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Essays on Macroeconomic Policy

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"A journey of a thousand miles begins with a single step"

Old Chinese Proverb

Resumo

Neste trabalho discute-se a política macroeconómica da União Europeia. Construiu-se um modelo estocástico dinâmico de equilíbrio geral com rigidez de preços. Introduziu-se uma nova regra de política monetária para o Banco Central Europeu. O modelo permite quantificar o Bem-Estar Social, relativamente à melhor escolha de regime monetário para os consumidores; ter um Banco Central autónomo ou pertencer à Zona Euro. O modelo foi calibrado para seis países que ainda não aderiram ao Euro, nomeadamente, Dinamarca, Hungria, Polónia, República Checa, Reino Unido e Suécia. Embora dois deles tenham uma cláusula de *opt-out*, as restantes economias terão que no futuro aderir ao Euro. Os resultados são conclusivos, e robustos a variações em parâmetros: todas as economias preferem manter a autonomia da política monetária.

Analisam-se também outras uniões monetárias, tais como Alemanha, Canadá, Suíça e E.U.A., tirando-se inferências para a construção Europeia. São analisadas as correlações regionais de ciclos económicos, e testada a existência de regiões periféricas. As diferenças entre estas economias e a União Europeia são pouco significativas; a construção Europeia em termos das variáveis analisadas parece ser tão viável como a construção das referidas economias. Assim, a perda da autonomia da política monetária, não será um custo tão elevado a suportar.

Palavras-Chave: Política Monetária na Zona Euro, Modelos Dinâmicos e Estocásticos de Equilíbrio Geral, Custos de Bem-Estar de Adesão ao Euro, Níveis de Integração Económica, Sincronização de Ciclos Económicos, Análise de *Clusters*.

Abstract

In this work we discuss the European Union macroeconomic policy. We build a dynamic stochastic general equilibrium model with sticky prices. We introduce a new policy rule for the European Central Bank. The model allows us to quantify the welfare value, regarding the best choice of monetary regime for consumers; having an autonomous Central Bank or belonging to the Eurozone. The model was calibrated for six countries currently outside the Eurozone: Czech Republic, Denmark, Hungary, Poland, Sweden, and the United Kingdom. Although two of them have an opt-clause, the remaining economies will have to join the euro in the future. Results are clear and robust to parameter changes; all economies prefer to keep monetary policy autonomy.

We analyze other monetary unions, such as Canada, Germany, Switzerland, and the United States and infer some results for the European Union. We analyze regional business cycles correlations and test the existence of periphery regions. The differences between these economies and the European Union aren't very significant. The European construction process, at least in terms of the analyzed variables, seems to be as viable as the referred economies. Hence, the loss of the monetary policy autonomy will not be such a heavy burden.

Keywords: Monetary Policy in the Eurozone, Dynamic General Equilibrium Models, Welfare Costs of Joining the Euro, Levels of Economic Integration, Business Cycle Synchronization, Cluster Analysis.

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The usual disclaimer applies.

Contents

Preface

In this work we discuss the macroeconomic consequences of the Euro on its member countries and analyze some of the business cycles properties of the economies belonging to this economic integration bloc. This topic is related to the optimum currency area literature initiated with seminal papers by Mundell (1961), Mackinnon (1963), and Kenen (1969).

The never ending discussion about European Union enlargement and also about its deepening makes this topic very actual and also very useful. Although it is a very discussed and important issue, the literature reveals some missing aspects to be studied. In this work we try to fill one of these voids by quantifying the costs of the loss of monetary policy flexibility.

Monetary policy is one important short run instrument to stabilize the economy. If the business cycle of a member country of the Eurozone is not strongly correlated with the remaining members, a common monetary policy could have the wrong effects for that economy, and hence the loss of the monetary policy instrument is bigger in this case. The European Central Bank does not look at the situation in each country when it decides whether or not to change the nominal interest rate; rather it looks at an aggregate for the Eurozone.

In face of these arguments, the study of business cycle correlations for these countries is also an important matter to take in hands. In this case, we choose to compare the evolution of the business cycle features of the European Union with other economies, that have been through a similar monetary unification process; and have already move to the next integration step, federalism.

