.384	0.072	0.190	0.327	4.728	6.899
Poland	2000	0.220	0.042	-0.263	0.087	0.404	0.568	8.368	9.973
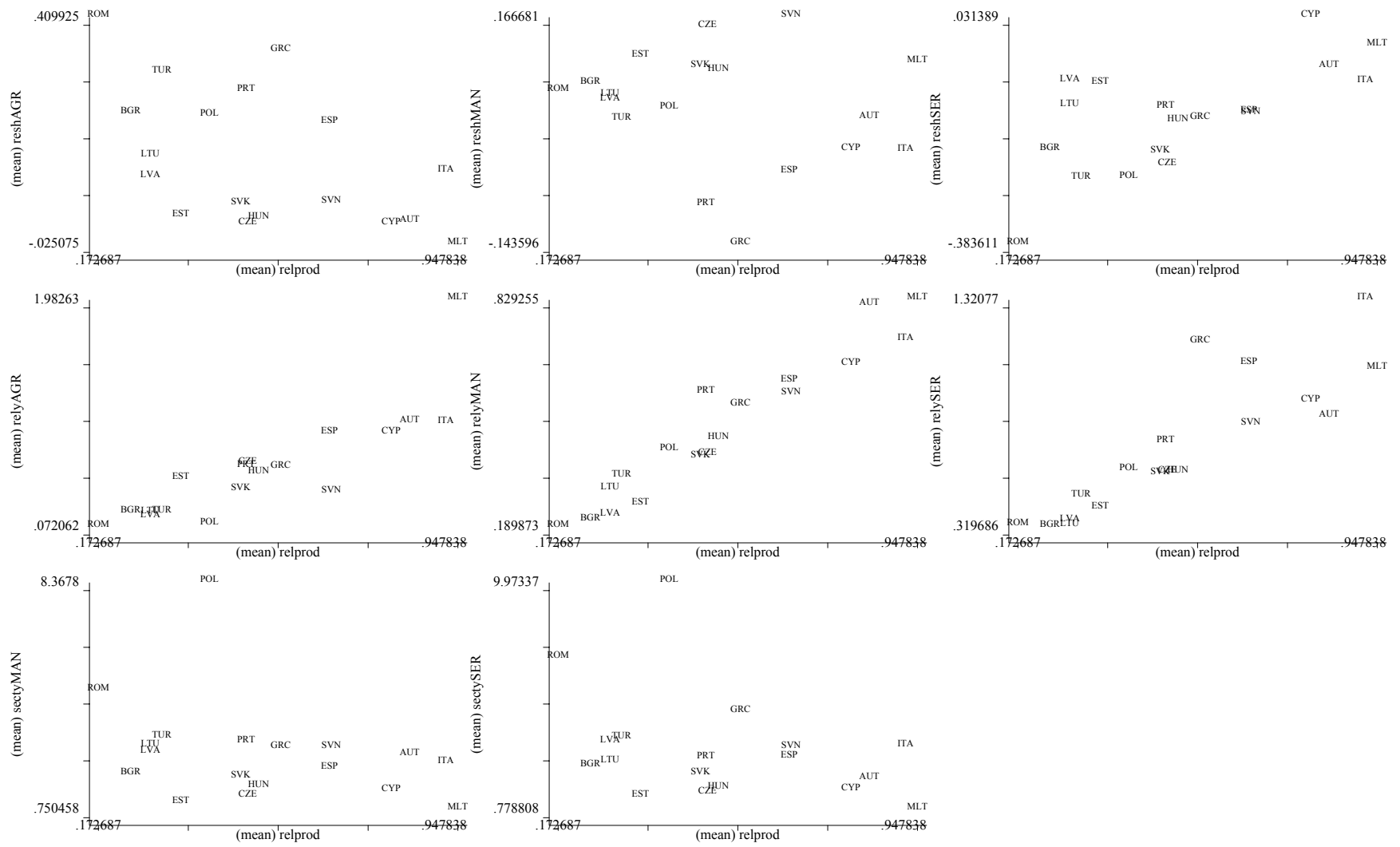
Figure 6.3: Sectoral Data for the Easterners

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Table 6.2. Sectoral Sources of Income Gaps

Country	Year	Total Gap	Within	Between	Covariance
Italy	1960	0.08	0.00	0.12	-0.04
Austria	1960	0.19	0.18	0.00	0.00
Spain	1960	0.49	0.28	0.19	0.02
Greece	1960	0.77	0.33	0.42	0.02
Portugal	1960	1.03	0.65	0.26	0.12
Malta	2000	0.06	0.09	0.02	-0.05
Cyprus	2000	0.24	0.23	0.02	0.01
Slovenia	2000	0.48	0.51	0.07	-0.10
Hunagary	2000	0.93	0.98	0.01	-0.06
Czech Rep.	2000	1.02	1.08	0.04	-0.10
Slovakia	2000	1.08	1.09	0.06	-0.06
Poland	2000	1.43	1.30	0.27	-0.14
Estonia	2000	1.85	1.88	0.04	-0.07
Turkey	2000	2.23	1.91	0.32	0.00
Latvia	2000	2.51	2.42	0.10	-0.01
Lithuania	2000	2.52	2.39	0.09	0.03
Bulgaria	2000	3.13	2.89	0.19	0.05
Romania	2000	4.79	4.09	0.68	0.03
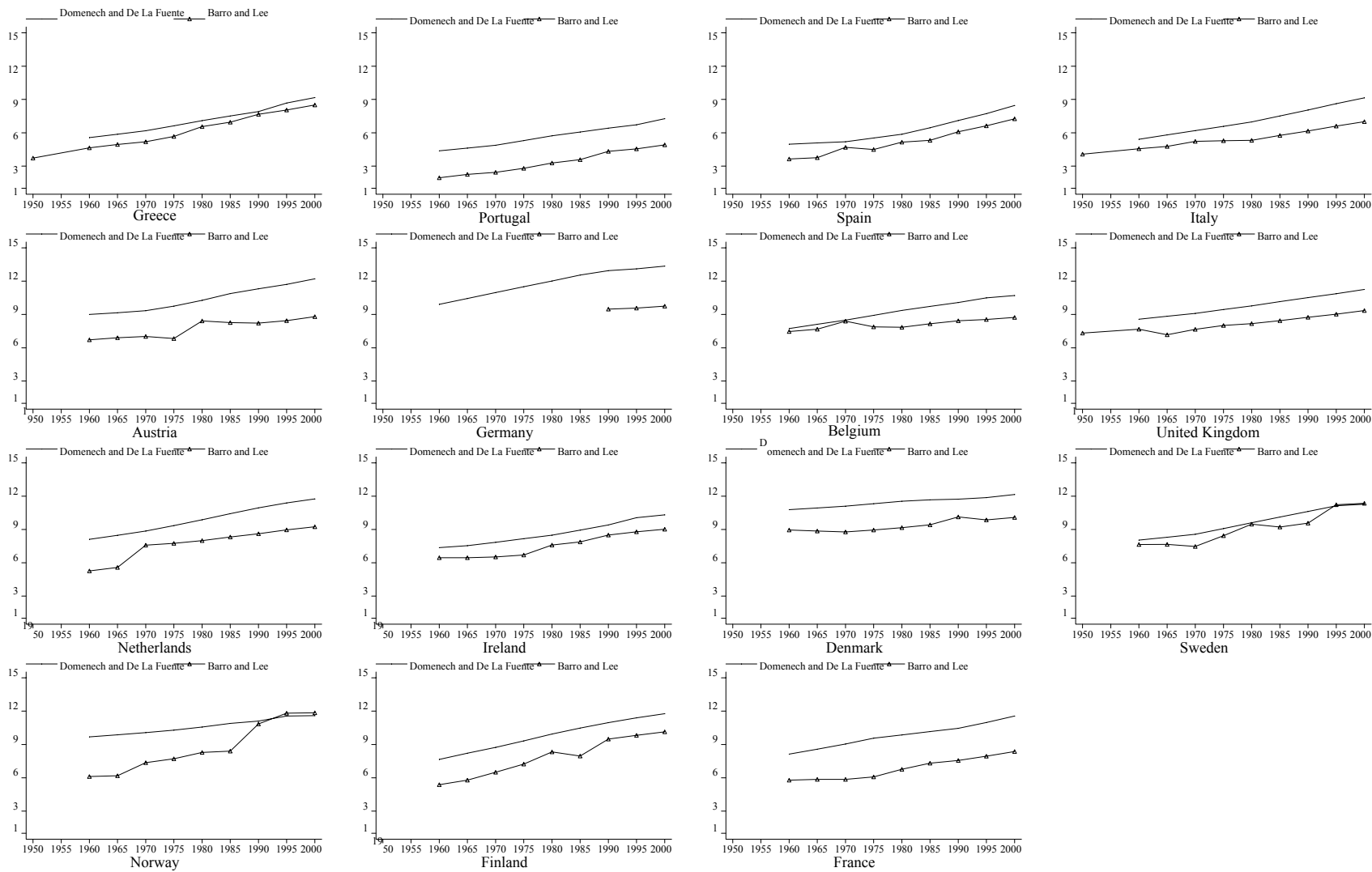
Figure A.1: Two Measures of Years of Schooling

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Comment on

Is Poland the Next Spain?

Francesco Caselli and Silvana Tenreyro

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On May 1st 2004 the European Union admitted ten new menbers, primarily from Eastern Europe. One of the main reasons why these countries have wanted to join the club is the hope that their levels of real labor productivity (GDP per man-hour) will converge to the level of Western Europe. This hope is based on the widely noted analogy between the Easterners and – some fifty years back – the so called Southerners (Italy, Spain, Greece, Portugal, and Ireland – a Southerner in spirit). These Southerners all had their spurts of above-average productivity growth. For example in Spain labor productivity relative to France (the benchmark for the "average" European experience) went from roughly 65 percent to over 90 percent. To varying degrees, the Easterners' current relative labor productivities are similar to the relative labor productivities of the Southerners before their convergence spurts. Caselli and Tenreyro's aim is to look behind the aggregate labor productivity numbers and present a few different approaches to decompose the overall convergence experience into more disaggregated processes. The result of this exercise can then be used to assess the supposed "road to convergence" of the new EU members.

The convergence experiences of the Southerners can be explained in at least four different (but not mutually exclusive) ways. These are:

1. Solovian convergence. Initially capital-poor countries have higher marginal productivities of capital (capital deepening).

2. Technological catch-up. Countries initially behind the world technology frontier experience faster improvements in technology than the leaders (TFP growth).

3. Gains from trade. Poorer countries – due to their initially more autarchic status – experience larger gains from trade as a proportion of GDP than rich countries.

4. Structural transformation. Poor countries undergo more radical structural transformations (resource reallocation from low-productivity to high-productivity sectors) than rich countries.

Casselli and Tenreyro show that, concerning the Western European convergence experience, the gains from trade hypothesis has not been a critical source of catching up. Instead, large labor reallocations towards more productive sectors have contributed substantially to the convergence experience. Moreover, substantial within-industry labor productivity convergence has occurred due to capital deepening and technical change.

What can we learn from the experience of the Southerners with regard to the prospects of convergence in the East? While a big part of the convergence in the South was caused by structural transformation, these potential – and relatively easy – gains constitute a relatively small share of the overall income gap in the East. A large share of the income gap is due to sizable within-industry productivity gaps. Convergence in the East, then, should presumably take place through – relatively hard – physical capital accumulation and TFP growth. A positive result for the East is the fact that there does not seem to be a human capital gap. As the income gap that still remains in the South is due to a failure to catch up in human capital, the Easterners should do even better in the long run. But the fact that the within-industry gaps are much larger, coupled with having to rely exclusively on the "within' margin, suggests that the long run may take a long time to arrive.

This analysis gives us valuable insights and information concerning the European convergence experience, past and future. The Easterners can be reassured that convergence will most probably take place, although they should expect convergence to be slow. Moreover, the analysis points out which types of convergence they should focus on. This gives the policymakers in the East a good idea which kind of policies they should be considering; i.e. policies directed towards technological catch up and capital accumulation. However, although labor reallocations towards more productive sectors represent just a small fraction of the income gap, they would still make a substantial difference in absolute terms. Hence, it is also important to pursue this route, as these reallocations will arguably raise income levels more quickly than TFP

growth and capital accumulation. In addition, this will give the citizens of these countries a clear indication that their hope is not futile.

Two remarks remain. One major puzzling result in the empirical analysis on total factor productivity growth is that TFP was not always initially lower in poor countries. This is not only hard to reconcile with catch-up theories of technological diffusion, it is simply not a very plausible outcome. One possible explanation is that the initial capital stock is not correctly specified. The construction of human capital stocks, only based on years of schooling, is also subject to caution. Educational qualifications may be relatively easy to measure, but offer only a poor proxy for human capital. What one wants is a direct measure of economically relevant skills.

Another remark concerns the *convergence accounting* exercise. The purpose of this exercise is to calculate the contributions of (relative) physical capital, human capital, and TFP growth to changes in (relative) incomes. Caselli and Tenreyro conclude that – as a general rule – Western European convergence is attributable in roughly equal parts to faster capital accumulation and technological improvement by the poorer countries. However, as technological improvements imply faster capital accumulation, the ultimate source of convergence may be just technological progress. At least, part of the faster capital accumulation is caused by faster TFP growth, implying a larger contribution from TFP growth.

Paul de Hek

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Natural volatility, welfare and taxation

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Cyclical components are analytically computed in a theoretical model of stochastic endogenous fluctuations and growth. Volatility is shown to depend on the speed of convergence of the cyclical component, the expected length of a cycle and on the altitude of the slump. Taxes affect these channels and can therefore explain cross-country differences and breaks over time in volatility. With exogenous sources of fluctuations, a special case of our model, decentralized factor allocation is efficient. With endogenous fluctuations and growth, decentralized factor allocation is inefficient and (time-invariant) taxes can (de-) stabilize the economy. No unambiguous link exists between volatility and welfare.

Keywords: Endogenous fluctuations and growth, welfare analysis, taxation, stochastic continuous time model, Poisson uncertainty

JEL classification numbers: C65, E32, E62, H3, O33

1   Introduction

There is a considerable heterogeneity across OECD countries in the variance of annual GDP growth rates. This variance ranges from 25% and 15% for Greece and Japan in the 1961 to 1983 period down to 1.7% and 1.3% for France and Italy for 1984 to 2003. Empirical studies show further that countries have breaks in their variance of growth rates over time (e.g. Kim and Nelson, 1999; McConnell and Perez-Quiros, 2000; Stock and Watson, 2003). Do these differences in volatility have only external causes such as terms of trade shocks, monetary or exogenous productivity shocks? Or is growth volatility of a country an endogenous, natural phenomenon of any growing economy and thereby also a function of various fundamentals of the economy under consideration, including economic policy? Stock and Watson (2003), surveying the literature on the "big moderation", attribute (roughly and with caveats) one quarter of the moderation in volatility in the US to improved policy, one quarter to good luck (lower volatility of productivity and commodity price shocks) and 50% to "unknown forms of good luck".

This paper provides a theory of volatility that helps understanding some possible deeper reasons behind these various sources of volatility. It is part of a small but rapidly growing literature that integrates endogenous short-run fluctuations with endogenous long-run growth (e.g. Bental and Peled, 1996; Matsuyama, 1999; Wälde, 1999, 2002, 2005; Francois and Lloyd-Ellis, 2003; Maliar and Maliar, 2004, Phillips and Wrase, 2005[2]). It argues that volatility of a country can be viewed to be something natural, inherently linked to its growth process. As a consequence, volatility is just as endogenous as is the GDP growth rate. Sustained per-capita growth is obtained by R&D causing jumps of technological frontiers (as in Aghion and Howitt, 1992 or Aghion, 2002). The resulting step function of labour productivity implies that growth and volatility can be traced back to the same source.[3] In this setup, volatility and long-run growth result primarily (but not exclusively) from the introduction of new technologies. "Lower volatility of productivity" or "other unknown forms of good luck" can therefore be traced back to changes in fundamentals of the economy. As both long-run growth and short-run volatility are endogenous and therefore react to changes in policy, we can analyze to what extent policy changes affect volatility and growth at the same time or independently of each other. Understanding breaks over time for e.g. the US seems to require a break in volatility without a break in the growth trend (McConnell and Perez-Quiros, 2000). In a model without an explicit analysis of growth, such a simultaneous analysis would not be possible.

We analyze two measures of volatility: the variance of the growth rate of the economy, a widely used measure in empirical regression work (e.g. Ramey and Ramey, 1995), and

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[2]These papers share the view that intentional investment into R&D can not only explain long-run growth but also short-run fluctuations - without invoking exogenous disturbances to the economy. At the risk of simplifying too much, short-run fluctuations and long-run growth result from the introduction of more productive technologies as new technologies increase TFP by a discrete amount, similar to a step function, and not smoothly and continuously as in standard models. Due to the explicit modelling of R&D processes, these models can be viewed to represent industrialized economies. Aghion, Banerjee and Piketty (1999) analyse an AK-type economy with borrowing constraints and investors and savers that are distinct agents. They find that when "the separation <between investors and savers> is large but not too large <...> we observe short-run instability" (p. 1375). If the separation is too large, there would be a permanent slump. Without separation, the economy converges to balanced growth. Hence, their intermediate case with growth and fluctuations seems to best describe developing countries.

[3]Stochastic models of this theoretical literature therefore share Beveridge and Nelson's (1981) econometric view that trend and cycle are driven by the same shock, i.e. (here) jumps in the technological frontier.

the coefficient of variation for cyclical components of time series, similar to those used in the RBC literature. It turns out that the variance of the growth rate does not - due to its complexity - lend itself to an intuitive theoretical analysis. Cyclical components have very simple moments, however, that reveal insightful relationships between model parameters and volatility. All measures are obtained analytically due to assuming a simple parameter restriction.

A question that arises immediately in a fluctuating economy asks whether higher or lower volatility should give rise to policy concerns. One possible answer to this question is a clear 'No'. The RBC approach is built (at least initially) on the belief that agents adjust optimally to a fluctuating world where markets are perfect and factor allocation is efficient (Kydland and Prescott, 1982; Long and Plosser, 1983)[4]. Lucas (1987, 2003) and others (surveyed in Lucas, 2003) show that, even in such a perfect world, welfare gains from removing all volatility do exist in principle (due to risk-aversion of households) but are quantitatively small. They amount to "about one-twentieth of 1 percent of consumption".[5]

The present paper argues that the belief that volatility per se is not an argument for welfare concerns in the Lucas sense is true indeed - as long as one beliefs that the engines of growth in an economy work under the absence of any imperfections as well. This assumption is implicit in standard RBC models where the growth process - in the Solow tradition - is viewed as exogenous. It is then easy to imagine indeed that in a perfectly competitive economy adjustment to exogenous disturbances takes place in an efficient way. This paper starts from the belief that (empirically speaking: at least to some extent) fluctuations in an economy are the result of the same type of technological progress that causes long-run growth. As the source of long-run growth and therefore short-run fluctuations is explicitly modelled, this endogeneity introduces various types of imperfections. Hence, if one believes that sources of growth are endogenous and taking the lessons from the "new" growth theory seriously (where it might be difficult in R&D based models to justify that endogenous technological progress comes along without any externalities), fluctuations go hand in hand with imperfections. This is true even in our setup where all firms operate under perfect competition, including R&D firms.[6]

We will see that an economy with exogenous growth and fluctuations is a special case of our more general model. In this special case, which could be argued to reflect the standard RBC approach, fluctuations and efficiency are no contradiction. In the general case with endogenous long-run growth and endogenous short-run fluctuations, fluctuations and efficiency contradict each other. Here as well, a simple parameter restriction allows us to derive a very intuitive closed form expression for the value function - the standard measure of welfare.

We relate our analysis of endogenous volatility and welfare to taxation for two reasons: First, there is a considerable heterogeneity in tax systems across countries and over time (e.g. Mendoza, Tesar and Razin, 1994; Padovano and Galli, 2001). For the US, two major tax reforms, the Tax Reform Act of 1986 and the Economic Recovery Tax Act of 1981 (see e.g. Auerbach and Slemrod, 1997), took place around the point in time where the break in

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[4]More recent work, analysing international linkages under imperfections or monetary business cycles under price staggering, include Chari, Kehoe and McGrattan (2000) or Kehoe and Perri (2002).

[5]Epaulart and Pommeret (2003), Krebs (2003) or Barlevy (2004) find that welfare gains from less volatility can be substantially larger and increase up to several percentage points. Lucas (2003) argues that welfare gains remain small under realistic parameter assumptions.

[6]There are by now various papers that stress that R&D and perfect competition does not contradict each other. The first paper seems to be Funk (1996). Later work includes Boldrin and Levine (2004), Hellwig and Irmen (2001) and Wälde (2002).

GDP volatility is usually identified (between the 4th quarter of 1982 and 3rd quarter of 1985, according to Stock and Watson, 2003). It is therefore natural to ask whether tax reforms or cross-country differences in tax systems are candidates for understanding differences in volatility. It is generally accepted that taxes can affect the growth rate of a country or its natural rate of unemployment - they could therefore also affect its natural amount of volatility. Second, the inefficiency introduced by the endogeneity of R&D and volatility can in principle be eliminated by appropriate taxes and subsidies. We do not require that the government has a lot of information about the current state of the economy and assume that it sets constant, i.e. time- and state-invariant, taxes on labour and capital income, wealth, consumption, investment and R&D.

Talking more precisely about our results, one contribution is the derivation of analytical measures of volatility in a model characterized by "standard" properties: infinite planning horizon of the representative agent, standard intertemporal optimization decisions concerning savings and investment under risk aversion, uncertainty from properties of technological progress and perfect competition for all production processes. Analytical measures for volatility (and also welfare) can be obtained by assuming a simple parameter restriction. Analyzing the behaviour of an economy for restrictions of this type has turned out to be very useful (e.g. Long and Plosser, 1983; Xie, 1991; Benhabib and Rustichini, 1994; Wälde, 2005). This restriction allows us to represent equilibrium properties of our economy by a simple linear stochastic differential equation for instantaneous utility. Using the methods presented by Garcia and Griego (1994), we can then analytically compute moments of time series as predicted by our model. We then use the coefficient of variation as our measure of volatility.

This parameter restriction also allows us to compute an explicit expression for welfare. In doing so, we obtain a deterministic differential equation that describes how the economy evolves in an expected sense, i.e. how expected instantaneous utility evolves for $\tau > t$, where t is today. This differential equation nicely shows that our economy behaves in this expected sense exactly as a deterministic Solow growth economy behaves with a fixed saving rate. Intuitively speaking, our stochastic economy turns out to be a Solow growth economy where labour productivity increases at (endogenous and optimally chosen) random points in time by discrete amounts.

Concerning the effects of taxation on volatility, we find that volatility is affected through three channels: The speed of convergence, the expected length of a cycle and the degree how strongly cyclical components are thrown back once a new technology arrives. All of these three channels can be easily related to properties of transitional paths towards some steady state. As taxes affect transitional paths of various economic variables, taxation affects volatility. For the equilibrium we analyze, taxes on labour and capital income and investment goods increase volatility, taxes on R&D and wealth have a stabilizing effect, a tax on consumption goods is neutral. A stabilization policy does not require knowledge about the current state of the economy. Taxes are constant and thereby time- and state-invariant. Nevertheless, higher or lower tax levels can stabilize or destabilize the economy.

Our welfare analysis shows that taxes on investment goods and R&D directly affect the source of volatility and growth, i.e. the portfolio choice between capital accumulation and R&D, and can therefore be used to internalize externalities. All other taxes are welfare reducing, given that they are used for some exogenous government expenditure (which, for simplicity, is modelled to have no welfare or productivity effect). When we look at the effects of taxes on volatility and welfare jointly, it turns out that stabilizing an economy is not necessarily welfare increasing. Increasing a tax on wealth or factor income reduces

welfare, but the tax on factor income increases volatility while the tax on wealth reduces volatility. The objective of government intervention should be to internalize external effects, as in standard public finance approaches. The efficient factor allocation would then be characterized by a certain corresponding amount of volatility. The causal link from volatility to welfare in the Lucas sense is therefore opened up with endogenous volatility and implies that one can only talk of (positive or negative) correlations between volatility and welfare.

Clearly, the (in-)efficiency of fluctuations has been discussed or analyzed at least since Keynes's General Theory. In contrast to the traditional RBC approach referred to above, many authors have stressed various types of inefficiencies in the economy which arise or are amplified because of fluctuations. In the recent literature, Aghion, Banerjee and Picketty (1999), also referred to above, argue that fluctuations contain phases where "savings are underutilized in the sense of being invested in an inferior asset". More quantitatively, Gali, Gertler and Lopez (2003) compute gains from stabilization that arise because of an inefficient factor allocation and the asymmetry of changes in inefficiencies over the cycle. Greenwood and Huffman (1991) study an economy whose inefficiency stems from taxation and find that a stabilization policy that builds on information about the current state of the economy is welfare improving. None of these papers stresses the inefficiency resulting from the joint endogeneity of long-run growth and short-run fluctuations. With exogenous growth and fluctuations, fluctuations are efficient, with endogenous fluctuations, they are not.

From a more positive (and not normative) perspective, understanding and explaining the effects of fiscal policy has a long tradition as well. Greenwood and Huffman (1991) find, following a RBC-type calibration approach, that taxes on average amplify variability of macroeconomic aggregates. Jones (2002) finds in his mainly econometric analysis that fiscal policy in the US (captured by the tax rates on labour and capital income and government purchases from 1958 to 1997) has not stabilized the economy to a strong degree. Burnside, Eichenbaum and Fisher (2004) argue that increases in US government military purchases increase tax rates on capital and labour income which in turn increase aggregate hours worked and decrease real wages. They argue that the neoclassical growth model can reasonably replicate these links. Fatás and Mihov (2003) empirically analyze the link between discretionary government spending and volatility and find that "aggressive use of fiscal policy generates undesirable volatility and leads to lower economic growth". To the best of our knowledge, ours is the first paper that proposes an explicit analytical expression for volatility. This expression allows to understand the different channels through which tax policy affects volatility. As we keep taxes constant, we highlight that a volatile economy is not necessarily the result of large variations in tax rates over time but could be the result of a too high or too low level of constant tax rates. Hence, breaks over time can result from a single change of a tax rate and cross-country differences result from differences in tax levels.[7]

2   The model

The model will be presented in three parts: technologies, the government and consumers. As the technological setup of our economy is close to the one in Wälde (2005), the first part will be relatively brief. The introduction of government activities and the implications for household behavior are new and will be presented in more detail.

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[7]From a modeling perspective, the present paper uses the model developed in Wälde (2005) and extends it for various tax rates and the government sector. The methods of Garcia and Griego (1994), on which most of our results here are based, were not used in Wälde (2005).

2.1 Technologies

Technological progress is labour augmenting and embodied in capital. All capital goods can be identified by a number denoting their date of manufacture and therefore their vintage. A capital good K_j of vintage j allows workers to produce with a labour productivity A^j, where $A > 1$ is a constant parameter. Hence, a more modern vintage $j + 1$ implies a labour productivity that is A times higher than labour productivity of vintage j. The corresponding production function reads $Y_j = K_j^\alpha (A^j L_j)^{1-\alpha}$, where the amount of labour allocated to that vintage is denoted by L_j and $0 < \alpha < 1$ is the output elasticity of capital. The sum of labour employment L_j per vintage equals aggregate constant labour supply, $\sum_{j=0}^{q} L_j = L$ where q is the most advanced vintage currently available.

Independently of which vintage is used, the same type of output is produced. Aggregate output is used for producing consumption goods C, investment goods I, as an input R for doing R&D and for government expenditures G,

$$C + I + R + G = Y = \Sigma_{j=0}^{q} Y_j. \tag{1}$$

The quantities C, I and R stand for *net* resources used for these activities, i.e. after taxation. All activities in the economy take place under perfect competition. The producer prices of the production, consumption, investment and research good will therefore be identical,

$$p_Y = p_C = p_I = p_R. \tag{2}$$

R&D is a risky activity. This is modelled by the Poisson process q where the probability per unit of time dt of an innovation, i.e. of successful R&D, is given by λdt, where λ is the arrival rate of q. At the level of an individual R&D firm f, there are constant returns to scale and the firm arrival rate is $\lambda_f = D^{-1} h (R/D) R_f$, where D captures the "difficulty" of doing R&D, $h(\cdot)$ is an externality and R_f are resources used by the firm. The difficulty function D and the externality $h(\cdot)$ are taken as given. As firm-level Poisson processes q_f can be added up, we obtain

$$\lambda = \frac{R}{D} h \left(\frac{R}{D} \right) = \left(\frac{R}{D} \right)^{1-\gamma}, \quad 0 < \gamma < 1, \tag{3}$$

at the sectoral level where $h(\cdot)$ implies decreasing returns to scale.

The exogenous function D captures the difficulty to make an invention. Following the arguments in Segerstrom (1998), an economy that discovered already many innovations needs to put more effort into a new innovation if this innovation is to come at the same rate λ. While the amount of innovations in the past can be measured in different ways, we simply capture it by the tax-independent current size K_*^{obs} of the capital stock of the economy,

$$D \equiv D_0 K_*^{obs}, \quad D_0 > 0. \tag{4}$$

This measure of the capital stock will be defined in (12).

The objective of R&D is to develop capital goods that yield a higher labour productivity than existing capital goods. When an innovation takes place, a first prototype of a production unit of size κ that yields a labour productivity of A^{q+1} becomes available. This distinguishes this approach from standard modeling of R&D where successful R&D is argued to lead to a blueprint only. As seems to be common in many cases (Rosenberg, 1994), only the development of a first "pioneer plant" that can be used for production characterizes success

of research. Technically, this implies that the capital stock of vintage $q+1$ is a function of the Poisson process q as well. The increment dq of this process can either be 0 or 1. As successful research means $dq = 1$, we can write

$$dK_{q+1} = \kappa dq. \tag{5}$$

The size of the prototype is exogenous to the model. We keep it proportional to the tax-independent size K_*^{obs} of the total capital stock,

$$\kappa \equiv \kappa_0 K_*^{obs}, \quad 0 < \kappa_0 \ll 1. \tag{6}$$

When resources are allocated to capital accumulation, the capital stock of vintage j increases if investment in vintage j exceeds depreciation δ,

$$dK_j = (I_j - \delta K_j)\, dt, \quad j = 0, ..., q. \tag{7}$$

In contrast to R&D, this is a deterministic process as capital accumulation simply means replicating existing machines.

Allowing labour to be mobile across all vintages such that wage rates equalize, total output of the economy can be represented by a simple Cobb-Douglas production function,

$$Y = K^\alpha L^{1-\alpha}, \tag{8}$$

where vintage specific capital stocks have been aggregated to an aggregate capital index K,

$$K = K_0 + BK_1 + ... + B^q K_q = \sum_{j=0}^{q} B^j K_j, \quad B \equiv A^{\frac{1-\alpha}{\alpha}}. \tag{9}$$

This index can be thought of as counting the "number of machines" of vintage 0 that would be required to produce the same output Y as with the current mix of vintages.

The evolution of the capital index K follows from (5) and (7) by applying the change of variable formula (CVF)[8] to (9),

$$dK = (B^q I - \delta K)\, dt + B^{q+1} \kappa dq. \tag{10}$$

The capital index increases continuously as a function of effective investment $B^q I$ minus depreciation. When an innovation takes place, the capital index increases by $B^{q+1}\kappa$.

2.2 Government

The government can levy taxes on capital (τ_K) and labour income (τ_L), wealth (τ_W), consumption expenditure (τ_C), investment (τ_I) and R&D expenditure (τ_R). A positive tax implies a real decrease in income or an increase in the effective price (consumer price), whereas a negative tax is a subsidy. The government uses taxation to provide basic government services G like rule of law. In order to focus on the effects of taxation from government expenditures, we assume that government expenditure does not affect household utility or production possibilities of the economy.

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[8]In models with Brownian motion as a source of uncertainty, the "rules" for computing differentials are based on Ito's Lemma. The expression Ito's Lemma is inappropriate in the presence of Poisson processes and the differentials are obtained from a change of variable formula. See e.g. Garcia and Griego (1994) and Sennewald (2005) for a rigorous background and Sennewald and Wälde (2005) for an introduction.

As argued in (2), producer prices are identical for all three production processes. When consumption and investment goods C and I or research services R are sold, they are taxed differently such that consumer prices are $(1 + \tau_C)\, p_C$, $(1 + \tau_I)\, p_I$, $(1 + \tau_R)\, p_R$. In order to rule out arbitrage between different types of goods, we assume that once a unit of production is assigned for a special purpose, it is useless for other purposes: once a consumption good is acquired, it cannot be used for e.g. investment purposes.

Taxes that increase the producer price have no theoretical upper bound. A 300% tax on the consumption good would imply that $3/4$ of the price are taxes going to the state and $1/4$ goes to the producer. Their lower bound is clearly -100%, where a good would be for free for the purchaser. The upper bound for taxes on income is 100% (instant confiscation of income), while there is no lower bound. Hence, $-1 < \tau_C, \tau_I, \tau_R$ and $\tau_L, \tau_K, \tau_W < 1$.

Our capital stock index K in (9) measures the size of the capital stock in units of vintage 0. Measured in units of vintage q, its size is $B^{-q}K$. This is also the value of the entire capital stock in pre-tax units of the consumption good, as the relative pre-tax prices are unity from (2). Measuring wealth in after-tax prices, i.e. in "purchasing power" terms, the price of the capital good increases by the tax τ_I and the price to be paid for one unit of the consumption good increases by τ_C. Hence, total wealth in the economy is given by

$$K^{obs} = La = \frac{1 + \tau_I}{1 + \tau_C} B^{-q}K, \tag{11}$$

where a is wealth of the representative household. The tax-independent measure of the capital stock, used in (4) and (6), can then be defined by

$$K_*^{obs} \equiv \frac{1 + \tau_C}{1 + \tau_I} K^{obs}. \tag{12}$$

2.3 Households

The economy is populated by a discrete finite number of sufficiently small representative households. They maximize expected utility $U(t)$, given by the "sum" of instantaneous utilities $u(\cdot)$ resulting from consumption flows $c(\tau)$, discounted at the rate of time preference ρ,

$$U(t) = E_t \int_t^\infty e^{-\rho[\tau - t]} u(c(\tau)) d\tau, \tag{13}$$

where the instantaneous utility function $u(\cdot)$ is characterized by constant relative risk aversion,[9]

$$u(c(\tau)) = \frac{c(\tau)^{1-\sigma}}{1-\sigma}, \quad \sigma > 0. \tag{14}$$

The budget constraint reflects investment possibilities in this economy and the impact of tax policy and shows how wealth a evolves over time. Households can invest in a risky asset by financing R&D and in an (instantaneously) riskless asset by accumulating capital. We measure wealth in units of the consumption good, priced at consumer prices. The budget

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[9] For analytical convenience and readability, we neglect the term $-(1-\sigma)^{-1}$, which is sometimes included in the instantaneous utility function.

constraint can intuitively best be understood by starting from (A.13) in the appendix,

$$da = \left(\frac{(1 - \tau_K) \sum_{j=0}^{q+1} w_j^K k_j}{(1 + \tau_C) p_C} + \frac{1 - \tau_L}{1 + \tau_C} \frac{w}{p_C} - c - \frac{1 + \tau_R}{1 + \tau_C} i \right) dt$$
$$- \left(\frac{1 - \tau_K}{1 + \tau_I} \delta + \tau_W \right) a \, dt + \left(\frac{1 + \tau_I}{1 + \tau_C} \kappa \frac{i}{R} - \frac{B - 1}{B} a \right) dq.$$

Nominal gross capital income $\sum_{j=0}^{q+1} w_j^K k_j$ from all vintages j is taxed at τ_K, yielding net capital income. Dividing by the consumer price $(1 + \tau_C) p_C$ of the consumption good gives real net capital income in units of the consumption good. The same reasoning applies to labour income w, consumption c and investment i into R&D. The expression on the first line therefore captures the increase in wealth a, measured in units of the consumption good at consumer prices. The first expression on the second line captures the wealth-reducing effect of the after-tax depreciation rate and of the tax on wealth. The tax rates τ_K and τ_I in front of the depreciation rate ensure that taxes are partly refunded i.e. only net (and not gross) investment will be taxed (cf. eqs. (A.14) and (A.2)). The second expression increases an individual's wealth in case of successful research by the "dividend payments" minus an economic depreciation term. Dividend payments at the household level are given by the share i/R of the successful research project the household financed times total dividend payments $\frac{1+\tau_I}{1+\tau_C} \kappa$. Dividend payments are determined by the size κ of the prototype times its after-tax price $(1 + \tau_I) / (1 + \tau_C)$ in units of the consumption good.[10] The term $1 + \tau_I$ implies that research yields not only a capital good (which would have a value of p_I) but already an installed capital good (whose value is $(1 + \tau_I) p_I$). Economic depreciation $(B - 1) / B$ results from the vintage capital structure as the most advanced capital good has a relative price of unity (cf. (2)) and all other vintages then lose in value relative to the consumption good.

After some further steps (especially the pricing equations for v_j), and using the notation for values after taxation, the budget constraint simplifies to

$$da = (r^* a + w^* - i^* - c) \, dt + \left(\kappa^* \frac{i}{R} - sa \right) dq, \tag{15}$$

where $i^* \equiv \frac{1+\tau_R}{1+\tau_C} i$, $\kappa^* \equiv \frac{1+\tau_I}{1+\tau_C} \kappa$, $s \equiv \frac{B-1}{B}$ and factor rewards are

$$r^* \equiv \frac{1 - \tau_K}{1 + \tau_I} r - \tau_W, \quad w^* \equiv \frac{1 - \tau_L}{1 + \tau_C} \frac{w}{p_C}, \quad r = B^q \frac{\partial Y}{\partial K} - \delta, \quad w = p_Y \frac{\partial Y}{\partial L}. \tag{16}$$

3 Endogenous cyclical growth

3.1 Equilibrium

Solving the model requires first order conditions for households for consumption and R&D expenditure. These two conditions, together with the aggregate capital accumulation constraint (10), the goods market equilibrium (1), optimality conditions of perfectly competitive firms and a certain taxation policy fixing G provides a system consisting of 7 equations that determines, given initial conditions, the time paths of K, C, R, Y, T, w and r.

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[10]We use the term dividend payments in a narrow sense, i.e. only for payments from successful R&D. Data on dividend payments would also include part of factor rewards r for capital.

Such a system can best be understood by introducing auxiliary variables that are similarly used in many other models as well: In the classic Solow growth model, capital per effective worker $K/(AL)$ is shown to converge to a steady state and the analysis of e.g. convergence can be separated from the analysis of long-run growth. In the present context, we define $\hat{K}(\tau)$ and $\hat{C}(\tau)$ as

$$\hat{K}(t) \equiv K(t)/A^{q(t)/\alpha}, \quad \hat{C}(t) \equiv C(t)/A^{q(t)} \tag{17}$$

which is almost identical to capital and consumption per effective worker as labor supply is constant here. These variables also allow us to separate the analysis of cyclical properties of the model from long-run growth. Most of the time, we will call $\hat{K}(\tau)$ and $\hat{C}(\tau)$ cyclical components of $K(t)$ and $C(t)$, as $A^{q(t)/\alpha}$ and $A^{q(t)}$ will turn out to be the stochastic trend in our economy.

"Detrending" in (17) is undertaken by dividing by measures of the current technology level that differs between capital and consumption. This is due to the fact that $K(t)$ is a capital index and not capital expressed in units of the consumption good. Capital measured in units of the consumption good would be detrended by $A^{q(t)}$ as well. When detrending other endogenous variables by $A^{q(t)}$ as well, these detrended variables turn out to be stationary and within a bounded range. Equilibrium properties can therefore best be illustrated by studying an equilibrium in cyclical components which consists of a system in 7 equations and 7 cyclical components as well.

3.2   An explicit solution

It would be interesting to analyze such a system in all generality. One would run the risk, however, of losing the big picture and rather be overwhelmed by many small results. We therefore restrict ourselves to a particular parameter set of the model that allows very sharp analytical results.

Theorem 1 *If the preference parameter σ of the utility function satisfies the relationship*

$$\sigma = \frac{(1-\tau_K)\alpha}{1-\tau_L-(\tau_K-\tau_L)\alpha}, \tag{18}$$

we obtain a linear solution for consumption and research

$$\hat{C} = \Psi\hat{K}, \quad \hat{R} = \Gamma\hat{K}, \tag{19}$$

where Ψ and Γ denote constant parameters given by

$$\Psi = \frac{1+\tau_I}{1+\tau_C}\left(\frac{\rho+\lambda\left(1-(1-s)\xi^{-\sigma}\right)}{\sigma}+\frac{1-\sigma}{\sigma}\left(\frac{1-\tau_K}{1+\tau_I}\delta+\tau_W\right)-\frac{1+\tau_R}{1+\tau_I}\Gamma\right), \tag{20}$$

$$\Gamma = \left(\frac{1+\tau_I}{1+\tau_R}\frac{\kappa_0}{D_0}\xi^{-\sigma}\right)^{\frac{1}{\gamma}}D_0. \tag{21}$$

The arrival rate is then constant and given by

$$\lambda = \left(\frac{1+\tau_I}{1+\tau_R}\frac{\kappa_0}{D_0}\xi^{-\sigma}\right)^{\frac{1-\gamma}{\gamma}}, \tag{22}$$

where we defined

$$\xi \equiv 1-s+\kappa_0. \tag{23}$$

Proof. App. B.1.4. ∎

Parameter restrictions as in (18) have proven useful to derive equilibrium properties which otherwise would not be easily visible (e.g. Long and Plosser, 1983; Xie, 1991; Benhabib and Rustichini, 1994; Wälde, 2005). What is peculiar about this condition is that a change in the tax rate τ_L or τ_K would at constant α require a change in σ for the closed form solution to prevail. As a change in preference or technology parameters following a change in policy is not convincing, we will restrict our policy analyses to identical income tax rates, i.e. $\tau_L = \tau_K \equiv \tau_F$. This simplifies (18) to[11]

$$\sigma = \alpha. \tag{24}$$

We will assume in what follows that $\xi < 1$ in (23), i.e. economic depreciation s due to the innovation is larger than the relative size of dividend payments κ_0.

3.3 Cyclical growth

Exploiting the implications of theorem 1 fully, we can summarize general-equilibrium behaviour of agents in a way as simple as e.g. in the Solow growth model with exogenous growth and a constant saving rate, even though we have forward-looking agents and an uncertain environment. In terms of cyclical components, our economy follows (19) and (app. B.1.3)

$$d\hat{K} = \left(\hat{Y} - \hat{R} - \delta\hat{K} - \hat{C} - \hat{G}\right) dt - \left(1 - A^{-1}\xi\right)\hat{K}dq \tag{25}$$

$$= \left(\frac{b_0}{\Psi^{1-\sigma}}\hat{K}^\alpha L^{1-\alpha} - \frac{b_1}{1-\sigma}\hat{K}\right) dt - \left(1 - A^{-1}\xi\right)\hat{K}dq, \tag{26}$$

where with Ψ and Γ from (20) and (A.36),

$$b_0 \equiv \frac{1 - \tau_F}{1 + \tau_I}\Psi^{1-\sigma}, \tag{27}$$

$$b_1 \equiv (1 - \sigma)\left(\frac{1 + \tau_C}{1 + \tau_I}\Psi + \frac{1 + \tau_R}{1 + \tau_I}\Gamma + \frac{1 - \tau_K}{1 + \tau_I}\delta + \tau_W\right)$$

$$= \frac{1 - \sigma}{\sigma}\left(\rho + \lambda\left[1 - (1 - s)\xi^{-\sigma}\right] + \frac{1 - \tau_K}{1 + \tau_I}\delta + \tau_W\right). \tag{28}$$

The differential equation (25) is the capital accumulation constraint (10), expressed for cyclical components and satisfying utility-maximizing behaviour of agents. Inserting (19) and some further steps (app. B.2.1) give the one-dimensional stochastic differential equation (26) in $\hat{K}$.

Note that the expressions containing parameters b_0 and b_1 have an economic meaning: the first term represents cyclical output of this economy, reduced by taxation. This is visible from $\hat{Y} = \hat{K}^\alpha L^{1-\alpha}$ (app. B.1.3). The b_1 term represents resource allocation to R&D and consumption, in addition to physical capital depreciation, all corrected for taxation. As (26) shows, b_1 also captures the speed of convergence of $\hat{K}$ relative to its steady state. The

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[11]The parameter restriction $\sigma = \alpha$ implies a relatively high intertemporal elasticity of substitution σ^{-1} of above unity. Wether the intertemporal elasticity of substitution implied by this restriction is plausible or not (for a discussion, see Wälde, 2005), the relevance of our results depends only on whether one believes that changes in σ will fundamentally change our insights. As will turn out further below, this is not the case.

differential equation (26) is illustrated in the following figure.
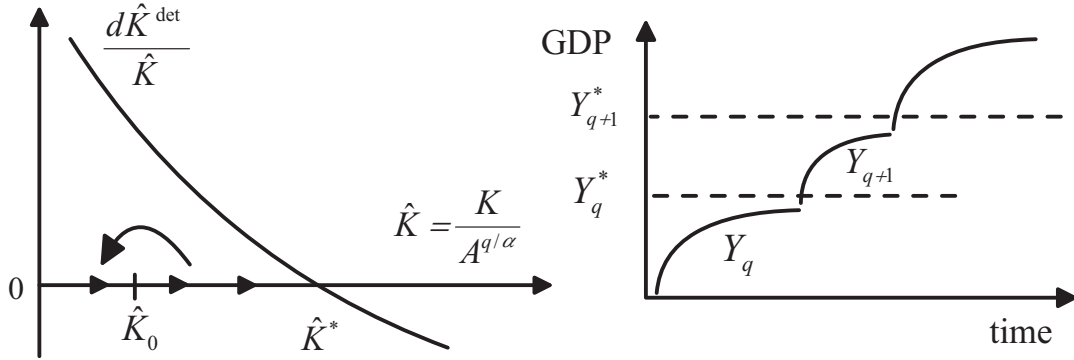
Figure 1: General equilibrium dynamics of the capital stock per effective worker and GDP growth cycles

The figure on the left plots $\hat{K}$ on the horizontal axis and the proportional (deterministic part of the) change $d\hat{K}/\hat{K}$ on the vertical one. The steady state $\hat{K}^*$ to which the economy approaches without any jumps in technology is from (26) and (27)

$$
\hat{K}^* = \left(\frac{1-\tau_F}{1+\tau_I} \frac{1-\sigma}{b_1} \right)^{\frac{1}{1-\alpha}} L = \left(\frac{1-\tau_F}{1+\tau_I} \frac{\sigma}{\rho + \lambda \left[1 - (1-s)\xi^{-\sigma} \right] + \frac{1-\tau_K}{1+\tau_I}\delta + \tau_W} \right)^{\frac{1}{1-\alpha}} L,
$$
(29)

where we used (28) for the second equality.

We can now start our analysis as we do in deterministic models. Assume an initial capital stock $\hat{K}_0$. Agents invest part of their savings in R&D, the rest goes to capital accumulation. Assuming a certain length of time without jumps, i.e. without successful innovation, the economy grows due to more capital and converges to the steady state $\hat{K}^*$. As in the Solow model, growth is initially high and approaches zero. Once a jump occurs and q increases by 1, the capital stock of the economy increases by the size κ of the prototype from (5). If the capital stock K remained unchanged, capital per effective worker $\hat{K}(\tau)$ from (17) would decreases by a discrete amount as the frontier technology increases by the discrete amount A. When we assume that the size of the new machine is sufficiently small relative to the technological improvement, $A^{-1}\xi < 1$ (which is the only empirically plausible assumption and which also follows from our assumption after (23)), the cyclical component $\hat{K}(\tau)$ falls due to an innovation, i.e. the economy is thrown back towards the origin in fig. 1. With a lower capital stock per effective worker, investment in capital accumulation becomes more profitable as the marginal productivity of capital is higher. Growth rates jump to a higher level and approach zero again unless a new innovation takes place.

The discrete increases of labour productivity by A imply a step function in TFP - in contrast to the smooth increase in TFP in balanced growth models. The implied evolution of GDP is shown in the right panel of fig. 1. Fluctuations are natural in a growing economy.

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4 Measuring welfare and volatility

4.1 The value function

Our measure of welfare is the value function which, by definition, is $V(t) \equiv \max_{\{c(\tau),i(\tau)\}}$ $E_t \int_t^\infty e^{-\rho[\tau-t]} u(c(\tau)) \, d\tau$. Pulling the expectations operator into the integral gives

$$V(t) = \max_{\{c(\tau),i(\tau)\}} \int_t^\infty e^{-\rho[\tau-t]} E_t u(c(\tau)) \, d\tau. \tag{30}$$

Obviously, the value of the optimal program depends on the evolution of expected instantaneous utility, $E_t u(c(\tau))$.[12]

4.1.1 Evolution of expected instantaneous utility

Let us now analyze how expected instantaneous utility,

$$m_1(\tau) \equiv E_t u(c(\tau)), \tag{31}$$

evolves. For notational simplicity, we denote

$$\Theta \equiv A^{1-\sigma}, \quad \Xi = \xi^{1-\sigma}. \tag{32}$$

Computing expected quantities as in (31) can be done in two ways. Either, a stochastic differential equation is expressed in its integral version, expectations operators are applied and the resulting deterministic differential equation is solved. Or, the stochastic differential equation is solved directly and then expectation operators are applied. The background for either approach is in Garcia and Griego (1994). We follow the first way here.

The evolution of $u(c(\tau))$, denoted by $u(t)$ for simplicity, is described by the differential equation (app. C.1.1),

$$du(t) = \left(b_0 \Theta^{q(t)} - b_1 u(t)\right) dt - b_2 u(t) dq(t), \tag{33}$$

where b_0 and b_1 are as in (27) and (28) and

$$b_2 \equiv 1 - \Xi \tag{34}$$

can be understood as a measure of the "novelty" of a new technology. When A is high, b_2 is high as well as a high degree of novelty increases b_2 through high economic depreciation s, defined before (16). Note that we assume $b_2 > 0$ which holds due to the plausibility assumption of $\xi < 1$ made after (23). This differential equation shows that $u(t)$ behaves similarly to $\hat{K}$ illustrated in fig. 1. Starting from some u_0, $u(t)$ moves towards the current steady state $b_0 \Theta^{q(t)}/b_1$ as long as no technology jump takes place, i.e. as long as $dq = 0$. When q jumps, $u(t)$ reduces by a small amount as agents postpone consumption[13] and as a fraction

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[12] The integral and the expectations operator can be exchanged when, under a technical condition, both the expected integral, i.e. our objective function (13), and the integral of the expected expression exist. The expected integral exists by assumption as otherwise the maximization problem of the household would be meaningless. The existence of the integral of the expected expression will be shown by computing it. The existence proof is therefore an ex-post proof. We are grateful to Ken Sennewald for discussions of this issue.

[13] This is due to $\sigma = \alpha$ and the implied intertemporal elasticity of substitution. Under an alternative condition and closed form solution, consumption would not decrease (Wälde, 2005, footnote 20). The behavior of the utility level after a technological jump is not important for subsequent results. The $\sigma = \alpha$ assumption would also matter for the link between growth and uncertainty (cf. e.g. de Hek 1999).

of their wealth depreciates economically. The difference to $\hat{K}$ consists in the behaviour of the current steady state. As $u(t)$ is the *level* of utility and not its cyclical component or utility per representative worker, the steady state moves to the right with each new technology. After an innovation and the subsequent reduction in $u(t)$, instantaneous utility approaches this new steady state until the next jump occurs - similar to GDP in fig. 1.

Given this stochastic differential equation and forming expectations about $u(\tau)$ for $\tau > t$ leads to a deterministic ordinary differential equation in $m_1(\tau)$. Computing a solution for this ODE is possible as its non-linearity can be removed by a variable transformation similar to the approach for the deterministic Solow growth model (e.g. Barro and Sala-i-Martin, 1995, p. 53). Defining g as the growth rate and β as the convergence rate of expected utility $m_1(\tau)$ (and keeping the difference to b_1 in (28), the speed of convergence of $\hat{K}$, in mind),

$$g \equiv (\Theta - 1)\lambda, \tag{35}$$

$$\beta \equiv g + b_1 + b_2\lambda = b_1 + \lambda[\Theta - \Xi], \tag{36}$$

respectively, we obtain (app. 7.1) an explicit expression for (31),

$$m_1(\tau) = e^{-(\beta - g)(\tau - t)}(u(t) - \mu) + e^{g[\tau - t]}\mu, \tag{37}$$

where

$$\mu \equiv \Theta^{q(t)}b_0/\beta. \tag{38}$$

The second term of this equation, $e^{g[\tau - t]}\mu$, says that expected utility, starting in t where $q(t)$ and $K(t)$ and thereby $u(t)$ are given as initial conditions, grows exponentially at the innovation rate g. From (35), the innovation rate is basically driven by the arrival rate λ. In the long run, g is the average growth rate of instantaneous utility. The first term says that $u(t)$ converges to μ at the convergence rate β. The term μ is the expected value, today in t, of instantaneous utility in $\tau \to \infty$, when instantaneous utility is deterministically detrended. This follows immediately from rewriting (37) as $e^{-g[\tau - t]}m_1(\tau) = e^{-\beta[\tau - t]}(u(t) - \mu) + \mu$.[14] Somewhat imprecisely but nevertheless useful, μ could be called "average instantaneous utility".

Apart from showing growth of expected quantities in our setup, equation (37) illustrates the similarity of the evolution of expected quantities in this setup to the evolution of quantities in the Solow growth model. When we replace μ by the Solow steady state utility level, the expected evolution here is identical to the certain evolution in Solow's model (where g and β would then stand for the growth and convergence rate in the Solow sense). In contrast to Solow, the role played by short-run convergence is ambiguous: while in the Solow model one usually assumes a capital stock that lies to the left of the steady state and convergence implies higher average growth rates between today and some future point in time τ, the capital stock here (and the implied consumption and utility level) will in 50% of all realizations lie to the right of the mean μ. Convergence then implies lower average growth rates.

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[14]Obviously, detrending is possible in at least two ways here: The "stochastic detrending" in (17) looks at past realizations of $q(t)$ and removes the stochastic trend $A^{q(t)/\alpha}$ or $A^{q(t)}$ of some stochastic trended variable $X(t)$. "Deterministic detrending" removes an expected growth trend by dividing expected expressions by its growth component $e^{g[\tau - t]}$. In either case, by definition, the resulting cyclical component has a finite constant long-run mean. Stochastic detrending also implies finite and constant higher long-run moments (app. 7.3), which, however, is not necessarily the case for deterministic detrending (app. 7.2).

4.1.2 Computing the value function

We can now insert the expression for utility under optimal behaviour from (37) into (30) and get, after computing deterministic integrals (app. C.1.2),

$$V(t) = \frac{\mu}{\rho - g} - \frac{\mu - u(t)}{\rho - g + \beta}. \tag{39}$$

The derivation assumed $\rho > g$ which makes the integral in (13) bounded.[15] While in deterministic models the growth rate of utility must not be larger than the time preference rate, in this stochastic model, the boundedness condition requires that the growth rate of expected instantaneous utility must not exceed the time preference rate.

The value function can best be understood by going back to equation (37): The value to which the expected value of deterministically detrended utility converges is μ. This value appears in (39) as $\mu/(\rho - g)$, i.e. the present value of utility that amounts to μ today, grows at rate g and where the discount factor is ρ. In addition, welfare today depends on a convergence term. If utility today is lower than μ, there will be convergence towards this long-run mean and utility will be lower compared to a situation where $u(t)$ equals or exceeds μ. However, the difference $\mu - u(t)$ is not as important as μ in the other term, as this effect is transitory. Hence, the present value of the convergence process is computed subject to the convergence rate β.

Note that an identical expression for the value function would result in an analysis of the Solow model. The only difference would consist in the meaning of μ. While here, μ stands for "average instantaneous utility", it would stand for steady state utility in Solow's model.

Summarizing, the value of the optimal program $V(t)$ basically depends on four crucial determinants: "average instantaneous utility" μ, utility today $u(t)$, the innovation rate g and the convergence coefficient β. Studying welfare effects of taxation can therefore be broken down into effects on these four elements that determine the value function.

4.2 The cyclical component

While the measure for welfare was straightforward, there is an almost infinite number of possible measures of volatility. The empirically oriented literature provides two examples: The variance of growth rates (e.g. of GDP) and the variance of cyclical components. App. 7.2 analyses the variance of the growth rate of instantaneous utility u in detail. It turns out that the resulting expression and therefore variances of all other time-series like e.g. GDP, do not lend themselves to a straightforward analysis. This is due to two facts. First, growth rates for long time horizons, i.e. for $\tau \to \infty$, do approach a constant mean but do not have finite variance or finite higher moments. Second, while annual growth rates have finite moments, they are extremely complex (cf. equ. (52)) and a comparative static analysis is close to intractable. We therefore use cyclical components as our basic random variable to measure volatility.