We build a dynamic stochastic general equilibrium model with sticky prices and technological, government consumption, and monetary shocks, in the tradition of Chari, Kehoe, and McGrattan (2002a). We introduce a new monetary policy rule for the European Central Bank, which is a weighted average Taylor rule, with economic weight by country in the inflation rate and in the output. The model allows us to quantify the welfare value, in percentage of consumption, relative to the best monetary regime for consumers. Consumers have to choose between two monetary regimes: to have an Autonomous Monetary Policy with the ability to stabilize the economy of its own country or leaving monetary policy in the hands of the European Central Bank, a regime we called Common Monetary Policy.

The model was calibrated for six countries currently outside the Eurozone, namely: Czech Republic, Denmark, Hungary, Poland, Sweden, and the United Kingdom. Although two of them have an opt-out clause, the remaining economies will have to join the European currency, sometime in the future.

We simulated the model with the two alternative monetary policy regimes referred. The first regime, Autonomous Monetary Policy is a simulation where the National Central Bank is autonomous in its decisions. In the second regime the European Central Bank is the monetary authority responsible for monetary policy and the National Central Bank looses the ability to stabilize the economy in the short run. With the simulation values, we can compare in terms of welfare, the amount of consumption that consumers are willing to give (or to receive) in order to stay indifferent between the two regimes. This is equivalent to calculate the compensating variation, associated with the full elimination of the Autonomous Monetary Policy regime.

Simulation results are significant and robust to changes in some chosen relevant parameters: All economies prefer to keep monetary policy autonomy, and keep an important macroeconomic stabilization instrument. From the results, some striking facts appear. Transition countries, namely, Czech Republic, Hungary, and Poland have a smaller cost of joining the European and Monetary Union (EMU) then developed countries, as it is the case of Denmark, Sweden, and the United Kingdom. The first group of countries are small open economies and very dependent on trade with the Eurozone. This last feature seems to favour the accession to the Eurozone. Hence, a higher trade share decreases entry costs to the EMU for Eastern and Central Europe countries. Other factors influence positively the cost of the loss of monetary policy autonomy for most of the economies at study, namely, the existence of technological shocks and a high risk aversion. We made other experiences, like testing the importance of government consumption shocks, but results are less striking for the economies at study.

We compare monetary unions that move to federalism, like Canada, Germany, Switzerland, and the United States of America and take some inference for the European Union construction process. We analyze the evolution of the regional business cycles correlations, through a rolling windows analysis technique, and also test the existence of core and periphery regions, by using cluster analysis.

Differences between these economies and the European Union are not very significative. The European integration process seems as reasonable as the previous monetary unification processes for these economies, at least in terms of the analyzed variables.

The average regional correlations for each monetary union have frequently been declining, and the standard-deviations for those correlations have frequently been increasing. This increase in standard-deviations means that dispersion between regions of the same country is wider. In Federal States, with the possibility to give federal grants aid to its regions, we would expect that disparities between regions to be not very significative and cyclical correlations to be high.

Even in the cases of reunified Germany and the European Union, that are the most recent integration processes, although correlations do not present yet a clear decreasing trend, the dispersion between regions, countries in the case of the European Union, has a growing trend. The European Union, in the last enlargement to the East and Central Europe, already presents signs of a trend inversion for the correlations, reflecting differences between stages of evolution between old and new members.

Results of the rolling windows technique, that present an apparent decline in average regional correlations and an increase in the standard-deviations of those correlations, seem to point to the existence of some dispersion between the regions of the monetary unions at study. This dispersion can have several causes, among them a possible separation between core and periphery regions. It's this possibility that we analyze using cluster analysis.

Cluster analysis did not reveal a clear pattern of core-periphery for the regions of the majority of the analyzed monetary unions. The German case presents a clear division between regions of Western and Eastern Germany, due to recent historical events. Cluster formation in the other monetary unions under study, with the exception of the European Union, seems to be made by geographical proximity. But, cluster evolution shows that regions that are part of the same cluster, are close, but are not the same through out time, so no clear pattern stands out.

In the case of the European Union, cluster formation does not show any clear pattern, but isolates most of the new members from the old ones. However, it puts new members in several clusters and not in a single one, making evident the weak correlations between these economies, due, as obvious, to their transition processes. Old members belong in its majority to the clusters where correlations are higher. Portugal and Spain, after accession, in 1986, present strong positive cyclical correlations and always belong to the same cluster, an event that did not occur before. Some of the old members present some specificities in some moments of time, namely, Germany, in the last periods appears isolated from the core of the founding members of the European Union; Ireland due to its strong growth in the 90's and previous crisis in the decades before that, sometimes appears isolated. Denmark also presents a behavior different from other member countries in the analyzed period.