4.2.1 The evolution of the cyclical component

Cyclical components of time series can be defined and therefore computed in many ways and the literature offers a large number of filters. None of these filters, given their computational complexity, would allow us to derive cyclical components that would yield an explicit

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[15]Hence, the integral of the expected expression exists. See footnote 12.

analytical expression for volatility. We therefore use a very simple filter, the Solow-type detrending rule used in (17), to compute our cyclical components. Usual filters, think of the Hodrick-Prescott filter, detrend by removing a smooth trend from a time series. Our filter captures the trend by a step function $A^{q(t)}$, caused by the discrete increases of $q(t)$. In spirit, however, these filters are very close as both remove past realizations of growth processes to obtain the cyclical components.
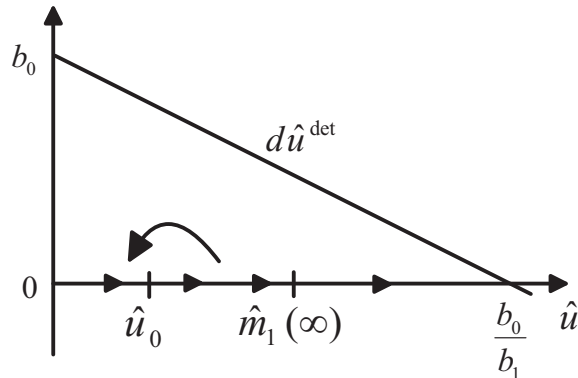
Figure 2: Detrended utility

In order to understand the detrending method proposed here, we look at the evolution of detrended utility.[16] We define detrended individual utility, in analogy to (14), as the component of utility that stems from the cyclical component of consumption in (17),

$$\hat{u} = \frac{(\hat{C}/L)^{1-\sigma}}{1-\sigma}. \tag{40}$$

With

$$\hat{b}_2 \equiv 1 - \Xi/\Theta, \tag{41}$$

detrended utility follows (app. 7.3)

$$d\hat{u}\left(t\right) = \left(b_0 - b_1\hat{u}\left(t\right)\right)dt - \hat{b}_2\hat{u}\left(t\right)dq(t). \tag{42}$$

This law of motion is basically identical to (33), only that the $\Theta^{q(t)}$ term is missing and $\hat{b}_2$ slightly differs from b_2. Again, we can gain an intuitive understanding by plotting in fig. 2 the deterministic part $(b_0 - b_1\hat{u}\left(t\right))$ with $\hat{u}\left(t\right)$ on the horizontal axis.

Obviously, the cyclical component of utility has a range between 0 and b_0/b_1, provided that $\hat{u}_0$ lies within this range. Starting from $\hat{u}_0$ and as long as no innovation takes place, the cyclical component approaches its upper bound. Each innovation reduces $\hat{u}\left(t\right)$ to $\left(1 - \hat{b}_2\right)\hat{u}\left(t\right)$, i.e. Ξ/Θ percent of its level before the innovation. As the reduction is proportional, $\hat{u}\left(t\right)$ is always positive.

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[16]In Lucas-type approaches, the measure of volatility is based on the evolution of consumption. For analytical tractability, we need to work with detrended utility. There are approximation rules, however, which allow to compute e.g. the coefficient of variation of consumption once the coefficient of variation of utility (a monotone transformation of consumption) is known (cf. e.g. Rinne, 1997).

4.2.2 The coefficient of variation

Exploiting again the methods in Garcia and Griego (1994), we can compute moments of this cyclical component. This follows similar step as above for (37). In fact, denoting the ith moment, in analogy to (31), by

$$\hat{m}_i(\tau) \equiv E_t \hat{u}(\tau)^i, \tag{43}$$

the first and second moment are given in the long run by (app. 7.3.2)[17]

$$\hat{m}_1(\infty) = \frac{b_0}{b_1 + \lambda \hat{b}_2}, \tag{44}$$

$$\hat{m}_2(\infty) = \frac{2b_0}{2b_1 + \lambda \left[1 - (1 - \hat{b}_2)^2\right]} \hat{m}_1(\infty). \tag{45}$$

Using these moments, computing the variance would be straightforward. As a measure of volatility, the variance seems less suitable in our context, however, as it is scale dependent. We therefore prefer the coefficient of variation (cv). Given that the variance of a random variable is the difference between its second moment and the square of its mean, we obtain

$$cv^2 \equiv \frac{\lim_{\tau \to \infty} var_t \hat{u}(\tau)}{\left(\lim_{\tau \to \infty} E_t \hat{u}(\tau)\right)^2} = \frac{\hat{m}_2(\infty)}{\left(\hat{m}_1(\infty)\right)^2} - 1. \tag{46}$$

When computing the second moment in all generality, an expression similarly complex as for the variance of the growth rate, presented in the appendix in (52) appears. When we focus on the long run where the convergence of the initial value $\hat{u}_0$ to $\hat{m}_1(\infty)$ in (42) is ignored, however, this measure simplifies. This would be the case for the variance of growth rates as well, see (53). Studying the long run with this measure of volatility is not at all as problematic as using growth rates, however. In the latter case, we analyze the variance of multi-annual growth rates. Those could never be observed. In the former case, looking at the long run simply means studying the volatility of some stationary long-run distribution. This corresponds to studying the variance of the cyclical component of a time series that is very long. This being said, our cv is (app. C.3.2)

$$cv^2 = \frac{\hat{b}_2^2}{2b_1/\lambda + 1 - \left(1 - \hat{b}_2\right)^2}. \tag{47}$$

To obtain a feeling for this measure, we go back to fig. 2. The first moment $\hat{m}_1(\infty)$ lies between 0 and the steady state b_0/b_1. This is intuitively clear, given the permanent convergence towards b_0/b_1 and the occasional being thrown back. As the process $\hat{u}(t)$ is completely described by (42), given an arrival rate λ, only the parameters of this process, b_0, b_1, $\hat{b}_2$ and λ, can show up in its moments. A larger b_0 and a smaller b_1 shifts the mean $\hat{m}_1(\infty)$ to the right; this is clear from fig. 2 as a larger b_0 and a smaller b_1 shift the $d\hat{u}$ line to the right. When $\hat{b}_2$ or λ increase, the mean shifts to the left as either jumps to the left are larger or more frequent.

The second moment has the same properties as the first moment $\hat{m}_1(\infty)$ with respect to b_0, b_1 and λ, as can be directly seen in (45). As the term $1 - \left(1 - \hat{b}_2\right)^2$ increases in $\hat{b}_2$, it

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[17] The structure of the moments is remarkable as it shows that the distribution of $\hat{u}$ exists, is unique and represents a generalization of the β-distribution. We are grateful to Christian Kleiber for pointing this out to us. For more discussion see app. 7.3.2.

also behaves as $\hat{m}_1(\infty)$ with respect to $\hat{b}_2$, i.e. it decreases in $\hat{b}_2$. Simply speaking, a larger range and more frequent jumps increase the second moment, a measure of dispersion.

Computing the cv then shows that it is independent of b_0. This is not surprising as b_0 is a scaling parameter and the cv is by construction scale independent. This can intuitively also be understood from fig. 2 where the effect of b_0 on the cyclical component could be removed by scaling both axes with $1/b_0$. The effect of other parameters will be discussed below.

4.2.3 Random walks and stationary cyclical components

Following the work of Nelson and Plosser (1982), the majority view seems to be now that most observed macroeconomic time series exhibit difference-stationarity rather than trend-stationarity.[18] This implies that theoretical models should predict difference stationary time paths as well, i.e. trends and cyclical components should both be stochastic as opposed to models where only cyclical components are stochastic and the trend is deterministic. An example of the latter type is given by King and Rebelo (1999), where the technology is $Y_t = A_t K_t^\alpha [N_t X_t]^{1-\alpha}$, labour productivity increases according to $X_{t+1} = \gamma X_t$ with $\gamma > 1$ and TFP follows $A_t = A_{t-1}^\rho e^{\varepsilon_t}$ with $\rho < 1$ and ε_t being normally iid. Models of the former type are presented e.g. by King, Plosser, Stock and Watson (1991) where the log of TFP is assumed to follow a exogenously given random walk with drift. Models with endogenous stochastic trends include King, Plosser and Rebelo (1988, sect. 3.3), Fatás (2000) or Barlevy (2004). Sources of fluctuations are exogenous in these models.

We now show that our model exhibits indeed a stochastic trend and stochastic stationary cyclical components. The crucial difference to models just cited is of course the endogeneity of shocks to TFP. How often shocks occur, i.e. how often the technology jumps, depends on decisions made by investors.[19] The well-known Aghion-Howitt (1992) random technological progress specification can therefore also endogenously account, once properly included in a model of growth and fluctuations, for business cycle properties so far replicated only in an exogenous way.

We can write (17) as $\ln K(t) = q(t)(\ln A)/\alpha + \ln \hat{K}(t)$, i.e. we split our time series $\ln K(t)$ into a trend component $q(t)(\ln A)/\alpha$ and into a stationary cyclical component $\ln \hat{K}(t)$, in the sense of Beveridge and Nelson (1981). Both the trend component and the stationary component are stochastic. Even though we are in continuous time, we can easily relate our trend component to a discrete time random walk as we can describe it by the pure random walk with drift: $q(t) = q(t-1) + \lambda + \varepsilon(t)$, where $\varepsilon(t) \sim (0, \lambda)$.[20] Hence, our trend component has a unit root and our cyclical component $\hat{K}(t)$ is stationary as just shown for $\hat{u}$.

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[18]More recent work on stationarity includes Bai and Ng (2004).

[19]Other models of endogenous fluctuations and growth, all cited in the introduction, are of a deterministic nature. The only exception is Bental and Peled (1996) who were the first to study endogenous fluctuations and growth. Unfortunately, their model is fairly complex which makes an explicit analysis of stochastic properties of trends and cycles a very hard task.

[20]The fact that the expectation and variance of $q(t) - q(t-1)$ are both equal to λ results from the distributional properties of a Poisson process. If the increment of the trend term was not constant, i.e. if e.g. A was vintage dependent and stochastic, the expectation and variance would differ. This would be an interesting extension for future work and should help in empirical applications.

5   Volatility, welfare and taxation

Given our measures of welfare and volatility derived in the last section, we can now ask how taxation affects these quantities.

5.1   Volatility and taxation

5.1.1   The volatility channels

Our central measure of volatility in (47) is affected through three channels: the speed of convergence b_1, the altitude of the slump $\hat{b}_2$ and the arrival rate λ. The interpretation of these parameters is based on (42) but other interpretations are possible. When we plot an arbitrary realization of our cyclical components in fig. 3, this becomes more transparent.

The range of our cyclical components is $]0, b_0/b_1[$. The upper limit corresponds to the steady state $\hat{K}^*$ for the cyclical component of capital in fig. 1. Hence, b_1 is at the same time a measure of the range of the cyclical component (cf. fig. 2, remembering that b_0 is only a scaling parameter) and thereby of its amplitude. The arrival rate λ also measures the expected number of jumps or (the inverse of) the expected length of a cycle. The simple reason why volatility depends on taxation is therefore the same reason why the steady state capital stock (29) (i.e. the speed of convergence), the novelty of a new technology or the arrival rate depend on taxation.
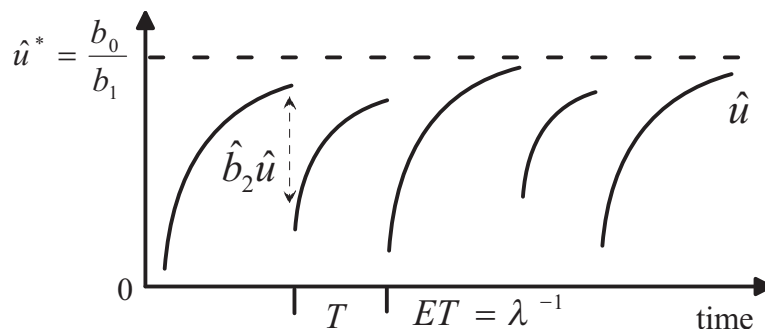
Figure 3: The cyclical components and their determinants b_1, $\hat{b}_2$ and λ

When we want to understand the effects of taxation, we can restrict attention to b_1 and λ as $\hat{b}_2$ is independent of taxation. The independence of $\hat{b}_2$ (and of b_2) from taxes follows from their definitions in (34) and (41) and the fact that ξ from (23), with s from (16) and κ_0 from (6), is independent of tax rates. Economically, this independence of $\hat{b}_2$ follows from the fact that dividend payments κ are not taxed and that economic depreciation s does not imply tax-exemption as does physical depreciation δ.

The tax effects on the arrival rate λ are straightforward from looking at (22) and are summarized in table 1. As the growth rate g of expected utility has λ as its only tax-dependent determinant, it has the same qualitative properties and is also included in the table. The composite parameter b_1 in (28) depends on taxes both directly and indirectly through the arrival rate. When we insert (22) into (28), we obtain unambiguous results,

except for τ_I (app. D.1.1).

	$\tau_L = \tau_K$ $^{(*)}$	τ_C	τ_R	τ_I	τ_W
b_1	$-$	0	$-$	$+$ $^{(1)}$	$+$
$b_2,\ \hat{b}_2$	0	0	0	0	0
g, λ	0	0	$-$	$+$	0
volatility	$+$	0	$-$	$+$	$-$
welfare	$-$		$-$	$\pm$	$\pm$	$-$

$(*)$ only joint changes of τ_L and τ_K can be studied, see (24)

(1) for high τ_I or τ_K and low δ

Table 1: Taxation effects on composite parameters, the arrival rate, volatility and welfare

5.1.2 Comparative statics

Let us now combine the effects of these three channels on volatility. As we have only two tax-dependent channels, b_1 and λ, taxation can affect volatility by either changing λ or b_1 (without the λ in b_1), or both. Clearly, when a tax has no effect on b_1 and λ, the cv is not affected by this tax either. This is the case for taxation of consumption.

When taxing wealth, the arrival rate and the "slump parameter" $\hat{b}_2$ are not affected, while the (inverse) range parameter b_1 increases and, as a consequence, volatility goes down. Economically speaking, a tax on wealth decreases the households' return r^* in (16) on savings and thereby implies a lower steady-state cyclical capital stock and utility level $\hat{u}$. Holding constant the length of a cycle but "squeezing" the cyclical components in fig. 3, the relative dispersion must be lower.

An increase in the income tax on capital and labour reduces the range parameter b_1 but not the arrival rate λ. As a consequence, volatility unambiguously increases in this tax. How can this result be understood? The speed of convergence b_1 in (28) reduces for two reasons: (i) only *net* investment is taxed (as discussed before (15)), i.e. a higher tax on capital increases the positive effect of the refunding policy and reduces the impact of the depreciation rate δ as visible in (28). A lower (effective) depreciation rate increases incentives for capital accumulation and the steady-state capital stock increases. (ii) Due to our $\sigma = \alpha$ restriction, direct effects of joint changes in capital and labour taxation just cancel out and only this indirect refunding effect is left over. Clearly, this second effect would not survive for $\alpha \neq \sigma$ and $\tau_K \neq \tau_L$ and should potentially overcompensate the first effect. Hence, currently, the effect of income taxation is the opposite of wealth taxation but should go in similar directions for more general cases.

When analyzing R&D and investment taxes τ_R and τ_I, results are at first sight less clear-cut as these taxes affect the arrival rate which affects the cv directly positively and indirectly negatively through λ. Computing the derivatives, however, we get unambiguous results as presented in table 1 above (app. D.1.2). The analytics for τ_R say in words: a higher tax on research depresses the arrival rate. When the arrival rate falls, the ratio b_1/λ increases and the cv falls. Intuitively, a higher τ_R makes investment in research less profitable and the arrival rate λ falls. Less frequent jumps in technology imply a lower volatility. A lower λ also decreases b_1 which by fig. 3 implies a larger range b_0/b_1 and higher volatility. This is because b_1 represents physical depreciation but also consumption and expenditure for research. A lower λ therefore implies ceteris paribus a lower b_1. This second indirect effect, however, is

not large enough such that the direct volatility decreasing effect of higher taxes on research dominates.

Given the explanations for the previous finding, understanding the result for τ_I is also easy: a higher tax on investment increases the arrival rate which again has a direct and an indirect effect on volatility. The direct effect via the frequency of jumps overcompensates the indirect effect on the range and volatility increases. The additional effect of taxation on investment via the depreciation rate δ makes the range increasing effect of a higher λ less strong such that the indirect effect is even weaker than under a change of τ_R. Consequently, volatility falls more when τ_I increases as when τ_R falls.

If growth and volatility were exogenous, i.e. if there was an arrival rate given by λ without any resources R being required for R&D, the model would from its basic structure resemble a simple RBC model. Any activity takes place under perfect competition and labour productivity improves by discrete amounts at random points in time. Volatility would still be affected by taxation as the arrival rate is only one out of three channels in our measure of volatility (47).[21] As argued in the introduction, however, an endogenous arrival rate allows us to investigate whether taxes can explain a break in volatility *without* affecting the growth rate. As McConnell and Perez-Quiros (2000) argue, there was a break in volatility in the US in 1984 without a break in the trend of GDP. Hence, given our results in table 1, this model predicts falling income taxes $\tau_L = \tau_K$ and rising wealth taxes τ_W to reduce volatility without affecting trend growth.

5.1.3 Quantitative importance

This section takes a first look at the quantitative properties of our model and asks whether changes in tax rates can have effects that are "sufficiently large". Clearly, our analytically convinient approach of assuming the parameter restriction (24) imposes strong restrictions for calibration purposes. Calibration here is also more ambitous than in standard circumstances as we have additional statistical properties of observed economies which we want to match: Table 2 shows on the left-hand side that the average (expected) length of a cycle and growth rate g and the tax elasticitiy of the growth rate enter as central predictions of the model. Reasonable values are obtained by choosing A, D_0 and the externality measure γ (cf. app. D.1.3 for details) [22]. Initial tax rates and exogenous parameters were set at $(\tau_I, \tau_R, \tau_C, \tau_F, \tau_W) = (.15, .00, .15, .30, .01)$ and $(\alpha, \delta, \rho, \kappa_0) = (.5, .075, .03, 10^{-12})$, respectively. The exogenous parameter values for δ and ρ are standard. The value for α depends on whether one perceives human capital to be captured by K as well. We set it somewhat higher than the pure national account value of .3. Intuitively, the size of the new machine κ is small relative to the capital stock in the economy as a whole. This explains the low value for κ_0.

	imposed		calibrated		
E length of cycle	E growth	tax elasticity of λ	A	D_0	γ
5 years	3%	0.33	1.16	1.55×10^{-10}	.75

Table 2: A simple calibration

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[21] The amount of volatility would therefore remain endogenous even in this exogenous shock economy. Volatility could, however, no longer be called "natural" as its source is exogenously imposed on the economy.

[22] Regression analyses show that the effect of taxation on growth is not without controversy: see e.g. Mendoza et. al. (1994) and Padovano and Galli (2001) for a survey.
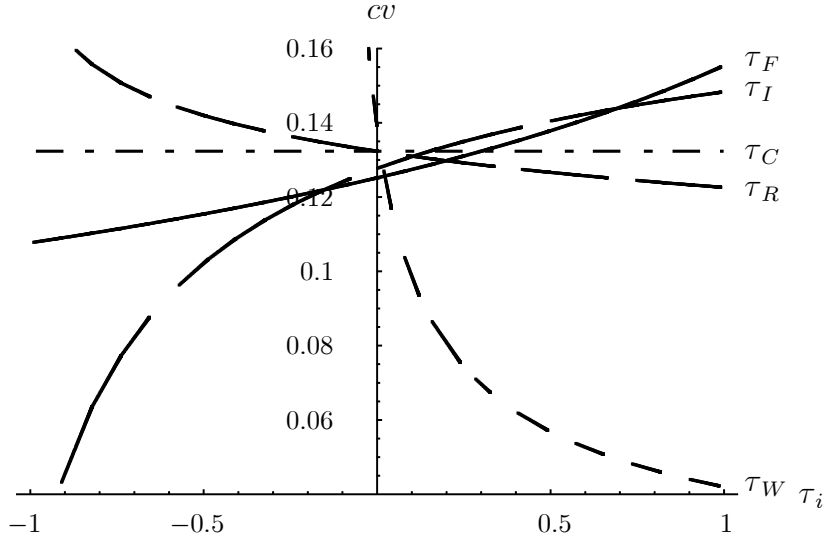
Figure 4: Quantitative dependence of the cv on tax rates

Given these parameter values, fig. 4 shows the coefficient of variation as a function of tax rates. Taxes vary from -1 (a subsidy) to 1. The coefficient of variation (cv) of the baseline calibration is .13. The coefficient of variation for an HP-filtered cyclical component of real GDP for the U.S. economy decreased from about .4 in the 1955:2-1984:1 period to about .2 in 1984:2-2004:2. The decline in the variance of quarterly growth rates are of similar pattern (see e.g. McConnell and Perez-Quiros 2000). This implies that endogenous fluctuations of our model match roughly 33% to 65% of observed fluctuations (dividing .13 by .4 and .2). This is remarkable given the absence of exogenous sources of volatility or the $\sigma = \alpha$ restriction.

Some tax rates, i.e. the tax on research τ_R and the tax on wealth τ_W reduce the cv of the baseline calibration potentially by 10% and 60%, respectively. Other tax rates, i.e. the tax on investment τ_I and the factor income tax τ_F increase the cv: a decrease of τ_F by 10 percentage points decreases the cv roughly by 3%. The break in volatility in the US could therefore be explained quantitatively only to some extent. It should be remembered, however, that tax effects enter only through the arrival rate λ and the speed of convergence b_1. Effects of τ_R and τ_I on λ are small by construction whereas effects on b_1 in (28) are - due to our explicit $\sigma = \alpha$ solution - only through τ_W, the arrival rate λ, and the refunding effect, as direct effects of τ_F just cancel out. The consumption tax τ_C does not affect the cv at all as the labour-leisure choice is not modelled. We summarize our quantitative findings by stating that the level of tax rates does have an effect on volatility. A more elaborate calibration exercise (no parameter restriction, endogenous labour and some exogenous source of volatility) is needed, however, before the quantitative importance can be judged more convincingly.

5.2 Volatility and welfare

5.2.1 The welfare channels and comparative statics

When we look at our measure of welfare (39), it is affected by taxation through four quantities, average instantaneous utility μ, current utility $u(c(t))$, and g and β, the growth and convergence rate. These four quantities in turn depend on four channels, b_0, b_1, λ and Ψ. We could now, following the approach from our measure of volatility, analyze the effects of taxation on these channels first and then combine the results and derive conclusions for

welfare. As this does not yield additional insight, we directly link welfare to taxation by the following

Theorem 2 (Taxation and welfare) *A tax reduces welfare (39) when the permanent component of welfare $\mu/(\rho - g)$ falls faster or increases less fast than the transition component $(\mu - u(t))/(\rho - g + \beta)$. Computing the derivatives, we get*

$$\frac{\left(\frac{\partial b_0}{\partial \tau_i}\frac{1}{b_0} - \frac{\partial \beta}{\partial \tau_i}\frac{1}{\beta}\right)(\rho - g) + \frac{\partial \lambda}{\partial \tau_i}(\Theta - 1)}{(\rho - g)^2}$$

$$< \frac{\left(\frac{\partial b_0}{\partial \tau_i}\frac{1}{b_0} - \frac{\partial \beta}{\partial \tau_i}\frac{1}{\beta} - \frac{u(t)}{\mu}\frac{1-\sigma}{\Psi}\frac{\partial \Psi}{\partial \tau_i}\right)(\rho - g + \beta) - \left(\frac{\partial b_1}{\partial \tau_i} + \frac{\partial \lambda}{\partial \tau_i}b_2\right)\left(1 - \frac{u(t)}{\mu}\right)}{(\rho - g + \beta)^2}.$$

Proof. app. D.2 ∎

The left-hand side is the derivative of the permanent component of welfare, the right-hand side is the derivative of the transition component (where both sides are divided by μ). Both derivatives can be both negative or positive.

Going through these derivatives for individual taxes shows that (compare table 1 and app. D.2) taxes on factor income, consumption and wealth have unambiguous negative effects on welfare while taxes on investment and R&D can increase welfare. Taxes τ_F, τ_C and τ_W decrease welfare as resources are taken away from households and G has in the model no productivity- or utility-enhancing effect. The potentially welfare increasing effect of τ_I and τ_R can best be understood when looking at the first order condition for investment in research: in our decentralized setup, the first order condition $(1 + \tau_R) V_a(a(t), q) = \lambda V_{\tilde{a}}(\tilde{a}, q + 1)\frac{(1+\tau_I)\kappa}{R}$ from (A.17) shows that individuals invest in R&D because of dividend payments κ^*, their increased wealth $\tilde{a}$ and the better technology $q+1$. Optimal investment in a planner economy, where the planner maximizes the Bellman equation (A.15) with respect to R rather than i and where $\Sigma a(t)$ stands for wealth in the economy as a whole, would satisfy $V_{\Sigma a}(\Sigma a(t), q) = \frac{\partial \lambda}{\partial R}[V(\Sigma \tilde{a}, q + 1) - V(\Sigma a, q)]$. Incentives to do research therefore results from $\partial \lambda/\partial R$, the effect of more resources on the probability λ to find a new technology, and the difference in well-being between a situation with more wealth and a better technology, $V(\Sigma \tilde{a}, q + 1)$, and today, $V(\Sigma a, q)$. While there are certainly various opposing effects, externalities are strongest for this trade-off between capital accumulation and R&D. It is therefore not surprising, that taxes τ_I and τ_R which are directly affecting this first order condition are best suited to potentially internalize externalities.

As the first order conditions for consumption is identical for the planner and the representative household, there are no externalities or imperfections present in the model apart from those visible in the difference between the first order conditions for R&D. Put differently, if the arrival rate equalled λ exogenously without any resources R being allocated to R&D, the decentralized economy would be efficient. This RBC-type version of our model would then predict that fluctuations allow for an optimal adjustment by individuals to exogenous disturbances. If one believes, however, that the process of finding and developing new technologies implies certain externalities (and that new technologies at least partially induce fluctuations), factor allocations in an economy "growing through cycles", to use Matsuyama's (1999) words, are inefficient.

5.2.2 The tax-link between volatility and welfare

Given the inefficiency of fluctuations, should taxes be used to stabilize the economy? In the literature, more volatility is usually associated with lower welfare: In perfect-market models (Lucas, 1987, 2003 or, more recently, Epaulard and Pommeret, 2003 and Barlevy, 2004), exogenous volatility implies fluctuations of consumption and the curvature of the utility function implies lower welfare than in an economy without fluctuations but identical average growth. Gali et al. (2003) focus on inefficiencies and argue - due to the inefficiency of the steady state and the larger welfare losses in recessions than welfare gains in booms - that fluctuations on average cause welfare losses.

This is not necessarily the case when fluctuations are endogenous: While the curvature of the utility function à la Lucas and the asymmetry as in Gali (and others) is welfare-reducing in our setup as well, volatility is only the result of the more fundamental factor allocation in an economy. Asking whether volatility is welfare reducing and by how much is therefore meaningful only if one believes that the sources of fluctuations are exogenous to an economy (which, in the real world, they are - to a certain extent). The welfare effects of endogenous fluctuations, however, can only be understood when understanding the welfare properties of the underlying factor allocation that causes these fluctuations. When this is done, it becomes clear that more or less fluctuations can be associated (and are not causal as in the exogenous fluctuation case) with higher or lower welfare. Tax policy should therefore not be used in all cases to stabilize the economy.

This association between welfare and volatility, illustrated for taxes with unambiguous welfare effects, is depicted in the following figure.
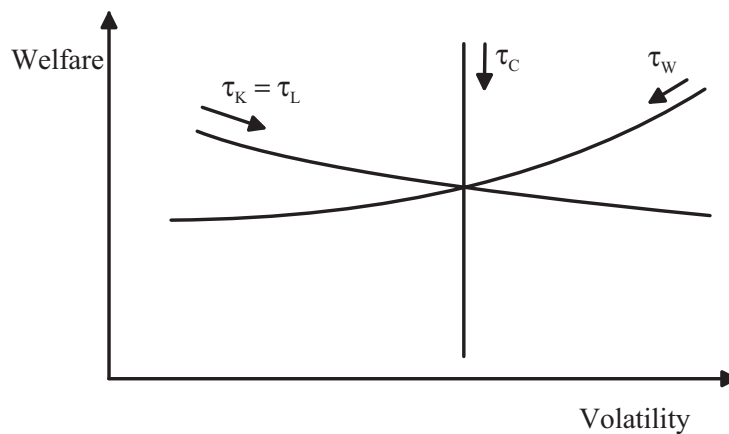
Figure 5: Welfare, volatility and taxation - anything goes

Arrows indicate in which direction to move on the line when the tax is increased. Fig. 5 shows that there is no association between volatility and welfare in general. It all depends on the source of the change in volatility. While certain taxes increase volatility and reduce welfare (τ_F), others reduce volatility but still decrease welfare (τ_W). Lowering the tax on wealth increases welfare as fewer resources are taken away from the economy as argued above. At the same time, volatility increases as the steady state capital stock (29) increases. Hence, despite the curvature of the utility function and the asymmetric effect of volatility on efficiency, more volatility implies higher welfare.