Hence, and taking in account the results presented in what concerns the rolling windows and cluster analysis techniques, the loss of autonomy of monetary policy will not be such a heavy burden on future member countries. The federal monetary unions at study, in special the USA and Canada, present very high bilateral correlations in the beginning of the sample, but in the last years the values for bilateral correlations are similar to the values found for the European Union. Cluster analysis shows that in the monetary unions analyzed, including the European and Monetary Union, does not seem to exist a strong evidence of a core-periphery pattern.

Since federal monetary unions seem to live well with their regional business cycles features and with a common monetary policy, does not seem to exist any reason the same can not happen in the European and Monetary Union, at least in what concerns the topics studied in this work. The European Union does not have a system of federal transfers to its member countries, but regarding the variables at study, this fact does not seems to influence the results, since they are similar.

Of course that questions of national sovereignty and political power have an important weight on decision of joining or not, and the economic weight of the country in the world economy is also an important factor. Other important socioeconomic factors as labor market regulations and specialization of the economies, among others, are also very important in the decision.

Chapter 1

A Dynamic Stochastic General Equilibrium Model (DSGEM) to Quantify the Welfare Loss of the EMU

1.1 Introduction

In this chapter we construct a dynamic stochastic general equilibrium model (DSGEM) to study the problem of the loss of monetary policy flexibility associated with the European and Monetary Union (EMU). The model is then being used to perform a welfare analysis and to compare between alternative monetary policy regimes, which is done in the next chapter.

In the model used in this work monetary policy has real effects in the economy, because sticky prices are introduced in the model, making agents slower in adjusting to monetary shocks. Hence, in this model, monetary policy can be useful as a short run economic policy. In the model, consumers are faced with two types of monetary policy regimes: (1) one in which the monetary policy is established by the European Central Bank (ECB), that only considers the (weighted) average economic situation of the Eurozone, which we call *Common Monetary Policy*, and (2) a monetary policy established by the National Central Bank of each of the countries under study, in which the National Central Bank only cares about the economic situation of the domestic economy, designated by *Autonomous*

Monetary Policy. The way we formalize the first monetary policy regime is an innovation in this type of models and gives a more realistic modelling of the monetary policy rule of the ECB. Holtemöller (2005) uses a monetary policy rule similar to the one we use for the ECB, but in a different economic framework. His framework does not allow him to perform welfare analysis, and this is the goal of the second chapter of this work.

General equilibrium models with nominal rigidities have been used to study the problem of the loss of independence of monetary policy, usually using extensions of the Obstfeld and Rogoff (1995) model. The referred model is used to compare between an autonomous monetary regime (multiple currencies and different monetary policies) and a monetary union. The model, in a two country framework, has been used to assess the consequences on individual welfare of the loss of exchange rate flexibility, when facing asymmetric shocks. Some conclusions drawn for the French economy, find that in the presence of asymmetric permanent shocks to either technology or government expenditures, it is beneficial to households living in the country hit by an asymmetric shock to join a monetary union (Carré and Collard, 2003). Other conclusions state that entry is welfare improving the smaller the country, the smaller the correlation of technological shocks between countries, the higher the variance of real exchange rate shocks, the larger the difference between the volatility of technological shocks across member countries, and the larger the gain in potential output, compared with the gain in potential output of a flexible exchange rate regime (Ca'Zorzi, Santis, and Zampolli, 2005).

When used to study the costs in terms of stabilization and welfare of joining a currency union, the class of models mentioned in the paragraph above, reveals that countries face a trade-off when joining a monetary union between higher instability in output and lower instability in inflation, and that this trade-off improves with the degree of cross-country symmetry of supply and demand shocks. These results lead to the conclusion that maintaining the monetary stabilization possibility proves to be always welfare improving, independently of the changes in the correlation and type of shocks (Monacelli, 2000).

To see the study of this subject in limited participation models the works of Cooley and Quadrini (2003), Metz (2004), and Furstenberg and Teolis (2002) are good references.