6   Conclusion

Growth rates above and below long-run trends are a common feature of all real-world economies. The present paper used a model that perceives endogenous fluctuations as a natural phenomenon of all endogenously growing economies by stipulating that new technologies increase labour productivity in a discrete way. Agents in this setup are not solely responding to shocks but rather are the source of shocks, i.e. jumps in technologies, due to their financing of innovation and growth. This framework was used to analyze the effects of taxation on volatility and the associated welfare effects. Due to a sharp decrease of volatility in the US and an almost simultaneous strong tax reform, taxation was expected to potentially explain part of the 'big moderation' starting in 1983.

We used the coefficient of variation of the cyclical component of a typical time series as our measure of volatility. It was shown that this measure is most tractable from a theoretical perspective and that three economically meaningful channels affect this measure: potential range of cyclical components, slumps and frequency of new technologies. Taxes affect these channels in various ways which allows, inter alia, to understand a change in volatility without requiring a simultaneous change in the growth rate of the economy.

Welfare effects associated with changes in volatility can be manifold. In a special case of our model where the source of long-run growth and short-run fluctuations is exogenous, factor allocation is efficient and volatility does not signal the need for stabilization. With endogenous growth and fluctuations, however, inefficiencies enter the economy and fluctuations hint at the possibility of welfare-increasing policy measures, even though all production and R&D activities were modelled to take place under perfect competition.

Stabilization is not necessarily welfare increasing, however: Lower volatility can imply higher or lower welfare, depending on whether the tax change reducing volatility implies higher or lower welfare. Analyzing the link between volatility and welfare should therefore not be restricted to the usual mono-causal link from an exogenous source of volatility and an endogenous welfare reaction but expanded to exogenous change in fiscal policy (or other exogenous changes in the economic environment) and how natural volatility and welfare react to this.

An important extension of the present analysis (and other papers in the literature on endogenous fluctuations and growth) would combine endogenous and exogenous sources of fluctuations. It appears reasonable to start an analysis of fluctuations of any real word economy by allowing for both endogenous jumps of and exogenous shocks to the technology as well as nominal sources of fluctuations. Labour market participation decisions and unemployment should also be included in future work. The implications of our analysis for the growth and volatility debate could also be worked out more precisely. With endogenous volatility, taxes (or other policy parameters) affect both long-run growth and volatility. As in our welfare argument, the causal link from volatility on growth becomes a correlation. The implied endogeneity of volatility in regression analyses could be tested.

7   Appendix

This appendix contains derivations that are interesting from a theoretical perspective beyond this specific paper. Section 7.1 derives the evolution of expected instantaneous utility. It uses methods that were developed in the applied mathematical literature, e.g. Garcia and Griego (1994). These methods are potentially useful also in other areas where Poisson processes are

used (e.g. all search and matching models in monetary or labour economics). Section 7.2 computes an explicit expression for the variance of the growth rate. Again, various methods are borrowed from Garcia and Griego (1994). Finally, section 7.3 computes the moments of our basic random variable. This forms the basis for our measure of volatility. Interestingly, we obtain a generalized β-distribution from this analysis.

Further derivations are included in the Referees' appendix which is available upon request.

7.1 Evolution of expected instantaneous utility

This section computes the expected value of instantaneous utility, conditional on the current state in t, given by $q(t)$ and $K(t)$. The results provide information about expected growth but are especially needed for computing the value function.

7.1.1 A lemma for $E\left(c^{kN_\tau}\right)$

We first compute some simple expectations that are used later.

Lemma 3 *Assume that we are in t and form expectations about future arrivals of the Poisson process. The expected value of $c^{kq(\tau)}$, conditional on t where $q(t)$ is known, is*

$$E_t(c^{kq(\tau)}) = c^{kq(t)}e^{(c^k-1)\lambda(\tau-t)}, \quad \tau > t, \quad c, k = const.$$

Note that for integer k, these are the raw moments of $c^{q(\tau)}$.

Proof. We can trivially rewrite $c^{kq(\tau)} = c^{kq(t)}c^{k[q(\tau)-q(t)]}$. At time t, we know the realization of $q(t)$ and therefore $E_t c^{kq(\tau)} = c^{kq(t)}E_t c^{k[q(\tau)-q(t)]}$. Computing this expectation requires the probability that a Poisson process jumps n times between t and τ. Formally,

$$
\begin{aligned}
E_t c^{k[q(\tau)-q(t)]} &= \sum_{n=0}^{\infty} c^{kn} \frac{e^{-\lambda(\tau-t)}(\lambda(\tau-t))^n}{n!} = \sum_{n=0}^{\infty} \frac{e^{-\lambda(\tau-t)}(c^k\lambda(\tau-t))^n}{n!} \\
&= e^{(c^k-1)\lambda(\tau-t)} \sum_{n=0}^{\infty} \frac{e^{-\lambda(\tau-t)-(c^k-1)\lambda(\tau-t)}(c^k\lambda(\tau-t))^n}{n!} \\
&= e^{(c^k-1)\lambda(\tau-t)} \sum_{n=0}^{\infty} \frac{e^{-c^k\lambda(\tau-t)}(c^k\lambda(\tau-t))^n}{n!} = e^{(c^k-1)\lambda(\tau-t)},
\end{aligned}
$$

where $\frac{e^{-\lambda\tau}(\lambda\tau)^n}{n!}$ is the probability of $q(\tau) = n$ and $\sum_{n=0}^{\infty} \frac{e^{-c^k\lambda(\tau-t)}(c^k\lambda(\tau-t))^n}{n!} = 1$ denotes the summation of the probability function over the whole support of the Poisson distribution which was used in the last step. ∎

Lemma 4 *Assume that we are in t and form expectations about future arrivals of the Poisson process. Then the number of expected arrivals in the time interval $[\tau, s]$ equals the number of expected arrivals in an unknown time interval of the length $\tau - s$ and therefore*

$$E_t(c^{k[q(\tau)-q(s)]}) = E(c^{k[q(\tau)-q(s)]}) = e^{(c^k-1)\lambda(\tau-s)}, \quad \tau > s > t, \quad c, k = const.$$

Proof. This proof is in appendix C.1.1, it simply applies lemma 3. ∎

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7.1.2 Expected instantaneous utility

We will use in what follows the martingale property of various expressions. These expressions are identical to or special cases of $\int_t^\tau f\left(q\left(s\right),s\right)dq\left(s\right)-\lambda\int_t^\tau f\left(q\left(s\right),s\right)ds$, of which Garcia and Griego (1994, theorem 5.3) have shown that it is a martingale indeed, i.e.

$$E_t\left[\int_t^\tau f\left(q\left(s\right),s\right)dq\left(s\right)-\lambda\int_t^\tau f\left(q\left(s\right),s\right)ds\right]=0,\tag{48}$$

where λ is the (constant) arrival rate of $q\left(s\right)$.

The integral version of (33) for $\tau>t$ is $u\left(\tau\right)=u\left(t\right)+\int_t^\tau b_0\Theta^{q(s)}-b_1u\left(s\right)ds-\int_t^\tau b_2u\left(s\right)dq\left(s\right)$. Applying (conditional) expectation operators gives $E_tu\left(\tau\right)=u\left(t\right)+E_t\int_t^\tau b_0\Theta^{q(s)}ds-E_t\int_t^\tau b_1u\left(s\right)ds$ $-E_t\int_t^\tau b_2u\left(s\right)dq\left(s\right)$. When we pull expectations into the integral (as in equation (30)), use lemma 3 and the martingale result (48), we get $E_tu\left(\tau\right)=u\left(t\right)+\Theta^{q(t)}\int_t^\tau b_0e^{(\Theta-1)\lambda[s-t]}ds$ $-\int_t^\tau b_1E_tu\left(s\right)ds-\lambda\int_t^\tau b_2E_tu\left(s\right)ds$. With $m_1\left(\tau\right)\equiv E_tu\left(\tau\right)$ from (31), we get $m_1\left(\tau\right)=u\left(t\right)$ $+\int_t^\tau\Theta^{q(t)}b_0e^{(\Theta-1)\lambda[s-t]}ds-\int_t^\tau b_1m_1\left(s\right)ds-\int_t^\tau b_2\lambda m_1\left(s\right)ds$ and differentiating with respect to time τ gives

$$\dot{m}_1\left(\tau\right)=\Theta^{q(t)}b_0e^{(\Theta-1)\lambda[\tau-t]}-\left(b_1+\lambda b_2\right)m_1\left(\tau\right).\tag{49}$$

The solution of this deterministic linear differential equation is

$$m_1\left(\tau\right)=m_1(t)e^{-(b_1+\lambda b_2)(\tau-t)}+\int_t^\tau\Theta^{q(t)}b_0e^{(\Theta-1)\lambda[s-t]}e^{-(b_1+\lambda b_2)(\tau-s-\tau+t)}e^{-(b_1+\lambda b_2)(\tau-t)}ds$$

$$=e^{-(b_1+\lambda b_2)(\tau-t)}\left(m_1(t)+\Theta^{q(t)}b_0\int_t^\tau e^{(b_1+\lambda b_2+(\Theta-1)\lambda)(s-t)}ds\right)$$

$$=e^{-(\beta-g)(\tau-t)}\left(u\left(t\right)+\Theta^{q(t)}b_0\frac{e^{\beta[\tau-t]}-1}{\beta}\right),$$

where the last line used $m_1\left(t\right)=E_tu\left(t\right)=u\left(t\right)$ and (36) for β. Rearranging gives (37) in the text.

7.2 The variance of the growth rate

This section derives an alternative expression for volatility, the variance of the growth rate. This measure is more common in empirical work (e.g. Ramey and Ramey, 1995 or McConnell and Perez-Quiros, 2000) than the variance of cyclical components, which in turn is used more intensively in the RBC literature.

It is not immediately clear, however, how this variance should be computed. Is it the variance of some long-run stationary distribution, $\lim_{\tau\to\infty}\text{var}_t\left[g_{\tau,t}\right]$, is it the variance of some "annual" growth rate of some long-run distribution, $\lim_{\tau\to\infty}\text{var}_t\left[g_{\tau+1,\tau}\right]$, or is it the variance of the next "period" in this model, $\text{var}_t\left[g_{t+1,t}\right]$? In a way, the choice of measure of variance is arbitrary. We therefore choose the one that comes closest to the estimation of the variance of observed growth rates. The counterpart to an observed annual growth rate for a "year" t in our model is $g_{t+1,t}$. Taking many drawings, there is a set of annual growth rates $\{g_{t+1,t}\}$ for which the variance can be estimated. Noting that annual growth rates are computed given the knowledge on t, the analytical expression corresponding to this is the t-contingent variance of $g_{t+1,t}$, i.e. $\text{var}_t\left[g_{t+1,t}\right]$.

Now, we can take advantage of the following straightforward relationship: The t-contingent variance of the growth rate of some random variable is the same as the t-contingent variance

of the random variable divided by some constant. In our case,

$$\text{var}_t \left[\frac{u(\tau) - u(t)}{u(t)} \right] = \frac{\text{var}_t u(\tau)}{u(t)^2}. \tag{50}$$

While this is trivial in a sense, it has the huge advantage that we can just compute the second moment of $u(\tau)$ and thereby obtain the theoretical counterpart of the variance of observed growth rates.

The variance of $u(\tau)$ is computed by first computing its second moment. To this end, the evolution of squared utility needs to be understood. It follows (app. C.2.2)

$$du(t)^2 = 2\left(b_0 \Theta^{q(t)} u(t) - b_1 u(t)^2\right) dt - \left(1 - (1 - b_2)^2\right) u(t)^2 dq.$$

Comparing it to (33) shows that the main difference, apart from the square term u^2 instead of u, is the interaction $\Theta^q u$ between Θ^q and u. When forming expectations, we therefore have to compute the expected interaction term, i.e. look at $\psi(s) \equiv E_t \Theta^{q(s)} u(s)$. After "some steps" (filling 6 pages in app. C.2), denoting

$$g_\psi \equiv (\Theta^2 - 1)\lambda > 0,$$
$$\beta_\psi \equiv g_\psi + b_1 + (1 - \Theta[1 - b_2])\lambda = b_1 + (\Theta^2 - \Theta\Xi)\lambda > 0, \tag{51}$$
$$\beta_2 \equiv g_\psi + 2b_1 + \left(1 - (1 - b_2)^2\right)\lambda,$$

the variance from (A.49) is

$$
\begin{aligned}
var_t(u(\tau)) \quad = \quad & \mu^2 \Bigg[e^{-(\beta_2 - g_\psi)(\tau - t)} \left(\frac{u(t)^2}{\mu^2} - \frac{2\beta^2}{\beta_2 \beta_\psi} \right) + \frac{2\beta^2}{\beta_2 \beta_\psi} e^{g_\psi[\tau - t]} \\
& \left(e^{-(\beta_\psi - g_\psi)(\tau - t)} - e^{-(\beta_2 - g_\psi)(\tau - t)} \right) \frac{2\beta}{\beta_2 - \beta_\psi} \left(\frac{u(t)}{\mu} - \frac{\beta}{\beta_\psi} \right) \\
& - e^{2g[\tau - t]} \left[e^{-\beta[\tau - t]} \left(\frac{u(t)}{\mu} - 1 \right) + 1 \right]^2 \Bigg].
\end{aligned}
\tag{52}
$$

The structure of the variance is similar to previous structures in e.g. (37) for expected utility. There are growth and convergence rates (51) and there are expected long-run quantities. As a measure of volatility, however, the variance of the growth rate is less suitable for a variety of reasons: First, when we let τ become very large, i.e. when we look at the "long run" $T \gg t$, we do get a simpler expression as all convergence terms disappear (appendix C.2.3),

$$\frac{var_t(u(T))}{u(t)^2} = \frac{\mu^2}{u(t)^2} \left(\frac{2\beta^2}{\beta_2 \beta_\psi} e^{g_\psi[T - t]} - e^{2g[T - t]} \right). \tag{53}$$

This expression, however, represents the variance of the growth rate between t and T, i.e. we would not compute the variance of annual growth rates but of $T - t$-year growth rates. Clearly, such a variance can never be estimated in reality. Second, the expression for the variance for annual growth rates, i.e. growth rates from t to $t+1$, is the complete expression in (A.50) for $\tau = t+1$. Understanding properties of this expression, like derivatives with respect to certain tax rates appears analytically hopeless. Third, as a potential theoretical way out, one could try and deterministically detrend $u(\tau)$ as discussed on page 14. Computing the variance of the growth rate of deterministically detrended $u(\tau)$ (and not of $u(\tau)$ as done here), however, does not yield a finite expression either as the variance grows at g_ψ while inserting $e^{-g[\tau - t]}$ in front of $u(\tau)$ in (50) would not compensate for g_ψ.

7.3 The cyclical component

7.3.1 The basic differential equation (42)

As $\hat{u} = \left(\hat{C}/L\right)^{1-\sigma}/\left(1-\sigma\right)$ from (40), we have $d\hat{u} = \frac{(1/L)^{1-\sigma}}{1-\sigma}d\hat{C}^{1-\sigma}$. With $\hat{C} = \Psi\hat{K}$ from (19), (26) and the change of variable formula (CVF), we obtain

$$d\hat{C}^{1-\sigma} = \Psi^{1-\sigma}d\hat{K}^{1-\sigma}$$

$$= \left(\frac{b_0}{\Psi^{1-\sigma}}\hat{K}^{\alpha}L^{1-\alpha} - \frac{b_1}{1-\sigma}\hat{K}\right)\left(1-\sigma\right)\Psi^{1-\sigma}\hat{K}^{-\sigma}dt + \left(\left(1-\left(1-A^{-1}\xi\right)\right)^{1-\sigma}-1\right)\Psi^{1-\sigma}\hat{K}^{1-\sigma}dq$$

$$= \left(b_0\hat{K}^{\alpha-\sigma}L^{1-\alpha}\left(1-\sigma\right) - b_1\hat{C}^{1-\sigma}\right)dt + \left(\left(A^{-1}\xi\right)^{1-\sigma}-1\right)\hat{C}^{1-\sigma}dq$$

$$= \left(b_0\hat{K}^{\alpha-\sigma}L^{1-\alpha}\left(1-\sigma\right) - b_1\hat{C}^{1-\sigma}\right)dt - \left(1-\Xi/\Theta\right)\hat{C}^{1-\sigma}dq.$$

Using $\sigma = \alpha$ from (24), inserting and simplifying yields

$$
\begin{aligned}
d\hat{u} &= \frac{(1/L)^{1-\sigma}}{1-\sigma}\left[\left(b_0\hat{K}^{\alpha-\sigma}L^{1-\alpha}\left(1-\sigma\right) - b_1\hat{C}^{1-\sigma}\right)dt - \left(1-\Xi/\Theta\right)\hat{C}^{1-\sigma}dq\right] \\
&= \left(b_0 - b_1\hat{u}\right)dt - \left(1-\Xi/\Theta\right)\hat{u}dq.
\end{aligned}
$$

7.3.2 Computing moments

The integral version of (42) for $\tau > t$ is $\hat{u}\left(\tau\right) = \hat{u}\left(t\right) + \int_t^\tau \left(b_0 - b_1\hat{u}(s)\right)ds - \int_t^\tau \hat{b}_2\hat{u}(s)dq(s)$. Using the martingale result (48), the expected value of $\hat{u}\left(\tau\right)$ is $E_t\hat{u}\left(\tau\right) = \hat{u}\left(t\right) + \int_t^\tau \left(b_0 - b_1E_t\hat{u}(s)\right)ds - \lambda\int_t^\tau \hat{b}_2E_t\hat{u}\left(s\right)ds$. This describes the evolution of the first moment of $\hat{u}$. Expressed as a differential equation and using the definition in (43), we obtain $\dot{\hat{m}}_1\left(\tau\right) = b_0 - (b_1 + \lambda\hat{b}_2)\hat{m}_1\left(\tau\right)$. The solution of this deterministic linear differential equation is $\hat{m}_1\left(\tau\right) = e^{-(b_1+\lambda\hat{b}_2)(\tau-t)}\left(\hat{m}_1(t) + \int_t^\tau e^{(b_1+\lambda\hat{b}_2)(s-t)}b_0ds\right) = e^{-(b_1+\lambda\hat{b}_2)(\tau-t)}\left(\hat{m}_1(t) + b_0\frac{e^{(b_1+\lambda\hat{b}_2)(\tau-t)}-1}{b_1+\lambda\hat{b}_2}\right)$, which can be simplified to

$$\hat{m}_1\left(\tau\right) = e^{-(b_1+\lambda\hat{b}_2)(\tau-t)}\left(\hat{m}_1\left(t\right) - \frac{b_0}{b_1+\lambda\hat{b}_2}\right) + \frac{b_0}{b_1+\lambda\hat{b}_2}. \tag{54}$$

As $b_1 + \lambda\hat{b}_2 > 0$, the first moment of $\hat{u}$ is in the long run given by $\hat{m}_1\left(\infty\right) \equiv \lim_{\tau\to\infty}\hat{m}_1\left(\tau\right) = \frac{b_0}{b_1+\lambda\hat{b}_2}$, as presented in (44).

For higher moments, the basic differential equation determining the evolution of $\hat{u}^n$ is from (42)

$$
\begin{aligned}
d\hat{u}^n &= n\hat{u}^{n-1}\left[b_0 - b_1\hat{u}\right]d\tau - \left(1-\left(1-\hat{b}_2\right)^n\right)\hat{u}^n dq \\
&= n\left[b_0\hat{u}^{n-1} - b_1\hat{u}^n\right]d\tau - \left(1-\left(1-\hat{b}_2\right)^n\right)\hat{u}^n dq. \tag{55}
\end{aligned}
$$

Using the integral version, applying expectations and the martingale result (48), we obtain $dE_t\hat{u}^n = \left(nb_0E_t\hat{u}^{n-1} - \left(nb_1 + \lambda\left[1-\left(1-\hat{b}_2\right)^n\right]\right)E_t\hat{u}^n\right)dt$. Using again (43),

$$\dot{\hat{m}}_n = nb_0\hat{m}_{n-1} - \left(nb_1 + \lambda\left[1-\left(1-\hat{b}_2\right)^n\right]\right)\hat{m}_n. \tag{56}$$

It can now be shown that all moments are constant for $\tau \to \infty$. This follows from (54) for the first moment and from appendix C.3.1 for the 2nd moment. This proof simply inserts (54) into (55) and solves the differential equation. Proofs for higher moments would follow an identical approach. Hence, for the long run where $\dot{\hat{m}}_n = 0$, we have from (56)

$$\hat{m}_n\left(\infty\right) = \frac{nb_0}{nb_1 + \lambda\left[1 - (1 - \hat{b}_2)^n\right]}\hat{m}_{n-1}\left(\infty\right).\tag{57}$$

By inserting $n = 2$, this directly implies (45), with $n = 1$, it becomes (44), remembering that $\hat{m}_0 = 1$ by definition.

A well-known theorem states that a distribution with limited range is completely characterized by its integer moments (e.g. Casella and Berger, 1990, th. 2.3.3.). As our long-run moments are constant and the range of $\hat{u}$ is finite, the distribution of $\hat{u}$ exists, is unique and stationery. Looking at the structure of moments in (57) further shows that the distribution of $\hat{u}$ is some generalized β-distribution: If $\hat{b}_2 = 1$, (57) can be written as $m_n^c(\infty) = \frac{nb_0}{nb_1 + \lambda}m_{n-1}^c(\infty)$. Starting from $\hat{m}_0 = 1$, repeated inserting yields

$$m_n^c(\infty) = \frac{b_0^n n!}{\prod_{i=1}^n (ib_1 + \lambda)} = \left(\frac{b_0}{b_1}\right)^n \frac{\Gamma(n+1)}{\prod_{i=1}^n (i + \lambda/b_1)} = \left(\frac{b_0}{b_1}\right)^n \frac{\Gamma(n+1)\Gamma(1+\lambda/b_1)}{\Gamma(n+1+\lambda/b_1)},$$

where $\Gamma(\cdot)$ is the gamma-function. The last expression represents, apart from the scaling factor $(b_0/b_1)^n$, the nth moment of a β-distribution with parameters 1 and λ/b_1. (On the β-distribution, see e.g. Johnson, Kotz and Balakrishnan (1995, ch. 25).) Since the β-distribution is determined by its moments, we conclude that, for $\hat{b}_2 = 1$, $\hat{u}$ has the asymptotic representation $\hat{u} = \left(\frac{b_0}{b_1}\right)^n X$, where $X \sim Beta(1, \lambda/b_1)$. When $\hat{b}_2 \neq 1$, we therefore obtain a generalized β-distribution which, to the best of our knowledge, has not been encountered before. Analyzing its properties in detail will have to be done in future research. We are indebted to Christian Kleiber for pointing this out to us. For related aspects, see Kleiber and Kotz (2003).

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Appendix

An additional Referees' appendix is available upon request.

Comments on "Volatility, Welfare and Taxation"

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This paper belongs to an important literature that attempts to integrate growth and volatility in order to understand the uneven nature of the economic growth process. Though the idea of growing in cycles was only recently formalized by Matsuyama (1999) it has been present in the literature on economic development for some time (Hirschman (1958). Endogenous growth and cycles have been modeled jointly using two approaches: the "innovation view" (e.g. Francois-Lloyd-Ellis (2003), Walde (2004) and this paper), and the "credit view" (e.g. Ranciere, Tornell and Westermann (2003)).

This paper is motivated by the fact that a large share of cross-country differences in volatility among OECD countries has not been explained. The authors suggest that differences in endogenous innovation cycles may explain this variation in output volatility. The core of the paper consists of an analysis of the relationship between two sources of volatility: the invention of new technologies and different tax policies.

The authors provide a very simple "Solowian" representation of a stochastic growth model with new inventions endogenous to the model. The economy evolves through a succession of research and capital accumulation phases. Research fosters discoveries that lead to the introduction of new prototypes. Once a new invention arrives, there is an abrupt increase in productivity which induces capital accumulation and a gradual decrease in the marginal productivity of capital that brings the economy back to a steady state growth path. This simple representation enables us to compute the long run expected growth, the long run expected welfare and the mean and volatility of the cyclical growth components**.**

The authors consider four tax policies and their effects: taxation on income, consumption, wealth, and investment in R&D.

First, they analyze the effects of taxation on cyclical volatility. Cyclical volatility depends on three factors: the frequency of cycles, the amplitude of cycles and smoothness of the cycles. Taxation can both have stabilizing or destabilizing effects. Taxing R&D reduces innovation and subsequently the frequency of cycles too. Capital taxation increases volatility through its impact on amplitude and smoothness while wealth taxation has the opposite effect.

Second, the authors analyze effect of taxation on welfare. In this case, both the long run – the permanent component – and the short run – cyclical fluctuations – should be factored in. A natural question is whether there can be short run pains and long run gains. For instance, it seems that although capital taxation increases short run volatility, it also increases welfare.

My main questions are the following:

- What is the link between volatility and growth? How much does reducing volatility reduce the engine of development - growing through cycles -?
- Can we apply the model to the data, for instance for US over the decades 1980-2000 that have seen a reduction in aggregate output volatility?
- An empirical analysis will need to incorporate:
  – Changes in tax rates
  – Intensity of R&D
  – Arrival rate of new innovation

I also have some minor issues with the specificity of the innovation process. First, what happens if more innovation today increases the probability of innovation tomorrow? Second, how does the model translate into a multi-country world where we observe both innovation and imitations?.

Finally, I would like to suggest an alternative view based on my research on credit cycles in emerging economies (Ranciere, Tornell, Westermann (2003). The main question here is: Is it better to have volatility and high growth than no volatility and no growth. A contrasting example is India and Thailand. The latter experienced a boom-bust cycle punctuated by severe financial crisis and the former more stable financial conditions. Nevertheless, Thailand has grown on average much faster than India:

Credit: GDP per capita:
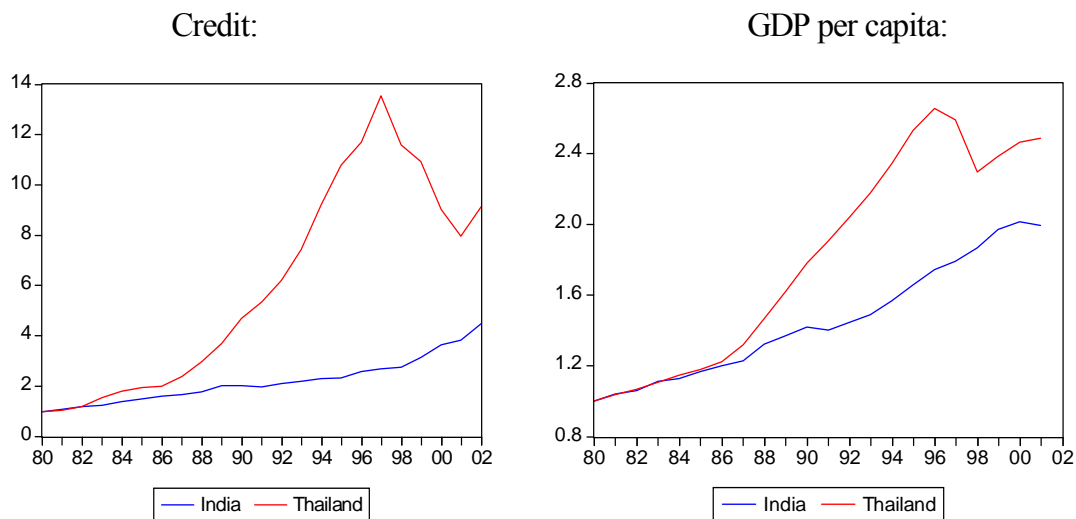
Note: The values for 1980 are normalized to one.