In the context of game theory see Hallet and Weymak (2002) and Monticelli (2003). For models with optimal linear feedback Taylor rules see Grauwe, Dewachter, and Aksoy (2002). Their results imply different conclusions about joining a currency union, with results depending, among others, on the degree of commitment to reducing inflation, on the number of countries and on the idiosyncrasy, type, and degree of correlation of the shocks.

This model tries to unify two types of literature: the optimum currency areas literature with seminal work by Mundell (1961), MacKinnon (1963), and Kenen (1969) and the dynamic stochastic general equilibrium models (DSGEM) literature in the tradition of Svensson and Wijnbergen (1989), Obstfeld and Rogoff (1995, 1998), and Chari, Kehoe, and McGrattan (2002a).[1]

In section 1.2 we present the model and in section 1.3 we show and discuss impulse response functions for the different shocks that economies face and for the two alternative monetary policy regimes. Section 1.4 concludes. In appendix, in section 1.5 of this chapter, we present the details of the first order conditions (FOC).

1.2 The Model

We developed a dynamic equilibrium model in the tradition of Chari, Kehoe, and McGrattan (2002a), but modified it to take into account an interest rate rule similar to that suggested by Taylor (1993), but that also allows for forward looking behavior. This setting permits us to construct a detailed quantitative analysis for the behavior of the main macroeconomic variables and, more importantly, to quantify the welfare gain associated with the various policy choices, which will be done in the next chapter.

There are two countries in the model with infinitely lived consumers and also competitive final goods producers and monopolistically competitive intermediate goods producers. This last group of agents sells their products to the final goods producers; the latter type of goods is non-traded. Trade between economies is in intermediate goods, produced by

[1]See Goodfriend and King (1997), Clarida, Gali, and Gertler (1999), and Lane (2001) for surveys on the topic of open economy macroeconomics models.

monopolists who can charge different prices in two countries.[2] Intermediate goods prices are set on local market currency, each producer having the right to sell his goods in the two countries. Final goods price are also set in units of domestic currency. Once prices are set, each intermediate goods producer must satisfy his demand.

The following goods exist in the economy in each period; labor, capital, real money balances and a continuum of intermediate goods indexed by $i \in [0,1]$ produced in the home country H, and a continuum of intermediate goods indexed by $i \in [0,1]$ produced in the foreign country F, which will be regarded as the EMU.

1.2.1 Consumers

In each period $t = 0, 1, ...$, consumers choose their allocations, facing the following budget constraints:

$$\begin{aligned} & P_t c_t + M_t + E_{t+1} Q_t B_{t+1} \\ \leq \quad & P_t W_t l_t + M_{t-1} + T_t + Q_{t-1} B_t + \Pi_t \end{aligned} \tag{1.1}$$

where c_t, l_t and M_t are respectively, consumption, labor and money, T_t are transfers of home currency, Π_t represents profits of the home country intermediate goods producers, P_t is the price of the final good and W_t represents real wages. The initial conditions M_{-1} and B_0 are given.

In this economy markets are complete. The asset structure is represented by having a set of government bonds designated B_t, which represents a vector of state contingent securities. B_t^* is the foreign consumers' holdings of this bond. Q_t is the vector of state contingent prices for the bonds.

Consumers choose consumption, labor, real money balances, and bond holdings to maximize their utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, l_t, M_t/P_t\right) \tag{1.2}$$

subject to the consumer budget constraints, where β is the discount factor.

[2] Knetter (1989, 1993) has some empirical studies on pricing to market.

1.2.2 Final Goods Producers

In country H final goods are produced from intermediate goods through the following production function:

$$y_t = \left[a_1 \left(\int_0^1 (y_{i,t}^H)^\theta di \right)^{\frac{\rho}{\theta}} + a_2 \left(\int_0^1 (y_{i,t}^F)^\theta di \right)^{\frac{\rho}{\theta}} \right]^{1/\rho} \tag{1.3}$$

where y_t is the final good and $y_{i,t}^H$ and $y_{i,t}^F$ are intermediate goods produced in H and F, respectively. This production function combines characteristics from trade and industrial organization theory, as in the works of Armington (1969) and Dixit and Stiglitz (1977). Parameter θ determines the mark-up of price over marginal cost (θ is the elasticity of substitution between goods produced in the same country, representing the market power of producers); ρ along with θ, determine the elasticity of substitution between home and foreign goods. Parameters a_1 and a_2, combined with θ and ρ, determine the ratio of imports to output.