Credit: Real Bank Credit Growth (source: IFS and authors caluclation)

GDP per Capita: Real GDP per Capita (source: Worldbank Development Indicators)

These findings are rationalized in a two-sector endogenous growth model with asymmetric financial opportunities. That is the coexistence of financially unconstrained firms in the tradable sector and financially constrained firms in the non-tradable sectors. In such an economy, the introduction of bailout guarantees funded by domestic taxation give rise to two equilibria:

Safe Equilibrium	Risky Equilibrium
1. No-Crisis	1. Boom-Bust Cycles

2. Low Leverage	2. High Growth Phase
	   1. high leverage
	   2. high investment

3. Low Investment	3. Crisis Episode
	   1. Credit Crunch
	   2. Bailout Foreign Investors

4. Low Growth	

Under certain conditions, growth and welfare are higher in the risky equilibrium. The reason is the presence of financial bottlenecks in the constrained sector that limit the development of the economy as a whole. Bailout guarantees redistribute from the non-constrained sector to the constrained sector for their mutual benefits.

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Investment Cycles

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Abstract

It is common amonst macroeconomists to view aggregate investment fluctuations as a rational response to fluctuating incentives, driven by exogenous movements in total factor productivity. However, this approach raises a number of questions. Why treat investments in physical capital as endogenous, while treating those in intangible capital as exogenous? Relatedly, why would productivity changes exhibit such strong co–movement across diverse sectors of the economy, and why are the short–run, empirical relationships between aggregate investment and measures of investment incentives, such as Tobin's Q, so weak? We address these and other related issues using a model of "implementation cycles" that incorporates physical capital. In doing so, we demonstrate the crucial role played by endogenous innovation and incomplete contracting, inherent to the process of creative destruction.

1 Introduction

Fluctuations in the aggregate investment rate are a central feature of the business cycle. As Figure 1 illustrates, the rate of U.S. investment in fixed, non–residential assets displays regular, and recurring patterns of activity over time.[1] According to Keynes (1936), investment fluctuations played a central *causal* role in driving business cycles. He argued that the co–movement of investment across diverse sectors of the economy was exogenously driven by a kind of mass psychology which he termed "animal spirits".[2] More recently, economists have attempted to understand movements in aggregate investment as an optimal response to measurable incentives. In the canonical Real Business Cycle (RBC) model, for example, fluctuations in aggregate investment are driven by exogenous fluctuations in total factor productivity (TFP) that change the incentives to produce investment goods relative to consumption goods. However, this increasingly standard approach raises a number of conceptual and quantitative questions.

First, why treat investment in tangible, physical capital as an endogenous response to incentives, while implicitly treating shifts in the production function as exogenous? Many of these shifts result from costly investments in intangible capital, which seem just as likely to respond endogenously to incentives. For example, re–organization of firms may require a costly re–allocation of managerial effort that will only take place if the anticipated returns are sufficiently high. Over the past 15 years there have been considerable advances in understanding the potential and actual role of endogenous innovation on long run growth, but this has had relatively little influence on business cycle research.[3]

Second, why do these apparent shifts in TFP take place in such a clustered fashion across diverse sectors of the economy? Assuming from the outset that TFP movements affect all sectors symmetrically seems no better on a conceptual level than directly assuming that investment co–moves across sectors because of animal spirits.[4] One possibility is that these shifts are the result of general purpose technologies (GPTs) which affect all sectors. However, there is little evidence supporting this idea at business cycle frequencies.[5] As Lucas (1981) reasons, while productivity

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[1] The investment rate fell during all post–war, NBER–dated recessions (the shaded regions in Figure 1) and typically rose during expansions. The only exceptions were around 1967 and 1987, which saw large declines in investment but aggregate slowdowns that were not dated as NBER recessions.

[2] One modern incarnation of this idea is to model animal spirits as purely exogenous, but self–fulfilling changes in expectations (see e.g. Farmer and Guo 1994). In this case, investment is optimal but the aggregate incentives are stochastically driven by "sunspots".

[3] One clue to the potential importance of viewing technology shifts as, at least partially, endogenous comes from the work of Hall (1988) who finds that the Solow residual is significantly correlated with factors that do not seem likely to have a direct impact on technology.

[4] The RBC literature generally takes this clustering of productivity improvements as given, and focuses on the propagation mechanism.

[5] We discuss this literature in more detail in the following section.

shocks may be important at the firm level, it is not immediately obvious why they would be important for economy–wide aggregate output fluctuations.

Thirdly, if investment really is optimally determined, why is the short–term empirical relationship between aggregate investment and contemporaneous measures of investment incentives apparently so weak? In particular, while there is some evidence of a long run relationship, neither micro nor macro level empirical work has generally found a significant short–run relationship between investment and Tobin's Q — the ratio of the equity value of firms, to the book value of the capital stock.[6] As is well known, one cannot infer from this that investment is sub–optimal because Tobin's Q need not reflect the *marginal* incentives to invest,[7] and because equity values are likely to include the values of intangible, as well as tangible, capital.[8] But then the question arises as to what kind of relationship we should expect to observe between investment and *measurable* proxies of financial incentives over the business cycle.

Figure 1 is suggestive of some kind of relationship. Figure 1(a) shows the investment rate and Tobin's Q for the US between 1953 and 2003. Figure 1(b) shows the rate of change in the four–quarter moving average of each time series.[9] In general there appears to be a lead–lag relationship, with the investment rate most highly correlated with the value of Tobin's Q three to four quarters earlier. It is this observation that has led some investigators to specify an exogenous "time–to–plan" period in their quantitative analyses (see Section 2). However, the relationship is more complex than this. In particular, Tobin's Q appears to lead investment especially during the latter part of expansions and recessions, with Q falling several quarters before investment declines and rising several quarters prior to expansions.[10] During the early phases of expansions and recessions the two series exhibit a contemporaneous correlation.

A final conceptual issue is whether it is reasonable to view investment declines, and hence recessions, as being driven by bad technology outcomes? The recent RBC literature has demonstrated that, in the presence of capital and labor market rigidities, it is not necessary to have *negative* shocks to TFP in order to generate downturns in output (see King and Rebelo, 2000). However, the traditional Keynesian view that recessions largely result from sharp declines in aggregate investment demand, driving production below capacity, seems consistent with the beliefs of policy–makers and many in the private sector. The implications of such views seem worthwhile to at least explore in a formal framework.

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[6] First suggested by Tobin (1968) and Brainard and Tobin (1969). See Cabellero, 1999 for a recent survey.

[7] As shown by Abel (1979) and Hayahsi (1982), when there are adjustment costs, marginal and average Q need not be equal.

[8] See Hall (2001b).

[9] Similar figures appear in Cabellero (1999).

[10] There are a number of rationalizations of this behavior in the literature. We discuss these in the next section.
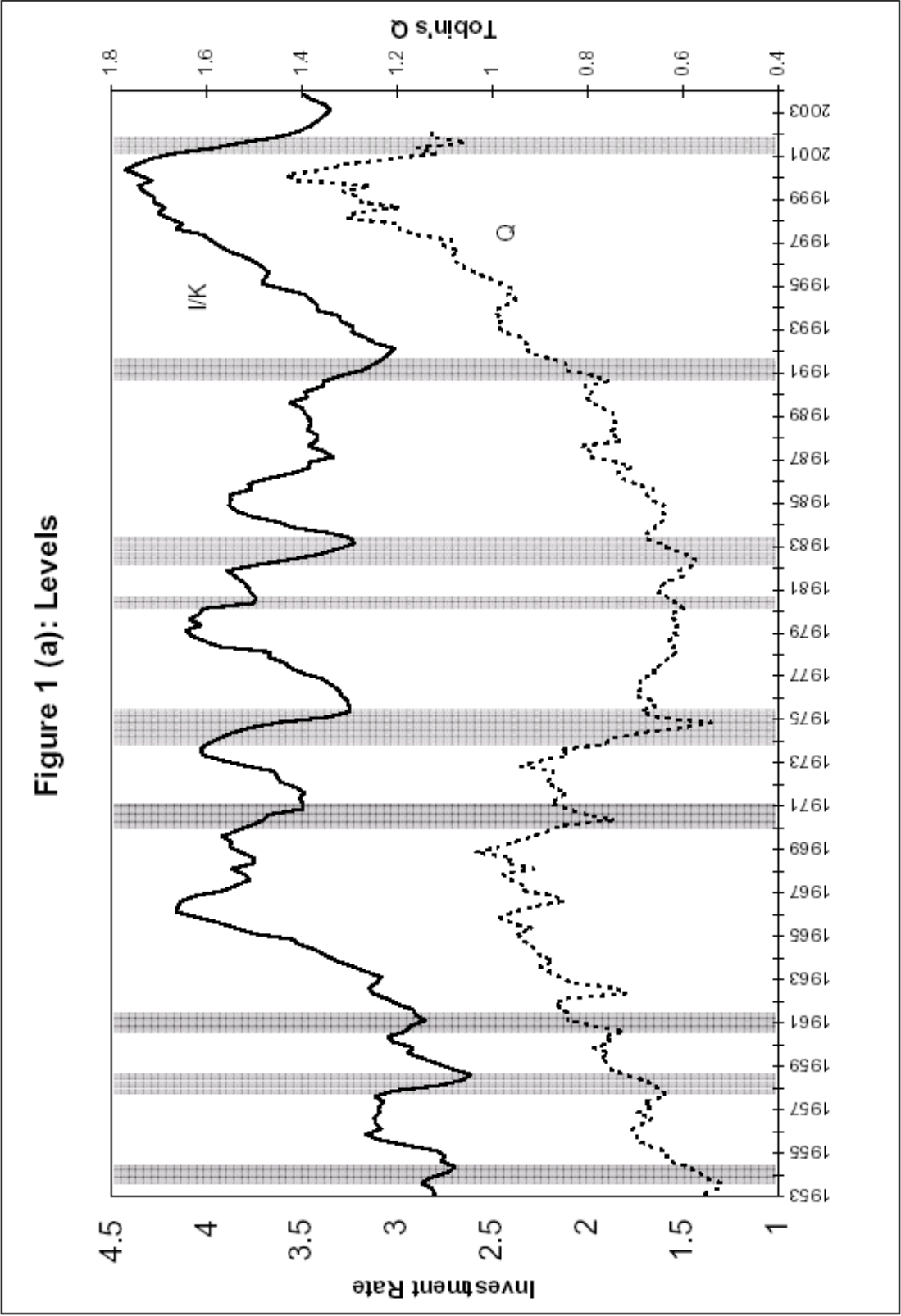
Figure 1 (a): Levels
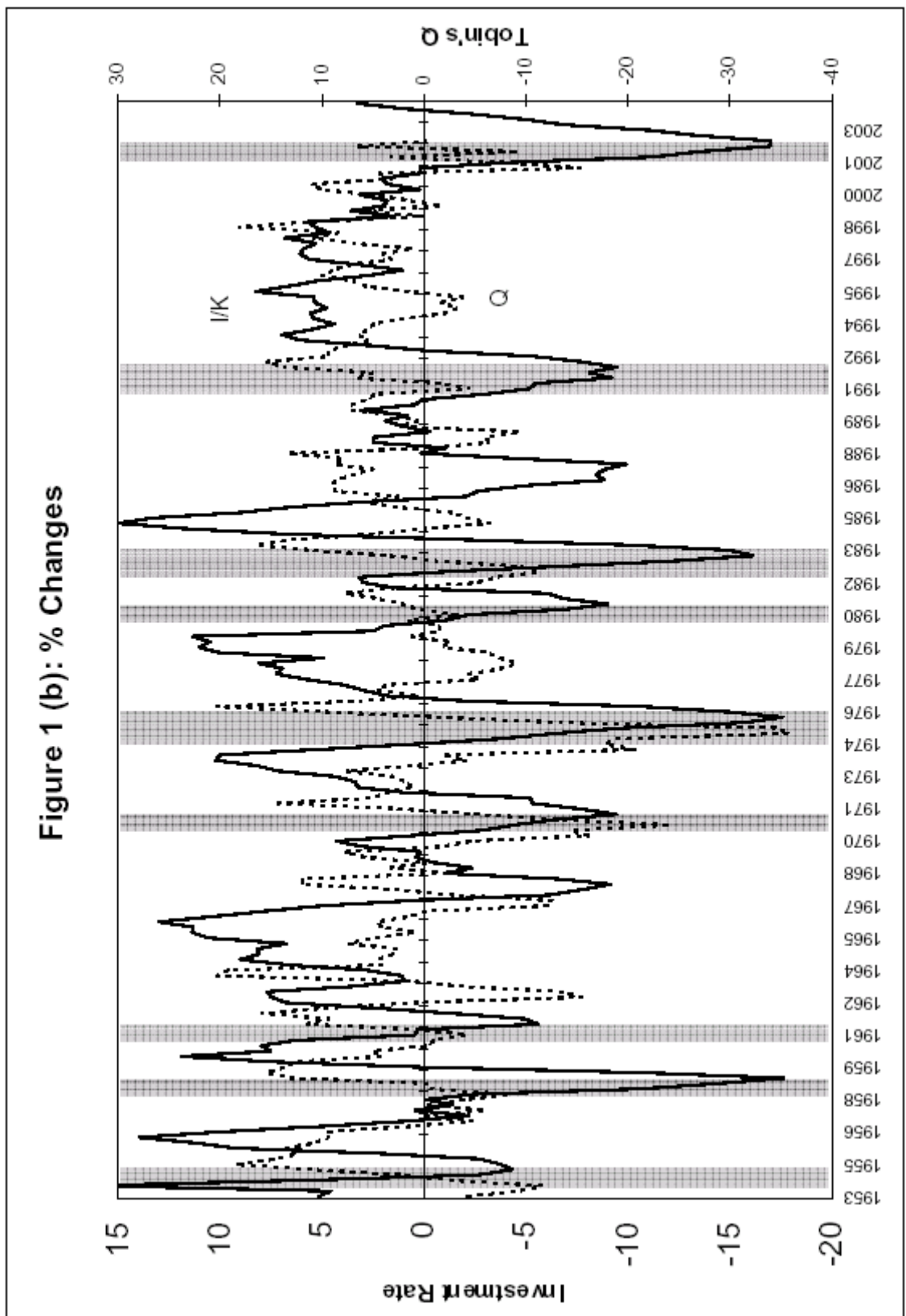
Figure 1 (b): % Changes

In this article, we take the view that in order to understand the relationships between aggregate investment, productivity and the stockmarket over the business cycle, one must deal head-on with the source and timing of productivity fluctuations, the reasons for sectoral co–movement, and the apparent delay in investment in response to incentives. Our starting point for thinking about these issues is Shleifer's (1986) model of "implementation cycles". He shows that in the presence of imperfect competition, the implementation of a productivity improvement by one firm may increase the demand for anothers' products by raising aggregate demand. This induces innovators, who anticipate short-lived profits due to imitation, to delay the implementation of their own innovation until others implement, thereby generating self–enforcing booms in aggregate activity. Though capable of generating both co–movement and delay in implementation, Shleifer's model cannot, however, serve as a framework for understanding investment cycles. This is because the sectoral co–movement that he establishes is not robust to the introduction of capital or, in fact, *any* storable commodity. Anticipating a boom, producers would produce early when wages are low, store the output, and sell in the boom when prices are high, thus undermining the cycle.[11]

Francois and Lloyd-Ellis (2003) show how a similar process of endogenous clustering can arise due to the process of "creative destruction" familiar from Schumpeterian endogenous growth models. Like imitation, potential obsolescence limits incumbency and provides incentives to cluster implementation. However, in their framework, where productive resources are needed to generate new innovations, allowing for the possibility of storage does not rule out clustering, and in fact yields a *unique* cyclical equilibrium.[12] Moreover, because this costly innovation tends to be bunched just before a boom, it causes a downturn in aggregate output (even if the measure of GDP includes this investment).[13] Because of its ability to accommodate storage, this framework is more promising as a vehicle for understanding investment. However, the addition of physical capital which is completely flexible after being installed still undermines their cyclical equilibrium.

Full flexibility of installed physical capital is, however, at odds with recent evidence on investment behavior. In particular, there is considerable direct evidence that many types of physical investment are not reversible and feature inflexible characteristics once installed (see Ramey and Shapiro, 2001, Kasahara, 2002). Doms and Dunne (1993) also document the considerable "lumpiness" of plant level investments, while Cabellero and Engel (1998) demonstrate the high skewness and kurtosis observed in aggregate investment data. Moreover, the variation in "shiftwork" over

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[11]Shleifer's model is also subject to a number of other criticisms including the fact that there are no downturns and that there is a continuum of multiple cyclical equilibria, making the predictions of the model rather imprecise. Moreover, while the timing of implementation booms is endogenous, the innovations themselves arise exogenously.

[12]Shleifer (1986) assumes that innovations arise exogenously. When innovation is endogenous, growth is intimately related to the business cycle.

[13]Our interpretation of innovation is not R&D, but rather labour–intensive activities such as re–organization or the development of new ideas. While capital–intensive R&D is often found to be mildly procyclical, Francois and Lloyd–Ellis (2003), discuss evidence that other kinds of innovative activities are counter–cyclical.

the business cycle (see Bresnahan and Ramey 1994, Hammermesh 1989 and Mayshar and Solon, 1993) is consistent with some degree of inflexibility in factor proportions, since it implies that capital is being used less intensively during recessions than is optimal ex ante.

Here we introduce physical capital into the framework developed by Francois and Lloyd-Ellis (2003) in order to understand the business–cycle relationships between investment, productivity and the stockmarket.[14] We model production in a way which captures, as simply as possible, the inflexibility of installed capital relative to uninstalled capital. Specifically, we assume that, once installed, capital becomes irreversible, lumpy and sector–specific. Moreover, we assume that while the ratio of utilized capital to labor hours can be increased as output expands and more capital is added, it cannot be adjusted as output contracts and no new capital is being added.[15] Instead we assume that capital utilization is variable, so that contractions are associated with under–utilization. Our assumptions are similar in effect to the assumption of "putty–clay" production technology.[16]

Along the equilibrium growth path that we study, expansions are triggered by the implementation of accumulated productivity improvements. These improvements arrive stochastically across sectors during the recession, gradually increasing firm values, so that Tobin's Q starts to rise prior to the boom. However, since firms optimally choose to delay implementation, investment lags behind the increase in Q. During the expansion, capital is accumulated continuously and smoothly. At its end, the economy enters a recessionary phase where capital ceases to be accumulated. As demand falls, the fact that the ratio of utilized capital to labor hours is fixed implies that producers continuously reduce capital utilization throughout the recession. This anticipated decline in demand causes Tobin's Q to fall during the preceding investment boom — thus Q leads investment into the recession too.

Although our focus here is on the nature of investment cycles, our results are delivered in a framework where the economy's aggregate fluctuations arise endogenously. There are no simple causal relationships between the variables of interest studied here, instead all of these are general equilibrium implications arising from the growth process. Expansions are "neoclassical", supply–side phenomena which directly raise both *potential* output, through the delayed implementation of

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[14]Using the simpler model of Shleifer (1986) as a vehicle for this analysis will not work, even with inflexible capital. Storage of *any* kind undermines the clustering of activity there. The endogenous innovation, present in Francois and Lloyd-Ellis (2003), is a necessary part of the equilibrium.

[15]To fix ideas, consider the example of a car manufacturer. As the demand for cars expands, it can add new equipment to a given workforce working at maximum capacity, thereby raising the capital–labour ratio and increasing labour productivity. However, as output contracts the manufacturer retains the installed capital (due to irreversibility), but uses it less intensively and reduces the number of shifts in proportion, so that the ratio of utilized capital to labour hours remains fixed. The lumpiness assumption implies that the manufacturer cannot rent out the capital to another car manfacturer during breaks between shifts.

[16]We discuss the relationship to that literature in Section 2.

productivity improvements, and *actual* output through increased production labor, re–utilization of installed capital and subsequent capital accumulation. Recessions are "Keynesian" demand–side contractions during which actual output falls below its potential, investment slows, and some capital resources are left under–utilized. These reductions in aggregate demand are an equilibrium response to the anticipated future expansion, as effort shifts into long–run growth promoting activities, and out of current production.[17]

A key feature of our model is that the owners of physical capital and the owners of intangible capital are distinct entities (e.g. banks and entrepreneurs). In our baseline model, we allow capitalists to offer a sequence of future prices per unit of *utilized* capital that they can *commit* to ex ante. During expansions, threat of entry from replacement capitalists induces the incumbent capitalist to offer a capital price sequence whose present value is just sufficient to cover the cost of the capital. However, during downturns, the competition faced by incumbent capitalists is diminished and, if they could, they would raise their price above the competitive level that they had originally offered. By assuming that incumbent capitalist are committed to prices offered before the downturn occurs, we effectively rule out such opportunistic behavior. In an extended version of the model (Section 9) we show that the same outcomes can be supported through endogenous, incomplete contracts.[18]

The paper proceeds as follows: Section 2 discusses the relationship between this paper and others in the literature. Section 3 sets up the basic model and Section 4 posits and describes the cyclical growth path. Section 5 develops the implications for the movement of key aggregates and prices through the posited cycle. Section 6 sets up the key existence conditions and Section 7 characterizes the stationary cyclical growth path. Section 8 explores the main implications of the cycle and Section 9 shows that our results are robust to allowing a greater range of contracting possibilities. Section 10 concludes. All proofs are in the Appendix.

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[17]Here we are assuming that all labour is skilled and is mobile across sectors. As we discuss in our conclusion, introducing unskilled labour with putty–clay production would also result in unemployment during recesions. A fuller treatment of unemployment, job creation, and destruction at cyclical frequencies is contained in a companion paper; Francois and Lloyd-Ellis (2004). That paper marries the Schumpeterian approach to productivity improvements with efficiency wages and job creation and destruction at cyclical frequencies. That paper abstracts from capital accumulation and investment at cyclical frequencies which are the focus here.

[18]The treatment of entrepreneurs and capital owners as distinct and subject to contracting limitations shares some features with Caballero and Hammour (2004). They allow no contracting at all so that surpluses are divided by Nash bargaining ex post. In contrast, we allow for some enforceable commitments – to price throughout, and quantity in Section 9. The assumed limits in contracting between these parties are an important source of inefficiency in both papers.

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2 Relationship to the Previous Literature

A standard way to think about the relationship between investment and Tobin's Q (common in the RBC literature) is to abstract from issues regarding intangibles, but to assume that capital is subject to quadratic costs of adjustment. The prediction of such a model is that investment should exhibit a positive contemporaneous relationship with Tobin's Q. Adding additional constraints such as a "time to build" assumption helps to smooth out the response of investment to measured incentives, but this alone cannot capture the observed delay of 3 to 4 quarters. In order to capture the lead–lag relationship discussed above, Christiano and Todd (1996), Bernanke, Gertler and Gilchrist (1999) and Christiano and Vigfusson (2001) also introduce a notion of "time to plan" — a fixed time period between the date when the decision to invest more (less) is made and the date when the actual funds are allocated.[19] Although this "does the job" in some sense, the assumption is somewhat ad hoc. Our approach offers an alternative rationalization that endogenizes the delay as a result of strategic timing decisions.

A second common approach to thinking about the relationship between Tobin's Q and investment emphasizes the role of intangibles in affecting the economy–wide value of firms. Hall (2001b), Hobijn and Jovanovic(2001) and Laitner and Stolyarov (2003), for example, all emphasize the long run implications of the IT revolution, the anticipation of which is dated to the early 1970's. The idea is that the stock market moved immediately with the arrival of the information, but investment was delayed until the 1990s.[20] Laitner and Stolyarov (2003) emphasize the capital and knowledge obsolescence caused by the arrival of such a general purpose technology (GPT). However, while their framework is applicable to long–term cycles, there is little evidence supporting the arrival of GPTs at business cycle frequencies (see Jovanovic and Lach, 1998, and Andolfatto and Macdonald, 1998).[21]

Our model incorporates the role of *both* knowledge capital and adjustment costs in determining the relationship between investment and Tobin's Q over the business cycle. With endogenous innovation, of course, a component of firm values must reflect the returns to intangible investments. In addition, our assumptions regarding capital can be viewed as reflecting a form of asymmetric

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[19]A more subtle avenue is explored by Wen (1998) who shows that a time to build framework with short lags in the production of capital can generate endogenously long lags in capital formation. This works through induced increases in demand for investment goods that arise after the initial productivity shock. He demonstrates that this induced demand channel increases the propagation of shocks and can quantitavely match seven year length business cycles provided there exist other factors able to generate high elasticity in investment good production.

[20]Beaudry and Portier (2003) document a lead-lag relationship between stock market values and productivity using post-war US data. The "news" shock which they identify — rising stock values but productivity increases with a lag — is also consistent with the underlying process of innovation and implementation that we establish here.

[21]Indeed, Laitner and Stolyarov (2003) cite evidence suggesting there have only been seven major technological innovations of this kind identified in the last 200 years.

adjustment costs (see also Cabellero, 1999). When expanding, capital adjustment is unimpeded but, once installed, capital is prohibitively costly to adjust and cannot be converted into a consumption good, nor into another capital good with different capital-labor intensity. In fact, our assumptions regarding the ex post inflexibility of capital are similar to those of the "putty-clay" model (Johansen, 1959), except that here capital is not vintage–specific and is infinitely lived.[22] As in the putty-clay model, however, the irreversibility we assume implies a tight connection between changes in demand and changes in employment and capacity utilization. Our assumption that investments are lumpy, in that they cannot be partly dismantled and used elsewhere is also consistent with micro evidence (see Cooper, Haltiwanger and Power, 1999).

Most previous work on endogenous cycles and growth has been restricted to single sector settings.[23] These works cannot be translated readily into a multi-sector setting because they include no force generating co-movement. One exception is the model developed by Matsuyama (1999, 2001)[24] who, like Shleifer (1986), emphasizes the role of short–lived monopoly power due to exogenous imitation. The cycles that arise in his model do not depend on delay to generate cyclical behavior, and are thus robust to capital accumulation through the cycle. However, Matsuyama's framework is more suited to understanding longer–term movements in the *nature* of growth, rather than business cycle fluctuations.[25] In particular, there is no phase of his cycle that could be called a recession: production and consumption never decline, and capital is always fully utilized.[26]

3 The Model

3.1 Assumptions

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[22] Fuss (1977) and Gilchrist and Williams (2000) present evidence supporting a putty-clay view of capital.

[23] Jovanovic and Rob (1990), Cheng and Dinopolous (1992), Helpman and Trajtenberg (1998), Li (2000), Aghion and Howitt (1998), Evans, Honkephoja and Romer (1998) and Walde (2001).

[24] Another exception is Francois and Shi (1999), but that model inherits the lack of robustness to storage in Shleifer (1986).

[25] Indeed, Matsuyama is careful to apply his model to longer term issues such as the US productivty slowdown.

[26] Morover the innovative process is capital intensive, suggesting R&D plays a central role.
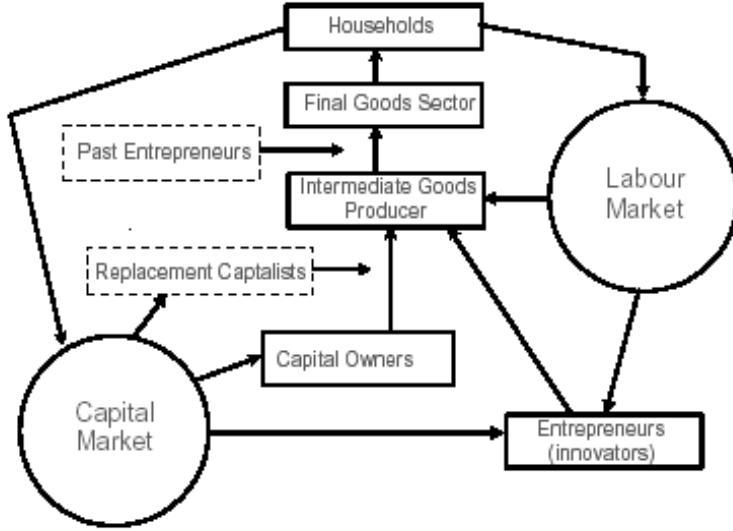
Figure 1: The Structure of the Economy

The structure of the economy is illustrated in Figure 1. There is no aggregate uncertainty. Time is continuous and indexed by $t \geq 0$. The economy is closed and there is no government sector. The representative household has isoelastic preferences

$$U(t) = \int_t^\infty e^{-\rho(\tau - t)} \frac{C(\tau)^{1-\sigma} - 1}{1 - \sigma} d\tau \tag{1}$$

where ρ denotes the rate of time preference and σ represents the inverse of the elasticity of intertemporal substitution. The household maximizes (1) subject to the intertemporal budget constraint

$$\int_t^\infty e^{-[R(\tau) - R(t)]} C(\tau) d\tau \leq S(t) + \int_t^\infty e^{-[R(\tau) - R(t)]} w(\tau) d\tau \tag{2}$$

where $w(t)$ denotes wage income, $S(t)$ denotes the household's stock of assets (firm shares and capital) at time t and $R(t)$ denotes the discount factor from time zero to t. The population is normalized to unity and each household is endowed with one unit of labor hours, which it supplies inelastically.

Final output can be used for the production of consumption, $C(t)$, investment, $\dot{K}(t)$, or can be stored at an arbitrarily small flow cost of $\nu > 0$ per unit time. It is produced by competitive firms according to a Cobb–Douglas production function utilizing a continuum of intermediates, x_i, indexed by $i \in [0, 1]$:

$$C(t) + \dot{K}(t) \leq Y(t) = \exp\left(\int_0^1 \ln x_i(t) di \right). \tag{3}$$

For simplicity we also assume that there is no physical depreciation. Intermediate i is purchased from an intermediate producer at price p_i. Intermediates are completely used up in production,

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but can be produced and stored for later use. Incumbent intermediate producers must therefore decide whether to sell now, or store and sell later at the flow storage cost ν.

Output of intermediate i depends upon the state of technology in sector i, $A_i(t)$, the stock of installed capital, $K_i(t)$, the variable rate at which that capital is utilized, $\lambda_i(t) \leq 1$, and labor hours, $L_i(t)$, according to the following production technology:

$$x_i(t) = \begin{cases} K_i(t)^\alpha \left[A_i(t)L_i(t)\right]^{1-\alpha} & \text{if } x_i(t) \geq x_i(z) \\ K_i(z)^\alpha \left[A_i(t)L_i(z)\right]^{1-\alpha} \min\left[\lambda_i(t), \frac{L_i(t)}{L_i(z)}\right] & \text{if } x_i(t) < x_i(z). \end{cases} \tag{4}$$

Here

$$z = \arg\max_{s<t} \{x_i(s)\} \tag{5}$$

is the date at which the last increment to capital was installed and $\{K_i(z), L_i(z)\}$ is the capital–labor combination chosen at that date. Labor hours are perfectly mobile across sectors but, installed capital, $K_i(t)$, is sector–specific, irreversible and non-divisible, so that any part of it that is not utilized cannot be used elsewhere (i.e. $\dot{K}_i \geq 0$). We denote the level of utilized capital by $K_i^u(t) = \lambda(t)K_i(t)$.

An implication of this structure is that during an expansion, when new capital is being built, a firm's ability to substitute between capital and labour is represented by Cobb–Douglas production isoquants (curved in Figure 2). However during a contraction, when the firm produces below capacity, its production possibilities are represented by Leontief production isoquants whose kink points lie along a ray from the origin to the chosen point on the full-capacity isoquant. In such a situation, the installed capital will optimally be used less intensively in proportion to the labor hours allocated to production. One interpretation of this is that there are fewer shifts.
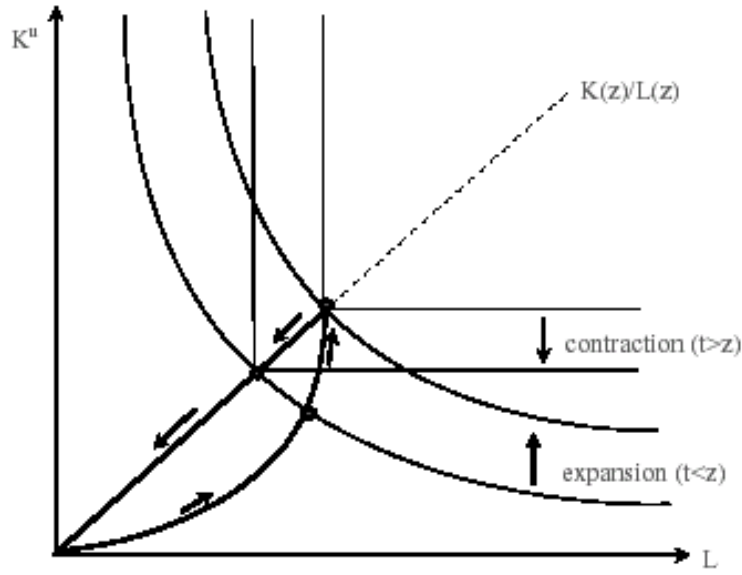
Figure 2: Implications of Inflexibility of Installed Capital

3.1.1 Innovation

The innovation process is exactly as in the quality–ladder model of Grossman and Helpman (1991). Competitive entrepreneurs in each sector allocate labor effort to innovation, and finance this by selling equity shares to households. The probability of success in instant t is $\delta H_i(t)$, where δ is a parameter, and H_i represents the labor hours allocated to innovation in sector i. At each date, entrepreneurs decide whether or not to allocate labor hours to innovation, and if they do so, how much. The aggregate labor hours allocated to innovation is given by $H(t) = \int_0^1 H_i(t)dt$.

New ideas and innovations dominate old ones by a factor e^γ. Successful entrepreneurs must choose whether or not to implement their innovation immediately or delay implementation until a later date.[27] Once they implement, the associated knowledge becomes publicly available, and can be built upon by rivals. However, prior to implementation, the knowledge is privately held by the entrepreneur.[28] We let the indicator function $Z_i(t)$ take on the value 1 if there exists a successful innovation in sector i which has not yet been implemented, and 0 otherwise. The set of instants in which new ideas are implemented in sector i is denoted by Ω_i. We let $V_i^I(t)$ denote

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[27]We adopt a broad interpretation of innovation. Recently, Comin (2002) has estimated that the contribution of measured R&D to productivity growth in the US is less that 1/2 of 1%. As he notes, a larger contribution is likely to come from unpatented managerial and organizational innovations.

[28]Even for the case of intellectual property, Cohen, Nelson and Walsh (2000) show that firms make extensive use of secrecy in protecting productivity improvements. Secrecy likely plays a more prominent role for entrepreneurial innovations, which are the key here.

the expected present value of profits from implementing a success at time t, and $V_i^D(t)$ denote that of delaying implementation from time t until the most profitable future date.

3.1.2 The Market for Fixed Capital

Entrepreneurs cannot simply "sell" their idea to capital owners, but must be involved in its implementation. We assume entrepreneurs have insufficient wealth to purchase the capital stock needed to implement, and hence must effectively rent it from capital owners (e.g. banks). In the basic version of our model, we assume that the capitalist is able to offer a rental price sequence *per unit of utilized capital* into the indefinite future $\{q_i(\tau)\}_{\tau=t}^{\infty}$. We assume that the price sequence represents a binding commitment that cannot be adjusted ex post. Under such a price sequence the present value of the capitalist's net income in sector i is therefore:

$$V_i^K(t) = \int_t^{\infty} e^{-[R(\tau)-R(t)]} \left[q_i(\tau) \lambda_i(\tau) K_i(\tau) - \dot{K}_i(\tau) \right] d\tau. \tag{6}$$

Since capital is sector specific, the price sequence that is offered in equilibrium is determined by the possibility of a "replacement capitalist" building an alternative capital stock to displace that of the current capital owner within the sector (see Figure 1). If the threat of entry were always sufficient to induce competitive pricing,[29] there would be no need for long–term price commitments. In the cyclical equilibrium that we study, however, the threat of entry is sufficient to lead to competitive pricing *only* during expansions. During contractions, replacement capitalists have reduced incentives for entry which, in the absence of price commitments, would allow incumbent capitalists to price gouge. Anticipating this, entrepreneurs demand binding price commitments from capital suppliers before entering the recession. A capital owner unwilling to provide such a commitment will be passed over in favor of a replacement capitalist who is.

It may seem unusual to assume that capital owners charge a rental price per unit of utilized rather than installed capital. This assumption simplifies the exposition considerably, by allowing us to decentralize the decisions of entrepreneurs and capital owners. In Section 9, we show that the equilibrium price sequences can be replicated as part of an endogenous, incomplete contracting equilibrium, in which contracts optimally specify the rental price of *installed* capital and the utilization rate.

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[29] In order to maintain competition in capital supply it will be assumed that, in the event of a competing capital stock being built, ties in tended prices are always broken in favour of the entrant. Due to storage costs, entry of replacement capital will imply scrapping of the pre-existing stock.

3.2 Definition of Equilibrium

Given initial state variables[30] $\{A_i(0), Z_i(0), K_i(0)\}_{i=0}^{1}$, an equilibrium for this economy consists of:

(1) sequences $\left\{\hat{p}_t(t), \widehat{q}_i(t), \hat{\lambda}_i(t), \hat{x}_i(t), \widehat{K}_i(t), \widehat{L}_i(t), \widehat{H}_i(t), \widehat{A}_i(t), \widehat{Z}_i(t), \widehat{V}_i^I(t), \widehat{V}_i^D(t), \widehat{V}_i^K(t)\right\}_{t \in [0,\infty)}$
for each intermediate sector i, and

(2) economy wide sequences $\left\{\widehat{Y}(t), \widehat{R}(t), \widehat{w}(t), \widehat{C}(t), \widehat{S}(t)\right\}_{t \in [0,\infty)}$
which satisfy the following conditions:

• Households allocate consumption over time to maximize equation (1) subject to the budget constraint, equation (2). The first–order conditions of the household's optimization require that

$$\widehat{C}(t)^\sigma = \widehat{C}(\tau)^\sigma e^{\widehat{R}(t) - \widehat{R}(\tau) - \rho(t-\tau)} \qquad \forall \ t, \tau, \tag{7}$$

and that the transversality condition holds

$$\lim_{\tau \to \infty} e^{-\widehat{R}(\tau)} \widehat{S}(\tau) = 0 \tag{8}$$

• Final goods producers choose intermediates, x_i, to minimize costs given prices p_i, subject to (3). The derived demand for intermediate i is

$$x_i^d(t) = \frac{Y(t)}{p_i(t)}. \tag{9}$$

• Intermediate goods producers choose combinations of utilized capital $K_i^u(t)$, and labour hours, $L_i(t)$ to minimize costs given factor prices, subject to (4):

$$K_i^u(t) = \frac{x_i(t)}{A_i^{1-\alpha}(t)} \left[\left(\frac{\alpha}{1-\alpha}\right) \frac{w(t)}{q_i(t)}\right]^{1-\alpha} \quad \text{and} \quad L_i(t) = \frac{x_i(t)}{A_i(t)^{1-\alpha}} \left[\left(\frac{1-\alpha}{\alpha}\right) \frac{q_i(t)}{w(t)}\right]^{\alpha}. \tag{10}$$

• The unit elasticity of demand for intermediates implies that limit pricing at the unit cost of the previous incumbent is optimal. It follows that

$$p_i(t) = \frac{q_i(t)^\alpha w(t)^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha} e^{-(1-\alpha)\gamma} A_i^{1-\alpha}(t)} \qquad \forall t \tag{11}$$

The resulting instantaneous profit earned in each sector is given by

$$\pi(t) = (1 - e^{-(1-\alpha)\gamma}) Y(t). \tag{12}$$

• Capital owners buy final output in the form of new capital if and only if $K_i^u(t) = K_i(t)$ and $\dot{K}_i^u(t) > 0$ and rent it to intermediate producers.

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[30]Without loss of generality, we assume no stored output at time 0.

- Labor markets clear:

$$\int_0^1 \widehat{L}_i(t)di + \widehat{H}(t) = 1 \qquad (13)$$

- Arbitrage trading in financial markets implies that, for all assets that are held in strictly positive amounts by households, the rate of return between time t and time s must equal $\frac{\widehat{R}(s) - \widehat{R}(t)}{s-t}$.

- Free entry into innovation — entrepreneurs select the sector in which they innovate so as to maximize the expected present value of the innovation, and

$$\delta \max[\widehat{V}_i^D(t), \widehat{V}_i^I(t)] \leq \widehat{w}(t), \quad \widehat{H}_i(t) \geq 0 \qquad \text{with at least one equality.} \qquad (14)$$

- At instants where there is implementation, entrepreneurs with innovations must prefer to implement rather than delay until a later date

$$\widehat{V}_i^I(t) \geq \widehat{V}_i^D(t) \quad \forall \, t \in \widehat{\Omega}_i. \qquad (15)$$

- At instants where there is no implementation, either there must be no innovations available to implement, or entrepreneurs with innovations must prefer to delay rather than implement:

$$\begin{aligned} \text{Either } \widehat{Z}_i(t) &= 0, & (16) \\ \text{or if } \widehat{Z}_i(t) &= 1, \ \widehat{V}_i^I(t) \leq \widehat{V}_i^D(t) \quad \forall \, t \notin \widehat{\Omega}_i. \end{aligned}$$

- Free entry into final output production.
- Free entry of replacement capital: $\widehat{V}_i^K(t) \leq \widehat{K}_i(t)$, where $\widehat{V}_i^K$ is the value of capital determined under the value maximizing sequence of price commitments.

4 The Posited Cyclical Growth Path

In this section, we informally posit a cyclical equilibrium growth path and the behavior of agents in the economy. We then detail the implications for investment, consumption and innovation.[31] In Section 5, we formally derive the implications of this behavior over each phase of the cycle, and Section 6 then demonstrates the consistency of the posited behavior of entrepreneurs and capitalists in an equilibrium steady state, and derives the conditions for existence.

Figures 3 and 4 depict the movement of key variables during the cycle. Cycles are indexed by the subscript v, and feature a consistently recurring pattern through their phases. The vth cycle features three distinct phases:

- The **expansion** is triggered by a productivity boom at time T_{v-1} and continues through subsequent capital accumulation, leading to continued growth in output, consumption and wages.

---

[31] There is a second equilibrium balanced growth path along which growth is constant and innovations are always implemented immediately. We chracterize this "standard" growth path in Appendix B.

Over this phase interest rates fall and investment declines. Since its productivity in manufacturing is high, no labor is allocated to innovation. As capital accumulates the returns to physical investment decline, while the return to innovation grows as the subsequent boom approaches. Eventually innovation and reorganization re-commence, drawing labor hours from production. Due to the rigidities of installed capital, the marginal product of capital drops to zero.

• The **contraction** thus starts with a collapse in fixed capital formation at time T_v^E. Intermediate producers experience a reduction in aggregate demand and cut back on the labour hours they employ in production. This labour effort is optimally re-allocated to relatively labor–intensive innovation and re–organization. Successful entrepreneurs find it optimal to delay implementation until the boom. Due to the rigidity of installed capital, labor's departure from production implies that capital is not fully utilized. Through the downturn the economy continues to contract through declining consumption expenditure, capital utilization falls and innovation and reorganization continue to increase.

• The **boom** occurs at an endogenously determined date, T_v, when the value of implementing stored innovations first exceeds the value of delaying their implementation. At that point, successful entrepreneurs implement, starting the upswing once again. The returns to production rise above those of innovation, drawing labor back into production. Returns to capital also rise with the new more productive technologies, so that capital accumulation recommences and the cycle begins again.
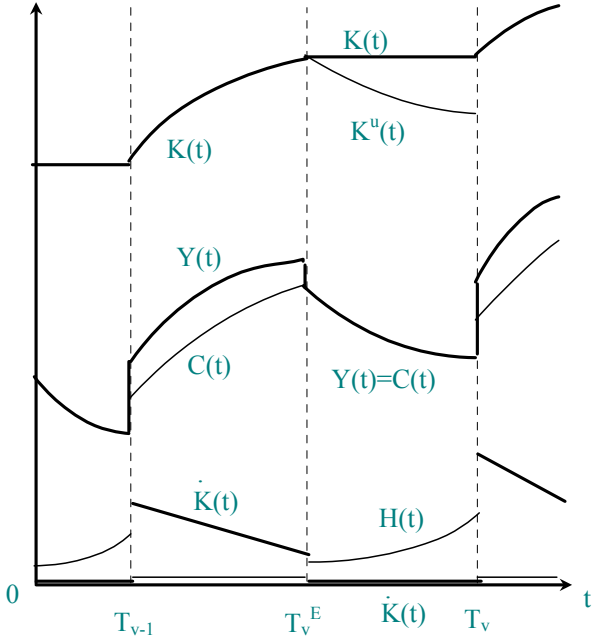
Figure 3: Evolution of Aggregates over the Cycle

16
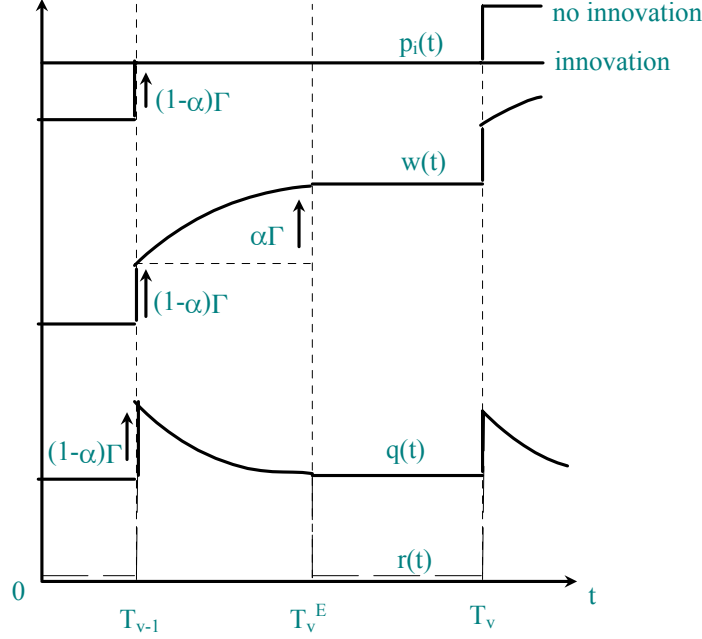
Figure 4: Evolution of Prices over the Cycle

4.1   Consumption

Since the discount factor jumps up at the boom, consumption exhibits a discontinuity during implementation periods. The optimal evolution of consumption from the beginning of one cycle to the beginning of the next is given by the difference equation

$$\sigma \ln \frac{C_0(T_v)}{C_0(T_{v-1})} = R_0(T_v) - R_0(T_{v-1}) - \rho\left(T_v - T_{v-1}\right). \tag{17}$$

where the 0 subscript is used to denote values of variables the instant after the implementation boom.[32]   Note that a sufficient condition for the boundedness of the consumer's optimization problem is that $\ln \frac{C_0(T_v)}{C_0(T_{v-1})} < R(T_v) - R(T_{v-1})$ for all v, or that

$$\frac{(1-\sigma)}{T_v - T_{v-1}} \ln \frac{C_0(T_v)}{C_0(T_{v-1})} < \rho \quad \forall\, v. \tag{18}$$

The discount factor used to discount from some time t during the cycle to the beginning of the next cycle is given by

$$\beta(t) = R_0(T_v) - R(t) = R_0(T_v) - R_0(T_{v-1}) - \int_{T_{v-1}}^{t} r(s)ds. \tag{19}$$

---

[32]Formally, for any variable $X(\cdot)$, we define $X(t) = \lim_{\tau \to t^-} X(\tau)$ and $X_0(t) = \lim_{\tau \to t^+} X(\tau)$.

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4.2 Innovation and Implementation

Let $P_i(s)$ denote the probability that, since time T_{v-1}, no entrepreneurial success has been made in sector i by time s. It follows that the probability of there being no entrepreneurial success by time T_v conditional on there having been none by time t, is given by $P_i(T_v)/P_i(t)$. Hence, the value of an incumbent firm in a sector where no entrepreneurial success has occurred by time t during the vth cycle can be expressed as

$$V_i^I(t) = \int_t^{T_v} e^{-\int_t^\tau r(s)ds} \pi_i(\tau)d\tau + \frac{P_i(T_v)}{P_i(t)} e^{-\beta(t)} V_{0,i}^I(T_v). \tag{20}$$

The first term here represents the discounted profit stream that accrues to the entrepreneur with certainty during the current cycle, and the second term is the expected discounted value of being an incumbent thereafter.

Lemma 1 *In a cyclical equilibrium, successful entrepreneurs can credibly signal a success immediately and all entrepreneurship in their sector will stop until the next round of implementation.*

Unsuccessful entrepreneurs have no incentive to falsely announce success. As a result, an entrepreneur's signal is credible, and other entrepreneurs will exert their efforts in sectors where they have a better chance of becoming the dominant entrepreneur.

In the cyclical equilibrium, entrepreneurs' conjectures ensure no more entrepreneurship in a sector once a signal of success has been received, until after the next implementation. The expected value of an entrepreneurial success occurring at some time $t \in \left(T_v^E, T_v\right)$ but whose implementation is delayed until time T_v is thus:

$$V_i^D(t) = e^{-\beta(t)} V_{0,i}^I(T_v). \tag{21}$$

In the cyclical equilibrium, such delay is optimal; i.e. $V_i^D(t) > V_i^I(t)$ throughout the contraction. Successful entrepreneurs are happier to forego immediate profits and delay implementation until the boom in order to ensure a longer reign of incumbency. Since no implementation occurs during the cycle, by delaying, the entrepreneur is assured of incumbency until at least T_{v+1}. Incumbency beyond that time depends on the probability that there has not been another entrepreneurial success in that sector up until then.[33]

The symmetry of sectors implies that entrepreneurial effort is allocated evenly over all sectors that have not yet experienced a success within the cycle. This clearly depends on some sectors

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[33] A signal of further entrepreneurial success submitted by an incumbent is not credible in equilibrium because incumbents have incentive to lie to protect their profit stream. No such incentive exists for entrants since, without a success, profits are zero. Note also that the reason for delay here differs from Shleifer (1986) where the length of incumbency is exogenously given.

not having already received an entrepreneurial innovation, an equilibrium condition that will be imposed subsequently (see Section 6). Thus the probability of not being displaced at the next implementation is

$$P_i(T_v) = \exp\left(-\int_{T_v^E}^{T_v} \widetilde{H}_i(\tau)d\tau\right), \tag{22}$$

where $\widetilde{H}_i(\tau)$ denotes the quantity of labor that would be allocated to entrepreneurship if no entrepreneurial success had occurred prior to time τ in sector i. The amount of entrepreneurship varies over the cycle, but at the beginning of each cycle all industries are symmetric with respect to this probability: $P_i(T_v) = P(T_v) \ \forall i$.

5 The Three Phases of the Cycle

5.1 The (Neoclassical) Expansion

During the expansion the economy's dynamics are essentially identical to those of the Ramsey model with no technological change:[34]

Proposition 1 : *During the expansion, capital and consumption evolve according to:*

$$\frac{\dot{C}(t)}{C(t)} = \frac{\alpha e^{-(1-\alpha)\gamma}\overline{A}_{v-1}^{1-\alpha}K(t)^{\alpha-1} - \rho}{\sigma} \tag{23}$$

$$\dot{K}(t) = \overline{A}_{v-1}^{1-\alpha}K(t)^{\alpha} - C(t). \tag{24}$$

To understand this, observe that between implementation periods, consumption satisfies the familiar differential equation:

$$\frac{\dot{C}(t)}{C(t)} = \frac{r(t) - \rho}{\sigma}, \tag{25}$$

where $r(t) = \dot{R}(t)$. As long as utilized capital is anticipated to grow, capitalists never acquire more capital than is needed for production, so that $K_i^u(t) = K_i(t)$. The existence of potential replacement capitalists implies that capital owners cannot earn excess returns on marginal units, so that $q_i(t) = q(t) = r(t)$. It follows that all firms choose the same capital–labour ratio and capital is rented at a competitive price equal to its marginal product net of profits to the entrepreneur:

$$r(t) = q(t) = \alpha e^{-(1-\alpha)\gamma}\overline{A}_{v-1}^{1-\alpha}K(t)^{\alpha-1}. \tag{26}$$

---

[34]Note that, unlike the Ramsey model, the rate of return on savings is not equal to the marginal product of capital, but rather is a fraction $e^{-(1-\alpha)\gamma}$ of it. This reflects the entrepreneurial share of this marginal product accruing as a monopoly rent.

where

$$\overline{A}_{v-1} = \exp\left(\int_0^1 \ln A_i(T_{v-1})di\right).$$

denotes the state of technology in use during the vth cycle. With all labour allocated to production, it also follows that aggregate final output can be expressed as

$$Y(t) = \overline{A}_{v-1}^{1-\alpha} K(t)^\alpha. \tag{27}$$

With technology fixed during this phase, the price of capital declines and the wage rises in proportion to the capital stock. Since the next implementation boom is some time away, the present value of engaging in entrepreneurship initially falls below the wage, $\delta V^D(t) < w(t)$, so that no labor is allocated to innovation or re–organization. During the expansion, $\delta V^D(t)$, grows at the rate of interest and eventually equals $w(t)$.[35] At this point, if all workers were to remain in production, returns to entrepreneurship would strictly dominate those in production. As a result, labor hours are re–allocated from production and into innovation, which triggers the contractionary phase.

5.2 The (Keynesian) Contraction

As labour is withdrawn from production, the ratio of utilized capital to labour hours and technology are both fixed. Consequently, the marginal product of capital remains constant. A further implication is that, through the contraction, the wage remains constant:

Lemma 2 : *The wage for $t \in [T_v^E, T_v]$ is constant and determined by the level of technology and the capital–labor ratio chosen at the last peak, $K(T_v^E)$:*[36]

$$w(t) = \bar{w}_v = (1-\alpha)e^{-(1-\alpha)\gamma}\overline{A}_{v-1}^{1-\alpha}K(T_v^E)^\alpha. \tag{28}$$

Since there is free entry into entrepreneurship, $w(t) = \delta V^D(t)$, and so the value of entrepreneurship, $\delta V^D(t)$, is also constant. Since the time until implementation for a successful entrepreneur is falling and there is no stream of profits (because implementation is delayed), the instantaneous interest rate necessarily equals zero. If it were not, entrepreneurial activity would be delayed to the instant before the boom. Therefore:

$$r(t) = \frac{\dot{V}^D(t)}{V^D(t)} = \frac{\dot{w}(t)}{w(t)} = 0. \tag{29}$$

---

[35] We derive conditions which ensure this is the case subsequently.

[36] Since the labour force is normalized to unity, the capital–labour ratio equals the capital stock during the expansion.

Note that this zero interest rate is consistent with the fact there is now excess (under–utilized) capital in the economy. Since marginal returns to new capital in this phase are zero, physical investment ceases and the only investment is that in innovation, undertaken by entrepreneurs.

Lemma 3 : *At T_v^E, investment in physical capital falls discretely to zero and entrepreneurship jumps discretely to $H_0(T_v^E) > 0$.*

A switch like this across types of investment is also a feature of the models of Matsuyama (1999, 2001) and Walde (2002). However, here factor intensity differences between innovation and production lead to a protracted recession.

Although investment falls discretely at $t = T_v^E$, consumption is constant across the transition between phases because the discount factor does not change discretely. With the fixed ratio of utilized capital to labor hours, the decline in output due to the fall in investment demand is proportional to the fraction of labor hours withdrawn from production. It follows that the fraction of labor hours allocated to entrepreneurship at the start of the downturn, $H_v = H_0(T_v^E)$, equals the rate of investment at the peak of the expansion:

$$H_v = \frac{\dot{K}\left(T_v^E\right)}{Y\left(T_v^E\right)} = 1 - \frac{C\left(T_v^E\right)}{\overline{A}_{v-1}^{1-\alpha} K(T_v^E)^\alpha}. \tag{30}$$

Although consumption cannot fall discretely at T_v^E, the zero interest rate implies that consumption must be declining after T_v^E,[37]

$$\frac{\dot{C}(t)}{C(t)} = -\frac{\rho}{\sigma}, \tag{31}$$

as resources flow out of production and into entrepreneurship.

Since $Y(t) = C(t)$, the growth rate in the hours allocated to production is also given by (31) and so aggregate entrepreneurship at time t is given by

$$H(t) = 1 - (1 - H_v)\, e^{-\frac{\rho}{\sigma}[t - T_v^E]}. \tag{32}$$

Note that due to the fixed capital-labor ratio, as labor leaves current production, capital utilization falls in the same proportion. It follows that the capital utilization rate specified in (10) is given by

$$\lambda(t) = (1 - H_v)e^{-\frac{\rho}{\sigma}(\tau - T_v^E)}. \tag{33}$$

---

[37]Although $r = 0$, strict preference for zero storage results from the arbitrarily small storage costs.