Final goods producers behave in a competitive way in each period t, choosing inputs $y_{i,t}^H$ for $i \in [0, 1]$ and $y_{i,t}^F$ for $i \in [0, 1]$ and y_t to maximize profits subject to (1.3). Prices are expressed in units of domestic currency. Price of intermediate goods produced at home and at the foreign economy, P_{t-1}^H and P_{t-1}^F, respectively, can at most depend on $t-1$, because producers set prices before period t. Factor demand functions are calculated by the resolution of the maximization problem and have the following expressions:

$$y_{i,t}^H = \frac{[a_1 P_t]^{\frac{1}{1-\rho}} \overline{P}_{t-1}^{H\,\frac{\rho-\theta}{(1-\rho)(\theta-1)}}}{P_{i,t-1}^{H\,\frac{1}{1-\theta}}} y_t \tag{1.4}$$

$$y_{i,t}^F = \frac{[a_2 P_t]^{\frac{1}{1-\rho}} \overline{P}_{t-1}^{F\,\frac{\rho-\theta}{(1-\rho)(\theta-1)}}}{P_{i,t-1}^{F\,\frac{1}{1-\theta}}} y_t \tag{1.5}$$

where $\overline{P}_{t-1}^H$ is the average price of inputs and is equal to:

$$\overline{P}_{t-1}^H = \left(\int_0^1 P_{i,t-1}^{H\,\frac{1}{1-\theta}} di \right)^{\frac{\theta-1}{\theta}}$$

and $\overline{P}^F_{t-1}$ is equal to:

$$\overline{P}^F_{t-1} = \left(\int_0^1 P^F_{i,t-1}{}^{\frac{1}{1-\theta}} di \right)^{\frac{\theta-1}{\theta}}$$

since all producers behave competitively, their economic profit is zero, and the final good price is given by:

$$P_t = \left(a_1^{\frac{1}{1-\rho}} \overline{P}^H_{t-1}{}^{\frac{\rho}{\rho-1}} + a_2^{\frac{1}{1-\rho}} \overline{P}^F_{t-1}{}^{\frac{\rho}{\rho-1}} \right)^{\frac{\rho}{\rho-1}} \tag{1.6}$$

which is independent of period t shocks.

1.2.3 Intermediate Goods Producers

Each intermediate good i, is produced according to a standard constant returns to scale production function:

$$y^H_{i,t} + y^{H*}_{i,t} = F\left(k_{i,t-1}, A_t l_{i,t}\right) \tag{1.7}$$

where $k_{i,t-1}$ and A_t are respectively capital and technology used in the production of the good, and $y^H_{i,t}$ and $y^{H*}_{i,t}$ are the quantities of the intermediate good produced in H, used in the production of the final good in country H and F, respectively. The law of motion for capital is given by:

$$k_{i,t} = (1-\delta)\, k_{i,t-1} + I_{i,t} - \phi\left(\frac{I_{i,t}}{k_{i,t-1}}\right) k_{i,t-1} \tag{1.8}$$

where $I_{i,t}$ is investment, function $\phi(.)$ represents adjustment costs, and δ is the depreciation rate. The initial capital stock $k_{i,-1}$ is given and is the same for all producers in this group. The adjustment cost function has the following expression:

$$\phi\left(\frac{I}{k}\right) = b\left(\frac{I}{k} - \delta\right)^2 /2 \tag{1.9}$$

the function is convex and satisfies the conditions $f(\delta) = 0$ and $f'(\delta) = 0$, implying that total and marginal costs of adjustment in steady-state are zero. b is the adjustment costs parameter.

Intermediate producers behave as imperfect competitors, setting their prices in a staggered way. Staggered price setting was first introduced by Fischer (1977), Phelps and Taylor (1977), and Taylor (1980). This model follows the specification of Taylor (1980). Introducing monopolists in this model is justified by a strand of research, which revealed the importance of a monopolistic sector in explaining such economic problems as economic growth or business cycles, as in the works of Calvo (1983), Betts and Devereux (2000), and Kollmann (2001). As usual this monopolistic setting ensures that output is determined by demand, at least in the short term when prices are fixed. Specifically, at the beginning of each period t a fraction $1/N$ of producers in H choose a home currency price $P^H_{i,t-1}$ for the home market and a price for the foreign market. As these prices are set for N periods, for this group of intermediate goods producers: $P^H_{i,t+\tau-1} = P^H_{i,t-1}$ and $P^{H^*}_{i,t+\tau-1} = P^{H^*}_{i,t-1}$ for $\tau = 0, ..., N-1$. Intermediate goods producers are indexed so that those with $i \in [0, 1/N]$ set prices in $0, N, 2N$, and so on, while those with $i \in [1/N, 2/N]$ set prices in $1, N+1, 2N+1$, and so on, for the N groups of intermediate producers. One possible justification for the existence of price rigidity is found in the menu costs theory developed by Akerlof and Yellen (1985) and Mankiw (1985).

Consider, for example, producers in a group, namely $i \in [0, 1/N]$, who choose prices $P^H_{i,t-1}$ and $P^{H^*}_{i,t-1}$, production factors $l_{i,t}$, $k_{i,t}$ and $I_{i,t}$ to solve the following problem:

$$\max E_0 \sum_{t=0}^{\infty} Q_t [P^H_{i,t-1} y^H_{i,t} + \\ + e_t P^{H^*}_{i,t-1} y^{H^*}_{i,t} - P_t W_t l_{i,t} - P_t I_{i,t}] \tag{1.10}$$

subject to (1.7), (1.8), and the constraints that their supplies to home and foreign markets, $y^H_{i,t}$ and $y^{H^*}_{i,t}$, must equal the amount demanded by home and foreign final goods producers, from equation (1.4) and analogue for F (equation (1.5)). Another constraint implies that prices are set for N periods. e_t is the nominal exchange rate. Optimal prices for $t = 0, N, 2N$ and so on, are:

$$P_{i,t-1}^{H}=\frac{\sum\limits_{\tau=t}^{t+N-1} E_\tau Q_\tau P_\tau v_{i,\tau}\Lambda_\tau^{H}}{\theta\sum\limits_{\tau=t}^{t+N-1} E_\tau Q_\tau \Lambda_\tau^{H}}$$

$$P_{i,t-1}^{H^*}=\frac{\sum\limits_{\tau=t}^{t+N-1} E_\tau Q_\tau P_\tau v_{i,\tau}\Lambda_\tau^{H^*}}{\theta\sum\limits_{\tau=t}^{t+N-1} E_\tau Q_\tau e_\tau \Lambda_\tau^{H^*}}$$

where $v_{i,t}$ is the real unit cost which is equal to the wage rate divided by the marginal product of labor, $W_t/F_{i,t}^{l}A_t$ and:

$$\Lambda_t^{H}=[a_1P_t]^{\frac{1}{1-\rho}}\,\overline{P}_{t-1}^{H}{}^{\frac{\rho-\theta}{(1-\rho)(\theta-1)}}y_t$$

$$\Lambda_t^{H^*}=[a_2P_t^*]^{\frac{1}{1-\rho}}\,\overline{P}_{t-1}^{H^*}{}^{\frac{\rho-\theta}{(1-\rho)(\theta-1)}}y_t^*$$

in a symmetric steady-state real unit costs are equal across firms, hence, in this steady state these formulas reduce to $P_i^{H}=P_i^{H^*}=Pv/\theta$, so that the law of one price holds for each good and prices are set as a mark-up $(1/\theta)$ over marginal costs Pv.

1.2.4 Technological Shocks

The technological shocks A_t and A_t^* are common to all intermediate goods producers of each country, following a stochastic $AR[1]$ process:

$$\log A_{t+1}=\rho^{A}\log A_t+\varepsilon_{t+1}^{A} \tag{1.11}$$

and

$$\log A_{t+1}^{*}=\rho^{A}\log A_t^{*}+\varepsilon_{t+1}^{A^*} \tag{1.12}$$

where technological innovations ε^{A} and ε^{A^*} have a normal distribution, with zero mean, σ^{A} standard deviation and are cross-country correlated, but are not correlated with the monetary and government consumption shocks described below.