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5.2.1 The Rental Price of Capital during Downturns

In the absence of a capital price commitment, intermediate producers would be vulnerable to an increasing rental price through the downturn. This is because replacement capital owners are better off waiting until the boom, when capital will be relatively cheap, rather than displacing the incumbent immediately and earning the rental rate for a relatively short time. To see this formally, observe that, in order to forestall entry by a competing capitalist, the incumbent capitalist is constrained to offer a price sequence, $q(\tau)$ and induced capital utilization, $\lambda(\tau)$ which satisfies

$$V^K(K(t), t) \leq K(t), \tag{34}$$

where $V^K(K(t), \tau)$ denotes the value of the installed capital at time τ. During the downturn $r(t) = 0$ and $\dot{K}(\tau) = 0$, so that for $t \in \left[T_v^E, T_v\right]$, the condition can be expressed as

$$\int_t^{T_v} q(\tau) \lambda(\tau) K(T_v^E) dt + e^{-\beta(T_v)} V^K\left(K(T_v^E), T_v\right) \leq K(T_v^E). \tag{35}$$

However competition from potential replacement capitalists at the beginning of the next cycle ensures that $V^K\left(K(T_v^E), T_v\right) = K(T_v^E)$. Dividing by $K(T_v^E)$ and re–arranging, using (33), yields a necessary restriction to forestall entry during the downturn:

$$(1 - H_v) \int_t^{T_v} q(\tau) e^{-\frac{\rho}{\sigma}(\tau - T_v^E)} d\tau \leq 1 - e^{-\beta(T_v)}. \tag{36}$$

The right hand side of this expression is constant throughout the downturn, but the left–hand side decreases through the downturn for a given sequence $\{q(\tau)\}_{\tau=t}^{T_v}$. It follows that, in the absence of a binding price commitment, the capitalist could raise $q(\tau)$ above what had previously been offered and still satisfy (36). Anticipating the potential for such price gouging, entrepreneurs demand the commitment before T_v^E, while the cost of replacement capital is still low. Any such price commitment must satisfy (36) which will bind at $t = T_v^E$:

Lemma 4 *Any price commitment $q_i^c(\tau)$ signed at some date $t \in [T_{v-1}, T_v^E)$ must satisfy:*

$$\int_{T_v^E}^{T_v} q^c(\tau)(1 - H_v) e^{-\frac{\rho}{\sigma}(\tau - T_v^E)} d\tau = 1 - e^{-\beta(T_v)} \tag{37}$$

There are a number of price sequences $q^c(\tau)$ that could satisfy this condition, however the average level of prices satisfying it through $t \in [T_{v-1}, T_v^E)$ is unique. Let this average in the *vth* cycle be

$$\overline{q}_v \equiv \frac{\int_{T_v^E}^{T_v} q^c(\tau)(1 - H_v) e^{-\frac{\rho}{\sigma}(\tau - T_v^E)} d\tau}{\int_{T_v^E}^{T_v}(1 - H_v) e^{-\frac{\rho}{\sigma}(\tau - T_v^E)} d\tau}. \tag{38}$$

Using (37), and integrating the denominator through the downturn this implies:

$$\overline{q}_v = \frac{1 - e^{-\beta(T_v)}}{(1 - H_v)\left(\frac{1 - e^{-\frac{\rho}{\sigma}\Delta_v^E}}{\rho/\sigma}\right)}, \tag{39}$$

where $\Delta_v^E = T_v - T_v^E$. The capitalist could never be made better off by committing to a price sequence that varies through the recession instead of the constant price $\overline{q}_v$.[38]

Given $\overline{w}_v$ and $\overline{q}_v$, entrepreneurs choose a cost–minimizing ratio of utilized capital to labor hours. Since this is constant through downturn, it follows that the installed capital–labour ratio at the peak must satisfy $\frac{K(T_v^E)}{L(T_v^E)} = \left(\frac{\alpha}{1-\alpha}\right)\frac{\overline{w}_v}{\overline{q}_v}$. Given the constant wage from (28) it then directly follows that:

Proposition 2 *Cost minimization ensures that capital is installed only up to the point at which the marginal return to capital is equal to its average rental price:*

$$q(T_v^E) = \alpha e^{-(1-\alpha)\gamma}\overline{A}_{v-1}^{1-\alpha}K(T_v^E)^{\alpha-1} = \overline{q}. \tag{40}$$

Equating (39) and (40), substituting for $1 - H_v$ using (30), it follows that the capital–consumption ratio at the height of the expansion can be expressed as:

$$\frac{K\left(T_v^E\right)}{C\left(T_v^E\right)} = \frac{\alpha e^{-(1-\alpha)\gamma}\left(\frac{1 - e^{-\frac{\rho}{\sigma}\Delta_v^E}}{\rho/\sigma}\right)}{1 - e^{-(1-\alpha)\Gamma_v}}. \tag{41}$$

Note that, since there is no depreciation and no capital is accumulated through the recession, $K\left(T_v^E\right)$ is also the capital stock at the beginning of the next boom

5.2.2 Does GDP really contract?

During this phase, $Y(t)$ is not equal to real GDP because it does not include the contribution of entrepreneurial inputs. This can easily be corrected as follows:

$$
\begin{aligned}
\text{GDP} &= Y(t) + \overline{w}_v H(t) \\
&= \pi(t) + \overline{w}_v\left(1 - H(t)\right) + \overline{q}_v K^u(t) + \overline{w}_v H(t) \\
&= (1 - e^{-(1-\alpha)\gamma})Y(t) + \overline{q}_v\lambda(t)K\left(T_v^E\right) + \overline{w}_v.
\end{aligned}
$$

Clearly, GDP contracts through this phase, because both profits and payments to capital owners, $\lambda(t)\overline{q}_v$, fall. Thus, the recession is not a result of mis–measurement, or because innovative inputs

---

[38]Under any variable price sequence that averages to $\overline{q}_v$, entrepreneurs would have incentive to increase demand for capital when $q(\tau) < \overline{q}_v$, store that output not needed to meet the demand of the final goods sector, and correspondingly reduce production, and demand over those τ such that $q(\tau) > \overline{q}_v$. By substituting capital demand to times when the price is low, returns to the capital owner would fall.

are not being counted. The reason is that, due to imperfect competition, wages are less than the marginal product of labour. As labour hours are transferred to innovative activities, the marginal cost in terms of output exceeds the marginal benefit of innovation. In effect, the transfer of labour imposes a negative externality on intermediate producers and capital owners.

5.3 The (Schumpeterian) Boom

We denote the improvement in aggregate productivity during implementation, $e^{(1-\alpha)\Gamma_v}$, where

$$\Gamma_v = \ln\left[\overline{A}_v/\overline{A}_{v-1}\right]. \tag{42}$$

Productivity growth at the boom is given by $\Gamma_v = (1 - P(T_v))\gamma$, where $P(T_v)$ is defined by (22). Substituting in the allocation of labor to entrepreneurship through the downturn given by (32) and letting

$$\Delta_v^E = T_v - T_v^E, \tag{43}$$

yields the following implication:

Proposition 3 : *In an equilibrium where there is positive entrepreneurship only over the interval $(T_v^E, T_v]$, the growth in productivity during the subsequent boom is given by*

$$\Gamma_v = \delta\gamma\Delta_v^E - \delta\gamma(1 - H_v)\left(\frac{1 - e^{-\frac{\rho}{\sigma}\Delta_v^E}}{\rho/\sigma}\right). \tag{44}$$

Over the boom, the asset market must simultaneously ensure that entrepreneurs holding innovations are willing to implement immediately (and no earlier) and that, for households, holding equity in firms (weakly) dominates holding claims on alternative assets (particularly stored intermediates). The following Proposition demonstrates that these conditions imply that during the boom the discount factor must equal productivity growth:[39]

Proposition 4 *Asset market clearing at the boom requires that*

$$\beta(T_v) = (1 - \alpha)\Gamma_v. \tag{45}$$

---

[39]Shleifer's (1986) model featured multiple expectations–driven steady state cycles. Such multiplicity cannot occur here because, unlike Shleifer, the possibility of storage that we allow forces a tight relationship between Γ_v and Δ_v^E as depicted in Proposition 3. Since Γ_v, Δ_v^E pairs must satisfy this restriction as well, in general, multiple solutions cannot be found.

During the boom, $\beta(T_v)$ equals the growth in firm values and wages grow in proportion to productivity. Since, just before the boom, $\delta V^I(T_v) = w(T_v)$, a corollary is that

$$\delta V_0^I(T_v) = w_0(T_v) = (1-\alpha)e^{-(1-\alpha)\gamma}\overline{A}_v^{1-\alpha}K(T_v^E)^\alpha. \tag{46}$$

The growth in output at the boom exceeds the growth in productivity for two reasons: first labor is re–allocated back into production, and second the previously under–utilized capital is now being used productively. Since just before the boom, both inputs are a fraction $(1-H_v)e^{-\frac{\rho}{\sigma}\Delta_v^E}$ of their peak levels, output growth through the boom is given by

$$
\begin{aligned}
\Delta \ln Y(T_v) &= (1-\alpha)\Gamma_v + (1-\alpha)\Delta \ln L + \alpha \Delta \ln K^u \\
&= (1-\alpha)\Gamma_v + \frac{\rho}{\sigma}\Delta_v^E - \ln(1-H_v) \tag{47}
\end{aligned}
$$

It follows directly from Proposition 4 that growth in output exceeds the discount factor across the boom. Since profits are proportional to output, this explains why firms are willing to delay implementation during the downturn.

The boom in output can be decomposed into a boom in consumption and investment. From the Euler equation, we can compute consumption growth across the boom:

$$\Delta \ln C(T_v) = \frac{(1-\alpha)}{\sigma}\Gamma_v. \tag{48}$$

Notice that whether the growth in consumption exceeds the growth in productivity at the boom, depends on the value of σ. In particular, if $\sigma < 1$, consumption growth must exceed aggregate productivity growth. Finally, since in the instant prior to the boom $C(T_v) = Y(T_v)$, it follows that the investment rate at the boom jumps to

$$\frac{\dot{K}_0(T_v)}{Y_0(T_v)} = 1 - (1-H_v)e^{\left(\frac{1-\sigma}{\sigma}\right)(1-\alpha)\Gamma_v - \frac{\rho}{\sigma}\Delta_v^E}. \tag{49}$$

6   Optimal Behavior During the Cycle

Optimal entrepreneurial behavior imposes the following requirements on our hypothesized equilibrium cycle:

• Successful entrepreneurs at time $t = T_v$ must prefer to implement immediately, rather than delay implementation until later in the cycle or the beginning of the next cycle:

$$V_0^I(T_v) > V_0^D(T_v). \tag{E1}$$

• Entrepreneurs who successfully innovate during the downturn must prefer to wait until the beginning of the next cycle rather than implement earlier and sell at the limit price:

$$V^I(t) < V^D(t) \qquad \forall\, t \in (T_v^E, T_v) \tag{E2}$$

• No entrepreneur wants to innovate during the slowdown of the cycle. Since in this phase of the cycle $\delta V^D(t) < w(t)$, this condition requires that

$$\delta V^I(t) < w(t) \qquad \forall\, t \in (0, T_v^E) \tag{E3}$$

• Finally, in constructing the equilibrium above, we have implicitly imposed the requirement that the downturn is not long enough that all sectors innovate:

$$P(T_v) > 0. \tag{E4}$$

Taken together conditions (E1) through (E4) are restrictions on entrepreneurial behavior that must be satisfied for the cyclical growth path we have posited to be an equilibrium.

Figure 5 illustrates the evolution of the value functions and wages through the cycle. Following the boom at T_{v-1}, δV^I remains above δV^D for a while so that if there were any new innovations, immediate implementation would dominate delay. However, over this phase, the relative value of labor in production, w, exceeds returns to entrepreneurship, so that no entrepreneurial successes are available to implement. Throughout this expansionary phase, investment occurs so that the wage continues to rise. At the same time, V^D also rises as the next implementation period draws closer. Throughout this phase V^I declines as the duration of guaranteed positive profits falls.

The end of the expansion corresponds to the commencement of entrepreneurship — when the increasing value of delayed implementation eventually meets the opportunity cost of labor in production, $w = \delta V^D$. Since, during the contraction, interest rates are zero, V^D remains constant so that the wage must also be constant. Initially, V^I continues to fall, but eventually rises again as the probability of remaining the incumbent at the boom, given that an entrepreneurial success has not arrived in one's sector, increases. This increase in V^I is the force that will eventually trigger the next boom that ends the recession. It occurs when V^I just exceeds V^D and entrepreneurs implement stored entrepreneurial successes, leading to an increase in productivity, a jump in demand, movement of labor back to production, and full capacity utilization.
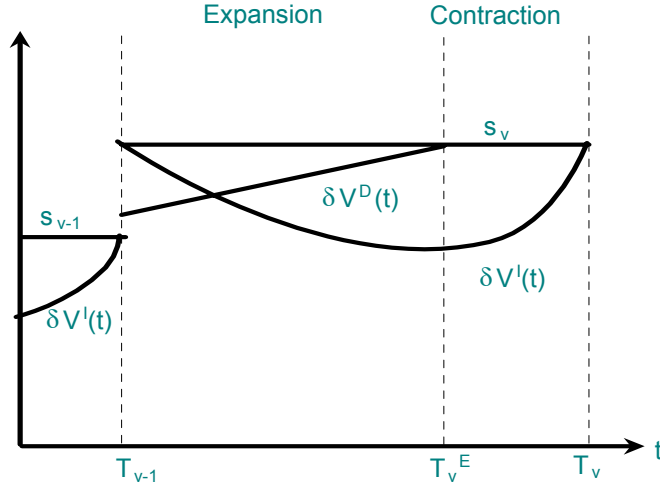
Figure 5: Existence

7   The Stationary Cyclical Growth Path

To allow a stationary representation, we normalize all aggregates by dividing by $\bar{A}_{v-1}$ and denote the result with lower case variables. First recall from Proposition 1, that the dynamics of the economy during the expansion are analogous to those in the Ramsey model without technological change. Let $c_v = c(T_v^E)$ and $k_v = k(T_v^E)$ denote the normalized values of consumption and capital at the peak of the vth expansion. Given initial values $c_0(T_{v-1})$ and $k_0(T_{v-1})$, and an expansion length Δ_v^X, it is possible to summarize the expansion as follows:

$$c_v = f(c_0(T_{v-1}), k_0(T_{v-1}), \Delta_v^X) \tag{50}$$

$$k_v = g(c_0(T_{v-1}), k_0(T_{v-1}), \Delta_v^X), \tag{51}$$

where $f(\cdot)$ and $g(\cdot)$ are well–defined functions. Since capital accumulation stops in the recession, and $\overline{A}$ rises by $e^{\Gamma_{v-1}}$, it follows that

$$k_0(T_{v-1}) = e^{-\Gamma_{v-1}} k_{v-1}. \tag{52}$$

From (31), consumption declines by a factor $e^{-\frac{\rho}{\sigma}\Delta_{v-1}^E}$ in the recession. When combined with its increase at the boom, from (48), this yields

$$c_0(T_{v-1}) = e^{\left(\frac{1-\alpha}{\sigma}-1\right)\Gamma_{v-1} - \frac{\rho}{\sigma}\Delta_{v-1}^E} c_{v-1}. \tag{53}$$

Substituting for $c_0(T_{v-1})$ and $k_0(T_{v-1})$ in (50) and (51) then yields

$$c_v = f(e^{\left(\frac{1-\alpha}{\sigma}-1\right)\Gamma_{v-1} - \frac{\rho}{\sigma}\Delta_{v-1}^E} c_{v-1}, e^{-\Gamma_{v-1}} k_{v-1}, \Delta_v^X) \tag{54}$$

$$k_v = g(e^{\left(\frac{1-\alpha}{\sigma}-1\right)\Gamma_{v-1} - \frac{\rho}{\sigma}\Delta_{v-1}^E} c_{v-1}, e^{-\Gamma_{v-1}} k_{v-1}, \Delta_v^X). \tag{55}$$

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Imposing stationarity, so that $\Gamma_v = \Gamma$, $k_v = k$, $c_v = c$, $\Delta_v^E = \Delta^E$ and $\Delta_v^X = \Delta^X$ for all v, on the system described by (44), (41), (54), (55) and (46) yields a system of five equations in the five unknowns that summarize the stationary cycle:

Proposition 5 *The stationary cycle* $(\Gamma, k, c, \Delta^E, \Delta^X)$ *satisfies the following system of equations:*

$$\Gamma = \delta\gamma\Delta^E - \delta\gamma\frac{c}{k^\alpha}\left(\frac{1 - e^{-\frac{\rho}{\sigma}\Delta^E}}{\rho/\sigma}\right) \tag{56}$$

$$\frac{c}{k} = \frac{1 - e^{-(1-\alpha)\Gamma}}{\alpha e^{-(1-\alpha)\gamma}\left(\frac{1-e^{-\frac{\rho}{\sigma}\Delta^E}}{\rho/\sigma}\right)} \tag{57}$$

$$c = f(e^{\left(\frac{1-\alpha}{\sigma}-1\right)\Gamma - \frac{\rho}{\sigma}\Delta^E}c, e^{-\Gamma}k, \Delta^X) \tag{58}$$

$$k = g(e^{\left(\frac{1-\alpha}{\sigma}-1\right)\Gamma - \frac{\rho}{\sigma}\Delta^E}c, e^{-\Gamma}k, \Delta^X) \tag{59}$$

$$\delta v_0^I(c, k, \Gamma, \Delta^E, \Delta^X) = (1-\alpha)e^{-(1-\alpha)\gamma}e^{-\alpha\Gamma}k^\alpha \tag{60}$$

where $v_0^I = V_0^I(T_v)/\bar{A}_v$.

The stationary cycle can be understood heuristically from the phase diagram in Figure 6. Here the process of capital accumulation in the expansionary phase, $t \in \left(T_{v-1}, T_v^E\right)$, within a steady state cycle is depicted.
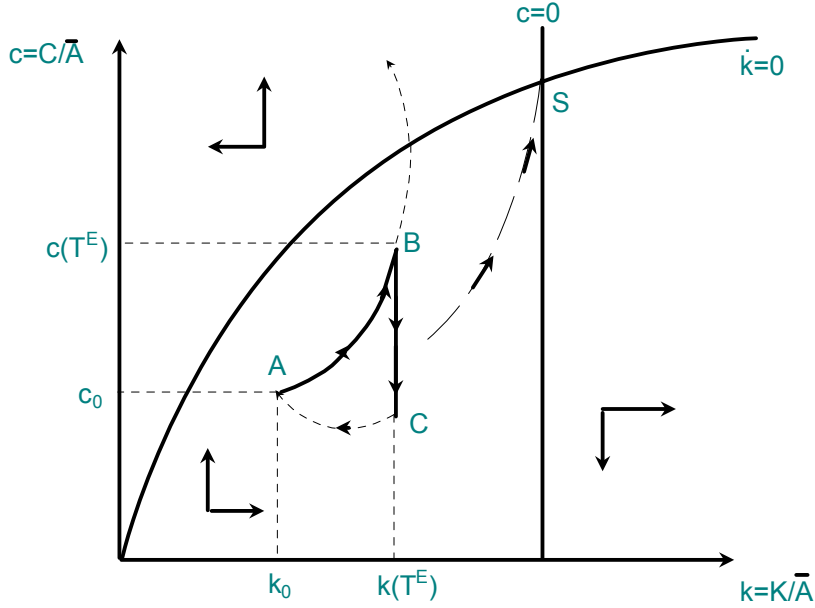
Figure 6: Phase Diagram

The economy does not evolve along the standard stable trajectory of the Ramsey model terminating at the steady state, S. Instead, the evolution of the cycling economy during the expansion is depicted by the path between A and B in the figure. Capital is accumulated starting at the point k_0 corresponding to point A in the diagram, according to (23) and (24). The point k_0 denotes the inherited capital stock at the boom. Accumulation ends at $k\left(T^E\right)$, at which point investment stops until the next cycle. Note that if allowed to continue along such a path the economy would eventually violate transversality, but capital accumulation stops and consumption declines so that the economy evolves from B to C through the downturn. During this phase, the dynamics of the economy are no longer dictated by the Ramsey phase diagram. When this phase ends, implementation of stored productivity improvements occurs at the next boom, and $\bar{A}$ increases, so that k fall discretely. If $\sigma < 1$, consumption grows by more than productivity at the boom, so that c rises discretely. The boom is therefore depicted by the dotted arrow back to point A. At this point, investment in the expansionary phase recommences for the next cycle. The connection between the two phases of the cycle arises due to the allocation of resources to entrepreneurship. This allocation of resources will be reflected in the size of the increment to $\bar{A}$, Γ.

7.1   A Numerical Example

We numerically solve the model for various combinations of parameters and check the existence conditions (E1)–(E4). We choose parameters to fall within reasonable bounds of known values, and present a baseline case given in Table 1:

Table 1: Baseline Parameters

Parameter	Value
α	0.22
γ	0.13546
σ	0.79
ρ	0.02
δ	1.39

The parameters α and γ were chosen so as to obtain a labor share of 0.7, a capital share of 0.2 and a profit share of 0.1. These values correspond approximately to those estimated by Atkeson and Kehoe (2002). The value of γ corresponds to a markup rate of around 15%. The intertemporal elasticity of substitution $\frac{1}{\sigma}$ is slightly high, but in Appendix C, we provide simulation results for various values below, including $\sigma = 1$. Given $\sigma = 0.79$, we calibrated δ and ρ so as to match a long–run annual growth rate of 2.2% and an average risk–free real interest rate of 3.8%, values

which correspond to annual data for the post–war US. The baseline case above yields a cycle length of a little less than 4 years, $H_v = .2044$, and $k_v = 7.668$. In this, and all simulations we have computed, steady state values are unique.[40]

8 Implications

8.1 Tobin's Q and Investment

Tobin's Q is typically measured as the ratio of the value of firms to the book value of their capital stock. In our model Tobin's Q is given by

$$Q(t) = \frac{V^K(t) + \Pi(t)}{K(t)}, \tag{61}$$

where $\Pi(t)$ denotes the stock market value of the intangible capital tied up in firms, and recall that $V^K(t)$ is the market value of their physical capital. Figure 7 illustrates the evolution of Tobin's Q, its tangible component (V^K/K) and aggregate investment over the cycle.

During an expansion $V^K(t) = K(t)$ and, the value of intangible capital is equal to the value of incumbent firms: $\Pi(t) = V^I(t)$. It follows that

$$Q(t) = 1 + \frac{V^I(t)}{K(t)} \qquad \forall t \in (T_{v-1}, T_v^E). \tag{62}$$

Since $V^I(t)$ declines and $K(t)$ grows during the expansion, $Q(t)$ must decline.

In the downturn, the value of the physical capital stock declines below the capital stock, so that

$$V^K(t) = \left[\bar{q} \int_t^{T_v} \lambda(\tau) d\tau + e^{-\beta(T_v)} \right] K(T_v^E) < K(T_v^E). \tag{63}$$

Also some sectors experience innovations, so there exist terminal firms who are certain to be made obsolete at the next round of innovation. At any point in time the measure of sectors in which no innovation has occurred is $P(t)$, therefore the total value of firms on the stockmarket is given by

$$\Pi(t) = (1 - P(t))[V^T(t) + V^D(t)] + P(t)V^I(t), \tag{64}$$

where $V^T(t)$ denotes the value of "terminal" firms who are certain to be made obsolete during the next wave of implementation. The value of these firms can be written as

$$V^T(t) = V^I(t) - \frac{P(T_v)}{P(t)} V^D(t). \tag{65}$$

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[40] Francois and Lloyd-Ellis (2003) explicitly establish uniqueness of the stationary cycle when capital accumulation is not allowed. It seems likely that the introduction of capital would not lead to an additional stationary cycle here, but we have not been able to establish this analytically.

Substituting into (64) yields

$$\hat{\Pi}(t) = V^I(t) + (1 - P(t)) \left[1 - \frac{P(T_v)}{P(t)} V^D(t) \right]. \tag{66}$$

Through the downturn, the value of intangible capital initially falls and then rises again as the economy approaches the next boom.[41] Immediately prior to the boom $P(t) = P(T_v)$, so that again $\Pi(T_v) = V^I(T_v)$. The value of Q during the downturn is thus given by

$$Q(t) = \bar{q} \int_t^{T_v} \lambda(\tau) d\tau + e^{-\beta(T_v)} + \frac{\hat{\Pi}(t)}{K(T_v^E)} \qquad \forall\, t \in [T_v^E, T_v). \tag{67}$$

During the contraction, then, $Q(t)$ initially declines as $K(t)$ remains unchanged and the decline in $V^k(t)$ dominates. However, eventually the growth in the value of intangible capital, $\hat{\Pi}(t)$, starts to dominate as we approach the boom, so that $Q(t)$ rises in anticipation. At the boom, since the book value of capital remains unchanged, but the market value of physical capital grows by a factor $e^{(1-\alpha)\Gamma_v}$, Tobin's Q rises rapidly.
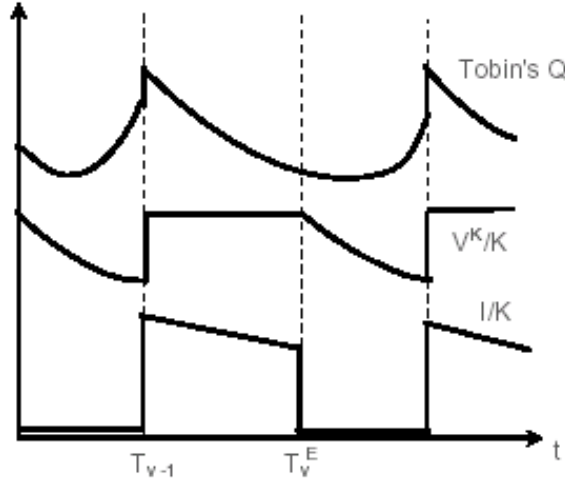
Figure 7: Tobin's Q and Investment

The qualitative behavior of Tobin's Q in our model thus accords quite well with its aggregate counterpart in US data. As illustrated in the introduction, Tobin's Q tends to reach a peak prior to the peak of expansions and then reaches a minimum before the end of the NBER–dated recessions. The most rapid periods of growth in Tobin's Q therefore start to occur before the end of recessions and continue through the subsequent boom just as they do in our stationary cycle.

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[41] This cyclical anticipation of future profits implicit in aggregate stock prices accords well with the findings of Hall (2001).

8.2   Additional Results

Although, our focus is on investment and the stockmarket, our model also *endogenously* generates behavior of a number of key variables that are qualitatively consistent with the facts:

• Output growth is characterized by a three–stage process — Output grows rapidly at the boom, at a lower rate during the subsequent expansion before turning negative. This is characterization is consistent with time–series evidence provided by non–linear econometric models of output (e.g. Dahl and Gonzalez–Rivera, 2003).

• Labour productivity is strongly pro–cyclical — During expansions, all labor is used in production and capital is fully utilized, so that labor productivity rises though capital accumulation. In contractions, labor is reallocated to innovative activities, capital utilization falls, and output declines. If utilized capital and labor were correctly measured, labour productivity should remain constant through the recession. If the re–allocation of labor were not fully measured, then it would appear that labor is being hoarded (see Fay and Medoff 1985),[42] and measured labour productivity would fall. This is consistent with the evidence of Fernald and Basu (1999), for example. Even if labour re–allocations were correctly accounted for, measured productivity would still fall since capital utilization is typically not well measured.

• Wages rise less than output during booms and expansions, and do not fall during contractions — as a result, wages are inherently less procyclical than output, which again is consistent with most evidence for the US. Since there are no aggregate employment fluctuations in our model, one must be careful in interpreting this implication. We discuss extensions of the model that would allow for unemployment in our conclusion.

• Labor and capital *inputs* into consumption and investment sectors are both pro–cyclical — the canonical RBC model implies that inputs into consumption are countercyclical (e.g. Christiano and Fisher 1995). The allocation of labor to consumption good production can be inferred from equation (48). As long as $\sigma < 1$ consumption growth exceeds productivity growth so that the allocation of labor and capital to consumption must rise at the boom. The reason labor in both consumption and investment good production can rise is because of the endogenous shutting down of entrepreneurship at the boom. This mechanism is similar to that generated by introducing "homework" in Benhabib, Rogerson and Wright (1991).

• The term spread is small during expansions and high midway through contractions — we define the term spread as the difference between a 30 year annualized interest rate and a 3 month interest

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[42]Entrepreneurship is, at best, likely to be only partially measured in the data, since much of it involves activities that will raise long-term firm profits but have little directly recorded output value contemporaneously.

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rate. The cycle analyzed here exhibits a low value of the term spread through the expansion, and a high value in the recession. The highest value occurs at the start of the recession then, towards the end of the recession it tracks down as the three month rate starts to include the increased discount over the boom. Similarly, at the start of the expansion the term spread is at its lowest point, thus again providing a leading indication of the imminent contraction. Estrella and Mishkin (1996) argue that the term spread is a superior predictor over other leading indicators at leads from 2 to 4 quarters.