1.2.5 Government Consumption Shocks

In the context of dynamic general equilibrium models with sticky prices, output in the short run is demand driven. Demand side shocks are usually represented by taste shocks. These shocks usually affect the consumption of tradable and non tradable goods. Government consumption consists mostly of non-traded goods; which in this particular model are final goods. Hence, in a large proportion, government spending shocks can be a substitute for taste shocks. Therefore in this model we used government consumption shocks to represent demand shocks. Government consumption shocks are modelled as $AR[1]$ processes, with the following expressions:

$$\log g_{t+1} = (1 - \rho^g)\, \mu^g + \rho^g \log g_t + \varepsilon^g_{t+1} \tag{1.13}$$

and

$$\log g^*_{t+1} = (1 - \rho^g)\, \mu^g + \rho^g \log g^*_t + \varepsilon^{g^*}_{t+1} \tag{1.14}$$

where government shocks ε^g and ε^{g^*} have a normal distribution, with μ^g mean, σ^g standard deviation. These shocks are not correlated with monetary shocks, with technological shocks, or with the foreign government consumption shocks.

1.2.6 Monetary Authority

Several empirical papers have shown that the Taylor rule seems to replicate in an accurate way the monetary policy rule of central Banks throughout the world, namely Taylor (1993). Clarida, Gali, and Gertler (1999) state that the Taylor Rule is consistent with the principles for optimal monetary policy, because implies the convergence of inflation to its target over time, also implies that the nominal interest rate adjusts more than one for one with the inflation rate, and finally the rule suggests that the policy maker should offset demand shocks and accommodate supply shocks, since these type of shocks do not affect the output gap, because they simultaneously affect effective and potential output.

For our benchmark case we assume that the Central Bank of country H uses a forward looking Taylor type interest rate rule formulated by Clarida, Gali and, Gertler (2000), represented by:

$$r_t^N = \rho^r r_{t-1}^N + (1-\rho^r)[\rho^\pi \pi_{t+1} + \rho^o O_t] + \varepsilon_t^{r^N} \tag{1.15}$$

where r_t^N is the nominal interest rate in period t for the domestic economy, $(\pi_{t+1} = \frac{P_{t+1}}{P_t} - 1)$ is the inflation rate between period t and $t+1$ for the domestic economy and O_t is the real gross domestic product at t of the domestic economy. $\varepsilon_t^{r^N}$ are shocks with a normal distribution, zero average, σ^{r^N} standard deviation and positive cross-country correlation. If $\rho^r > 0$ the rule exhibits some degree of inertia, as the Central Bank does not fully adjust to current changes in the economy.

Interest rates in country F, the Eurozone, are set according to the rule:

$$\begin{aligned} r_t^{N^*} &= \rho^r r_{t-1}^{N^*} + (1-\rho^r)[\varpi \rho^\pi \pi_{t+1} + (1-\varpi)\rho^\pi \pi_{t+1}^* + \\ &\quad + \varpi \rho^o O_t + (1-\varpi)\rho^o O_t^*] + \varepsilon_t^{r^{N^*}} \end{aligned} \tag{1.16}$$

where ϖ is the weight of the home country's GDP in the Eurozone. For the benchmark case, when the home country is outside the EMU (*Autonomous Monetary Policy*), we set $\varpi = 0$. $r_t^{N^*}$ is the nominal interest rate in period t for the foreign economy (representing the Eurozone), $(\pi_{t+1}^* = \frac{P_{t+1}^*}{P_t} - 1)$ is the inflation rate between period t and $t+1$ for the Eurozone and O_t^* is the real gross domestic product at t of the Eurozone. As usual we allow for monetary policy shocks $\varepsilon_t^{r^{N^*}}$ with a normal distribution, zero average, $\sigma^{r^{N^*}}$ standard deviation. When we use the Taylor rule of the ECB as the policy rule (*Common Monetary Policy*), the domestic economy has no monetary policy authority; we therefore imposed the following restriction on the nominal interest rate:

$$r_t^N = r_t^{N^*} \tag{1.17}$$

which replaces (1.15).

New money balances of the home currency are distributed to consumers in the home country in a lump-sum fashion by having transfers satisfy:

$$P_t g_t + T_t = M_t - M_{t-1} \tag{1.18}$$

this last equation represents the home government budget constraint, where g is government consumption.