9   Endogenous Incomplete Contracting

In describing the cyclical equilibrium above we have assumed that capital owners can offer long term commitments with respect to the rental price per unit of utilized capital. While it simplifies the exposition, this assumption is problematic for two reasons. First, one would normally expect the rental price to be per unit of *installed* capital. Secondly, during the recession such price commitments are clearly ex–post inefficient — if a more productive technology has arrived in a sector, would it not be Pareto improving to break the commitment so as to induce early entry by new innovators who might fully utilize the capital? In this section, we relax the assumption of price–commitment and instead only allow agents to write long term, enforceable supply contracts. We show that the behavior described above can be derived as the equilibrium outcome of constrained–efficient contracting between agents. A key incompleteness in the contracting environment arises as a natural consequence of the process of creative destruction — capital owners cannot write contingent contracts regarding innovations that do not exist yet.

As with exogenous price commitments, prior to the peak of each cycle, capital owners compete by offering long term contracts. However, since entrepreneurs lose their productive advantage when displaced by superior producers, they cannot make unconditional promises to purchase capital into the indefinite future. All such contracts are thus contingent upon the entrepreneur continuing production. Note further that the existence of an exclusive contract over the supply of capital in sector i, places the intermediate producer in that sector in a strong market position relative to its rivals. In order to prevent ex–post price gouging by the intermediate goods producer, the final goods producer will also demand a contract over the supply of intermediate goods. Such a contract will also be written prior to the peak, when there is still effective competition from the past incumbent.[43]

Intermediate Supply Contracts written at t specify future output, $x_i(\tau)$, and prices,

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[43] Though conceptually feasible, contracts written over the supply of labor and final output are redundant in the equilibria we study and will not be considered further.

$p_i(\tau)$, for all τ up to a chosen contract termination date, T_i^X. Thus, such a contract is a tuple: $\left\{\{x_i(\tau), p_i(\tau)\}_{\tau \in [t, T_i^X]}, \ T_i^X\right\}$. Since the productive advantage of an intermediate producer lasts only until a superior technology is implemented in that sector, contracts allow the termination of agreements before T_i^X if shutting down production. Otherwise, the parties can break contracts only by mutual agreement. The value of the arrangement to final goods producers is denoted $V^Y(t)$.

Lemma 5 *Given a sequence of input prices $w(t)$, $q(t)$ for $t \in [T_{v-1}, T_v)$, an intermediate supply contract specifying price and quantity sequences satisfying (11) and (9) for $t \in [T_{v-1}, T_v)$ maximizes the present value of the intermediate producers profits $\max\left[V_i^I(t), V_i^D(t)\right]$ subject to $V^Y(t) \geq 0$.*

Capital Supply Contracts specify future binding levels of installed capital, $K_i(\tau)$, and an effective price for each unit of installed capital, $\lambda_i(\tau)q_i(\tau)$, for all τ up to a chosen contract termination date, T_i^K. Thus a contract signed at time t is a tuple $\left\{\{K_i(\tau), \lambda_i(\tau)q_i(\tau)\}_{\tau \in [t, T_i^K]}, \ T_i^K\right\}$. Contracts can be altered under the same conditions as in intermediate supply contracts. In equilibrium, capital supply contracts written at t must be undominated:

$$\max\left[\widehat{V}_i^I(t), \widehat{V}_i^D(t)\right] + \widehat{V}_i^K(t) \geq \max\left[V_i^I(t), V_i^D(t)\right] + V_i^K(t).$$

The existence conditions (E1) through (E4) take as given that entrepreneurs do not produce in excess of current demand and store their output until the boom. Provided that the incumbent entrepreneur does not terminate the capital supply contract, (45) ensures that storage across the boom is not optimal. However, since the capital utilization and rental price sequences that we have derived previously imply that the capital stock is being under–utilized, it is possible that just before the boom, a rival entrepreneur who has successfully innovated may be able to "buy out" the contract and utilize all the capital, meeting the current demand for output and storing the remainder until the boom.

This rival would not benefit from taking over the capital contract of the incumbent under identical terms. From (45), producing output and storing it until the boom is not optimal if he must pay a constant amount $\bar{q}$ for capital. Moreover, under (E2) implementation and sale before the boom is not optimal. However, the rival may be willing to take over the use rights if able to pay $\overline{q}_v$ for the amount $K(t)$ in the incumbent's contract, utilize extra units of idle capital at some price $\widetilde{q} < \overline{q}_v$, and store. Clearly any $\widetilde{q} > 0$ for the excess units would be amenable to the capitalist. The most the rival will be willing to pay per period for the current capital is $\overline{q}_v K(T_v^E)$,

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since $e^{-\beta(T_v)}q_0(T_v) = \overline{q}_v$. To buy out the contract, the rival must compensate the incumbent for the loss of profits sustained for the remainder of the cycle and must offer the capitalist at least the payment he is currently receiving, $\overline{q}_v(1 - H_v)e^{-\frac{\rho}{\sigma}(t-T_v^E)}K(T_v^E)$ per period. It follows that such a contract buy–out will not a be mutually acceptable at time t if

$$\int_t^{T_v} \pi(\tau)d\tau + \int_t^{T_v} \overline{q}(1 - H_v)e^{-\frac{\rho}{\sigma}(\tau-T_v^E)}K(T_v^E)d\tau \geq \int_t^{T_v} \overline{q}K(T_v^E)d\tau. \qquad (68)$$

The following proposition provides a sufficient condition for this to hold throughout the downturn:

Proposition 6 *Provided that*

$$(1 - (1 - \alpha)e^{-(1-\alpha)\gamma})(1 - H_v)e^{-\frac{\rho}{\sigma}\Delta_v^E} > \alpha e^{-(1-\alpha)\gamma} \qquad (E5)$$

capital supply contracts specifying price and quantity sequences given by (69), (74), (33) and (40) are undominated.

In effect, condition (E5) explains how it is possible for there to be under–utilized capital during a recession even though there exist rivals who could potentially use the capital stock more profitably. The reason is that the capital stock is "lumpy", so that the rival cannot use part of it while the incumbent continues to produce. For this reason, the rival must compensate the incumbent for his profit loss and this "endogenous" fixed cost is too large for entry to be profitable under recessionary demand conditions. Entry does not become profitable until the boom. There, demand is high and entry costs low because the previous incumbent's profits do not need to be compensated — they have already been destroyed by the implementation of a superior production process. In our numerical simulations, we find that (E5) is rarely binding, so it does not appear to be a strong requirement for existence of the cyclical equilibrium.

In the absence of exogenous price commitment, the cyclical equilibrium is supported by limitations on the contracting environment. The critical, and we think realistic, assumption is that only future prices and quantities can be contracted ex ante. Allowing for a richer set of contracting possibilities would overturn this result. For example, if the new incumbent entrepreneur (who arrives probabilistically in the downturn) could somehow be party to the contract prior to time T_v^E, then full utilization of the capital through the downturn could also be contracted ex ante. Such a rich contracting environment, however, seems to require unrealistically complex and difficult to observe details to be enforceable between the parties. Thus endogenous under–utilization, which corresponds to that observed in actual business cycles, arises here due to natural limitations in contracting.

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10   Concluding Remarks

This article shows how the qualitative relationship between investment and Tobin's Q over the US business cycle, arises quite naturally in a model of endogenous cyclical growth. During recessions, entrepreneurs delay the implementation of innovations, whose present value is reflected in stock market values, until demand is high and the expected length of incumbency is maximized. Once these innovations are implemented, the marginal product of capital jumps, inducing a prolonged investment boom. During this period of high investment, the incentives to innovate are low and subsequent booms are far away, so that the market value of existing firms starts to decline. This decline anticipates the subsequent crash in investment, as resources are shifted out of current production and into longer term activities.

In order to study these cycles in the rate of fixed capital formation, we have extended the existing literature on endogenous implementation cycles. The extension is non–trivial because the introduction of physical capital into models like that of Shleifer (1986) undermines the existence of cycles by allowing agents to store. In the presence of costly, endogenous innovation, however, a unique cyclical equilibrium emerges which is robust to storage (and therefore the introduction of capital).

Our model also generates movements in other aggregates over the cycle which are qualitatively similar, in some respects, to those observed in US data. It should be reiterated that these results arise in a framework where both the economy's cyclical behavior and its growth path are fully endogenized. Moreover, the framework we explore has remarkably few degrees of freedom; the model is fully specified by five exogenous parameters: two summarizing household preferences, two underlying the productivity of entrepreneurship, and one pinning down factor shares in production.

We do not claim that the current framework is capable of providing a quantitative account of the business cycle. However, in future work we will build on this parsimonious structure to explore a number of key extensions:

• Aggregate uncertainty and stochastic cycle lengths — The length and other characteristics of actual business cycles, vary from cycle to cycle and look rather different from the deterministic stationary equilibrium cycle described here. Introducing some degree of aggregate uncertainty would help to address this. However, in order to develop such an extension we need to develop a deeper understanding of the local transitional dynamics of the model. It turns out that these dynamics are not as complex as one might expect at first blush. The reason is that the path back to the stationary cycle (at least locally) involves the accumulation of only one factor: either physical capital or intangible. Although a full analysis of these local dynamics is beyond the

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scope of the current paper, we believe it is feasible.

• Unemployment — A natural way to introduce unemployment into the model is to allow for unskilled labour which cannot be used in entrepreneurship and is not directly substitutable with skilled labor in production. With putty–clay production, the marginal value of this unskilled labor falls to zero during the downturn and some fraction of unskilled workers would become unemployed (just like physical capital). In a competitive labor market, this would drive unskilled wages down to their reservation level. However, in the presence of labor market imperfections, such as efficiency wages and search frictions, the dynamics of unemployment and wages interact with the process of creative destruction in a more complex manner. In further work we explore these dynamics more fully.

• Government policy — The framework developed here (as well as its extensions) provide a natural framework for thinking about counter–cyclical policy. First, the question arises as to whether removing or reducing cycles is a valid policy objective at all. Francois and Lloyd–Ellis (2003) show that switching from the cyclical equilibrium to a corresponding acyclical one would reduce long–run growth but increase welfare. Similar results are likely to carry over to the stationary cycle in the current model. A second issue is that of how to implement a counter–cyclical policy. The recession here is Keynesian in that it is associated with deficient demand, and the government could intervene, for example, by raising demand for goods and services and taxing savings. However, such a policy would effectively channel resources away from innovative activities and may dampen growth. On the other hand the anticipation of higher demand during a downturn might stimulate innovation, so the overall effect is unclear.

Appendix A – Proofs

Proof of Lemma 1 We show: (1) that if a signal of success from a potential entrepreneur is credible, other entrepreneurs stop innovation in that sector; (2) given (1) entrepreneurs have no incentive to falsely claim success.

Part (1): If entrepreneur $i's$ signal of success is credible then all other entrepreneurs believe that i has a productivity advantage which is e^γ times better than the existing incumbent. If continuing to innovate in that sector, another entrepreneur will, with positive probability, also develop a productive advantage of e^γ. Such an innovation yields expected profit of 0, since, in developing their improvement, they do not observe the non-implemented improvements of others, so that both firms Bertrand compete with the same technology. Returns to attempting innovation in another sector where there has been no signal of success, or from simply working in production, $w(t) > 0$, are thus strictly higher.

Part (2): If success signals are credible, entrepreneurs know that upon success, further innovation in their sector will cease from Part (1) by their sending of a costless signal. They are thus indifferent between falsely signalling success when it has not arrived, and sending no signal. Thus, there exists a signalling equilibrium in which only successful entrepreneurs send a signal of success.∎

Proof of Proposition 1: First note that in the absence of uncertainty or adjustment costs, and as long as utilized capital is anticipated to grow, capital owners never acquire more capital than is needed for production, so that

$$K_i^u(t) = K_i(t). \tag{69}$$

Substituting into (6) and differentiating with respect to time yields

$$\dot{V}_i^K(t) = r(t) V_i^K(t) - q_i(t) K_i(t) + \dot{K}_i(t) = \dot{K}_i(t). \tag{70}$$

Since, during this phase, $V_i^k(t) = K_i(t)$, it follows that $q_i(t) = q(t) = r(t) \ \forall \ i$. Combining (**??**) with (9), (10) and (11), it follows that all firms choose the same capital–labour ratio. From the production function we have

$$\ln Y(t) = \int_0^1 \ln \frac{Y(t)}{p_i(t)} di \tag{71}$$

Substituting for $p_i(t)$ using (11) yields

$$0 = \int_0^1 \ln \frac{q(t)^\alpha w(t)^{1-\alpha}}{\mu e^{-(1-\alpha)\gamma} A_i^{1-\alpha}(T_{v-1})} di \tag{72}$$

which re-arranges to (73)

$$q(t)^\alpha w(t)^{1-\alpha} = \alpha^\alpha (1-\alpha)^{1-\alpha} e^{-(1-\alpha)\gamma} \overline{A}_{v-1}^{1-\alpha}. \tag{73}$$

Thus, the input price index for $t \in [T_{v-1}, T_v^E]$ is constant and uniquely determined by the level of technology

Through this phase, capital is rented at a competitive price, i.e. its marginal product net of profits to the entrepreneur:

$$r(t) = q(t) = \alpha e^{-(1-\alpha)\gamma} \overline{A}_{v-1}^{1-\alpha} K(t)^{\alpha-1}. \tag{74}$$

Using this in the consumer's Euler equation yields the equations in Proposition 1.■

Proof of Lemma 3: Suppose instead that there exists an intermediate phase in which neither capital is accumulated nor entrepreneurship occurs. Consider the first instant of that phase. Since in the instant prior to that capital was being accumulated, the marginal return to investment in physical capital must exceed ρ. Since the marginal product of capital cannot jump downwards discretely at full capital utilization, there are only two possibilities: either (1) $r(T_v^E) = \rho$ at the start of the intermediate phase or (2) $r(T_v^E) > \rho$ at the start of the intermediate phase. Situation (2) can be ruled out directly since, by assumption, in the intermediate phase there is no entrepreneurship, and so it must be the case that $r > \rho$ and investment will occur. Situation (1) occurs if the marginal return to capital converges continuously to $r = \rho$ along the neoclassical accumulation phase. But this corresponds exactly with the path of accumulation along the stable trajectory of the Ramsey model which does not converge in finite time — this would then imply an infinite length to the capital accumulation phase.■

Proof of Proposition 3: Long–run productivity growth is given by

$$\Gamma_v = (1 - P(T_v))\gamma \tag{75}$$

Integrating (32) over the downturn and substituting for $H(\cdot)$ using (32) yields

$$1 - P(T_v) = \delta \int_{T_v^E}^{T_v} \left(1 - (1 - H_v)e^{-\frac{\rho}{\sigma}[t - T_v^E]}\right) d\tau. \tag{76}$$

Substitution into (75) and integrating gives (44).■

Proof of Lemma 4: If $V_i^k(t) > K_i(t)$ it is feasible for the the builder of a new capital stock in sector i to commit to a price sequence $q_i^c(\tau)$, which would be strictly preferred by the current incumbent producer. A preferred sequence for the leading producer would be one in which prices

were no higher than the contracted sequence above, but which had a strictly lower price in at least one instant. This is feasible if $V_i^k(t) > K_i(t)$. Finally, no new capitalist would enter offering a sequence $V_i^k(t) < K_i(t)$, so that any equilibrium price sequence must at least satisfy (37).■

Proof of Proposition 4: For an entrepreneur who is holding an innovation, $V^I(t)$ is the value of implementing immediately. During the boom, for entrepreneurs to prefer to implement immediately, it must be the case that

$$V_0^I(T_v) > V_0^D(T_v). \tag{77}$$

Just prior to the boom, when the probability of displacement is negligible, the value of implementing immediately must equal that of delaying until the boom:

$$\delta V^I(T_v) = \delta V^D(T_v) = w(T_v). \tag{78}$$

From (77), the return to entrepreneurship at the boom is the value of immediate (rather than delayed) incumbency. It follows that free entry into entrepreneurship at the boom requires that

$$\delta V_0^I(T_v) \leq w_0(T_v). \tag{79}$$

The opportunity cost of financing entrepreneurship is the rate of return on shares in incumbent firms in sectors where no innovation has occurred. Just prior to the boom, this is given by the capital gains in sectors where no entrepreneurial successes have occurred;

$$\beta(T_v) = \log\left(\frac{V_0^I(T_v)}{V^I(T_v)}\right). \tag{80}$$

Note that since the short–term interest rate is zero over this phase, $\beta(t) = \beta(T_v)$, $\forall\, t \in (T_v^E, T_v)$. Combined with (78) and (79) it follows that asset market clearing at the boom requires

$$\beta(T_v) \leq \log\left(\frac{w_0(T_v)}{w(T_v)}\right) = (1-\alpha)\Gamma_v. \tag{81}$$

Free entry into entrepreneurship ensures that $\beta(T_v) > (1-\alpha)\Gamma_v$ cannot obtain in equilibrium.

Provided that $\beta(t) > 0$, households will never choose to store final output from within a cycle to the beginning of the next either because it is dominated by the long–run rate of return on claims to future profits. However, the return on stored intermediate output in sectors with no entrepreneurial successes is strictly positive, because of the increase in its price that occurs as a result of the boom. If innovative activities are to be financed at time t, it cannot be the case that households are strictly better off buying claims to stored intermediate goods rather than holding claims to firm profits. In sectors with no entrepreneurial success, incumbent firms could sell such

claims, use them to finance greater current production and then store the good to sell at the beginning of the next boom when the price is higher. In this case, since the cost of production is the same whether the good is stored or not, the rate of return on claims to stored intermediates in sector i is $\log p_{i,v+1}/p_{i,v} = (1-\alpha)\Gamma_v$. It follows that the long run rate of return on claims to firm profits an instant prior to the boom must satisfy

$$\beta(T_v) \geq (1-\alpha)\Gamma_v. \tag{82}$$

Free–entry into arbitrage ensures that $\beta(T_v) < (1-\alpha)\Gamma_v$ cannot obtain in equilibrium. Because there is a risk of obsolescence, this condition implies that at any time prior to the boom the expected rate of return on claims to stored intermediates is strictly less than $\beta(t)$. Combining (81) and (82) yields the condition in the statement of the Proposition.∎

Proof of Proposition 5: Substituting for $1 - H_v$ in Proposition 3 using (30), we can express the size of the boom as

$$\Gamma_v = \delta\gamma\Delta_v^E - \delta\gamma\frac{c_v}{k_v^\alpha}\left(\frac{1 - e^{-\frac{\rho}{\sigma}\Delta_v^E}}{\rho/\sigma}\right), \tag{83}$$

Propositions 4 and 2 yield

$$\alpha e^{-(1-\alpha)\gamma}\frac{c_v}{k_v} = \frac{1 - e^{-(1-\alpha)\Gamma_v}}{\left(\frac{1-e^{-\frac{\rho}{\sigma}\Delta_v^E}}{\rho/\sigma}\right)}. \tag{84}$$

Finally, asset market clearing over the boom (conditions (78) to (81)) imply:

$$\delta v_0^I(c_v, c_{v-1}, k_v, k_{v-1}, \Gamma_v, \Gamma_{v-1}, \Delta_v^E, \Delta_v^X) = \frac{w_0(T_{v-1})}{\bar{A}_{v-1}} = (1-\alpha)e^{-(1-\alpha)\gamma}e^{-\alpha\Gamma_{v-1}}k_{v-1}^\alpha, \tag{85}$$

where

$$v_0^I = V_0^I(T_{v-1})/\bar{A}_{v-1} \tag{86}$$

$$= \int_{T_{v-1}}^{T_v^E} e^{-\int_{T_{v-1}}^\tau r(s)ds}\frac{\pi(\tau)}{\bar{A}_{v-1}}d\tau + e^{-\int_{T_{v-1}}^{T_v^E} r(s)ds}\int_{T_v^E}^{T_v}\frac{\pi(\tau)}{\bar{A}_{v-1}}d\tau + P(T_v)\frac{V_0^I(T_v)}{\bar{A}_v}. \tag{87}$$

$$= (1 - e^{-(1-\alpha)\gamma})\left[\int_{T_{v-1}}^{T_v^E} e^{-\int_{T_{v-1}}^\tau r(s)ds}y(\tau)d\tau + e^{-\int_{T_{v-1}}^{T_v^E} r(s)ds}\int_{T_v^E}^{T_v}y(\tau)d\tau\right] + \left(1 - \frac{\Gamma_v}{\gamma}\right)\frac{w_0(T_v)}{\delta\bar{A}_v} \tag{88}$$

$$= (1 - e^{-(1-\alpha)\gamma})e^{-\alpha\Gamma_{v-1}}k_{v-1}^\alpha\int_{T_{v-1}}^{T_v^E} e^{-\int_{T_{v-1}}^\tau r(s)ds}\left(\frac{k(\tau)}{k_0(T_{v-1})}\right)^\alpha d\tau$$

$$+ e^{-\int_{T_{v-1}}^{T_v^E} r(s)ds}\left\{(1 - e^{-(1-\alpha)\gamma})c_v\delta\left(\frac{1 - e^{-\frac{\rho}{\sigma}\Delta_v^E}}{\rho/\sigma}\right)\right.$$

$$\left. + \left[1 - \delta\Delta_v^E + \delta\frac{c_v}{k_v^\alpha}\left(\frac{1 - e^{-\frac{\rho}{\sigma}\Delta_v^E}}{\rho/\sigma}\right)\right](1-\alpha)e^{-(1-\alpha)\gamma}k_v^\alpha\right\}. \tag{89}$$

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Proof of Lemma 5: Due to the unit elasticity of final producer demand, intermediate producing entrepreneurs wish to set price as high as possible. Thus, contracting a lower price at any instant is not optimal for the leader in i. Offering a $p_i^c(t) > p_i(t)$ in any instant would lead to a bid by the previous incumbent that would be both feasible and preferred by the final good producer. Thus $p_i^c(t)$ is the profit maximizing price and $x_i^c(t) = \frac{Y(t)}{p_i^c(t)}$ for all $t \in [T_v, T_{v+1})$.$\blacksquare$

Proof of Proposition 6: Condition (68) can be expressed as

$$\int_t^{T_v} \pi(\tau)d\tau \geq \int_t^{T_v} \overline{q}K(T_v^E)\left(1 - (1 - H_v)e^{-\frac{\rho}{\sigma}(\tau - T_v^E)}\right)d\tau$$

$$(1 - e^{-(1-\alpha)\gamma})Y(T_v^E)\int_t^{T_v}(1 - H_v)e^{-\frac{\rho}{\sigma}(\tau - T_v^E)}d\tau \geq \overline{q}K(T_v^E)\int_t^{T_v}\left(1 - (1 - H_v)e^{-\frac{\rho}{\sigma}(\tau - T_v^E)}\right)d\tau$$

Since $\overline{q}K(T_v^E) = \alpha e^{-(1-\alpha)\gamma}Y(T_v^E)$, this can be expressed as

$$(1 - e^{-(1-\alpha)\gamma})\int_t^{T_v}(1 - H_v)e^{-\frac{\rho}{\sigma}(\tau - T_v^E)}d\tau \geq \alpha e^{-(1-\alpha)\gamma}\int_t^{T_v}\left(1 - (1 - H_v)e^{-\frac{\rho}{\sigma}(\tau - T_v^E)}\right)d\tau$$

$$(1 - (1-\alpha)e^{-(1-\alpha)\gamma})(1 - H_v)\int_t^{T_v}e^{-\frac{\rho}{\sigma}(\tau - T_v^E)}d\tau \geq \alpha e^{-(1-\alpha)\gamma}(T_v - t)$$

Since this holds with equality at $t = T_v$, a sufficient condition is that the left hand side declines more rapidly with t than the right hand side. That is

$$(1 - (1-\alpha)e^{-(1-\alpha)\gamma})(1 - H_v)e^{-\frac{\rho}{\sigma}(t - T_v^E)} > \alpha e^{-(1-\alpha)\gamma} \tag{90}$$

This will hold for all t if holds for $t = T_v$. Hence, condition $(E4)$ follows.$\blacksquare$

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Appendix B: The Acyclical Growth Path

Proposition 7 : *If*

$$\frac{(1 - e^{-(1-\alpha)\gamma})\gamma(1-\sigma)}{1 - \alpha e^{-(1-\alpha)\gamma}} < \frac{\rho}{\delta} \tag{91}$$

then there exists an acyclical equilibrium with a constant growth rate given by

$$g^a = \max\left[\frac{[\delta(1 - e^{-(1-\alpha)\gamma}) - \rho(1-\alpha)e^{-(1-\alpha)\gamma}]\gamma}{1 - \alpha e^{-(1-\alpha)\gamma} - \gamma(1-\sigma)(1-\alpha)e^{-(1-\alpha)\gamma}}, 0\right]. \tag{92}$$

Proof: Substituting for x_i and p_i into (10) yields $K_i = K$, and $L_i = L = 1$ for all i with q and w given by:

$$q(t) = \frac{\alpha e^{-(1-\alpha)\gamma}Y(t)}{K(t)} \tag{93}$$

$$w(t) = (1-\alpha)e^{-(1-\alpha)\gamma}Y(t). \tag{94}$$

Since $q(t) = r(t) > 0$, accumulating capital dominates storage, so that:

$$\dot{K}(t) = Y(t) - C(t), \tag{95}$$

Since all successes are implemented immediately, the aggregate rate of productivity growth is

$$g(t) = \delta\gamma H(t) \tag{96}$$

No–arbitrage implies that

$$r(t) + \delta H(t) = \frac{\pi(t)}{V^I(t)} + \frac{\dot{V}^I(t)}{V^I(t)} \tag{97}$$

Since, innovation occurs in every period, free entry into entrepreneurship implies that

$$\delta V^I(t) = w(t). \tag{98}$$

Along the balanced growth path, all aggregates grow at the rate g. From the Euler equation it follows that

$$r(t) = \rho + \sigma g. \tag{99}$$

Differenting (94) and (98) w.r.t. to time, using these to substitute for $\frac{\dot{V}^I(t)}{V^I(t)}$ in (97), and using (99) to substitute for $r(t)$ and (12) to sustitute for $\pi(t)$, we get

$$\rho + \sigma g + \frac{g}{\gamma} = \frac{\delta(1 - e^{-(1-\alpha)\gamma})}{(1-\alpha)e^{-(1-\alpha)\gamma}} + g. \tag{100}$$

Solving for g yields (92).∎

Appendix C: Simulation Results

Table 2: Comparative Stationary Cycles

Parameters					$k(T_v^E)$	g	Δ
σ	δ	ρ	α	γ			
.79	1.39	.02	.22	.13546	7.668	2.200	3.92
.78					7.577	2.185	1.69
.80					7.743	2.213	5.87
	1.38				7.778	2.191	5.06
	1.40				7.553	2.207	2.65
		.0197			7.565	2.183	1.46
		.0203			7.74	2.213	6.05
			.213		7.332	2.213	5.61
			.227		8.008	2.185	2.08
				.13446	7.843	2.177	5.29
				.13646	7.491	2.221	2.47
.9	1.593				6.574	2.541	5.29
1	1.861				5.407	2.967	4.12

Table 2 lists the numerical implications for growth, cycle length and terminal values of capital stocks for various combinations of parameter values, including the baseline case. A first thing to note is the extreme sensitivity of cycle length, $\Delta = \Delta^X + \Delta^E$, to changes in parameters. In contrast, the long–run growth rate is much less sensitive to changes in parameters than along the acyclical growth path. Generally, increases in parameters that directly raise the impact of entrepreneurship, δ and γ, increase the growth rate, as in the acyclical steady state. Changes in σ and ρ also have effects similar to those present in the acyclical steady state. Additionally, however, changes in these parameters alter cycle length in ways which counterveil, and sometimes overshadow, the direct effects. For example, increasing σ, lowering inter-temporal substitutability, generally induces lower growth in the acyclical steady state because consumers are less willing to delay consumption to the future. A similar effect is present here. However, as the table shows, this increase also raises cycle length and amplitude, inducing more entrepreneurship and a larger boom. The net effect, as the table shows, is an increase in growth rate for this configuration.

Values of σ closer to 1 do not satisfy our existence conditions given the values of other parameters assumed in the baseline case. However, if we allow δ to rise somewhat, higher values of σ are consistent with the cycle (see the last two rows of Table 2). Intuitively, with higher entrepreneurial productivity, both the size of booms and the average growth rate tend to be higher in equilibrium. As a result, households are willing to delay consumption enough even for low elasticities of intertemporal substitution. As can be seen, the long–run growth rate in such cases tends to be higher and the cycles shorter.

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