1.2.7 Equilibrium Conditions

All maximization problems for country F are analogous to these problems, where the allocations and prices in the foreign country are denoted with an asterisk. An equilibrium requires several market-clearing conditions. The resource constraint in the home country is given by:

$$y_t = c_t + g_t + \int_0^1 I_{i,t} di \tag{1.19}$$

The labor market-clearing condition is:

$$l_t = \int l_{i,t} di \tag{1.20}$$

similar conditions hold for the foreign country. The market-clearing condition for contingent bonds is:

$$B_t + B_t^* = 0 \tag{1.21}$$

The state of the economy when monopolists make their pricing decisions (previously of period t) must record the capital stocks for a representative monopolist in each group in the two countries, the prices set by the other $N-1$ groups in both countries, and the period $t-1$ monetary shock, but not period t monetary shock, and period t and $t-1$ technological and government consumption shocks. Period $t-1$ shocks help forecast the shocks in period t and current shocks are included in the state of the economy when the remaining decisions are taken. Consumers and final good producers know current and past realizations of shocks. Monopolists know the past and current realizations of technological and government consumption shocks, but only know past realizations of monetary shocks. Different timing assumptions lead to similar conclusions.

Several procedures are necessary to solve the model: First, to make economies stationary we deflate all first order conditions for the nominal variables by the growth rate of prices mu; second, we derive the steady state equations and conditions for some stationary variables; third, we apply logs and linearize the first order conditions around the steady state, and finally we solve the system of equations. We use the Blanchard and Kahn (1980) approach to solve the model.

We use a first order Taylor expansion log-linearized around the steady state. Several authors suggest that first order Taylor expansions may produce welfare reverse ordering, for example in situations where we want to compare different types of economic regimes (incomplete markets with complete markets for instance). See Sims (2002), Kim and Kim (2003), and Schmitt-Grohé and Uribe (2004) for discussions on this problem. That is not the case here, with the only difference being the policy rule of the Central Bank. Besides, computational costs can increase substantially as the order of the Taylor expansion increases. There are few specific literature references about higher order expansions and some approaches can in fact result in the accumulation of useless higher order terms.

1.3 Impulse Response Functions

In this section we explain in detail the behavior of the benchmark economies in the presence of shocks, by using impulse response functions for the three types of shocks of the model. We discuss the impact of government consumption, technological, and monetary policy shocks in the context of the two monetary policy regimes stated above, namely *Common Monetary Policy* and *Autonomous Monetary Policy*. This analysis will allow us to evaluate the usefulness of the model for the purpose of the next chapter, and also to explain in detail the behavior of the economies in the presence of shocks and for the two monetary policy regimes. The three subsections below analyze the behavior of the economies in the presence of negative shocks: first, a recession caused by a negative government consumption shock in economy H; second, a recession caused by a negative technological shock in economy H, and finally a recession caused by a positive shock in monetary policy, i.e., an increase in the nominal interest rate.[3]

Variables in the figures presented below are real consumption (C), real investment

[3] In this section we use specific parameter values for Czech Republic, that are calculated in Chapter 2, to calibrate the model.

(I), real output (Y), money (M), prices (P), labor (L), nominal interest rate (R), and net exports in percentage of GDP ($\frac{NX}{Y}$). The superscript $*$ identifies foreign variables. Impulse response functions represent deviations from the steady-state values, except in the cases of the nominal interest rates.

1.3.1 Government Consumption Shocks

Figure 1.1 shows impulse response functions for a negative government consumption shock in the *Common Monetary Policy* regime. When a negative government consumption shock hits the domestic economy, output decreases initially in the first period and labor falls in the first six periods. In contrast, a decrease in government consumption makes private consumption increase. This effect results from the fact that consumers expect net taxes to decrease after a fall in government consumption, and therefore they increase present consumption.

Labor falls because consumption increases for the same level of work; this is caused by the anticipated increase in wealth (due to the expected fall in taxes), but most of all because firms have reduced production and therefore need fewer workers.

The movements of domestic and foreign consumption and investment are closely correlated because they follow the same interest rate when making their decisions and also because the calibrated trade share between the country and the foreign economy (the Eurozone) is large; this leads to a close correlation between the movements of output and hence of the production factors.

Because consumption and investment rise, output also begins to increase after the first period, due to the rise in demand for the final good. Final good producers increase their demand for intermediate goods in order to satisfy the increasing demand for the final good.

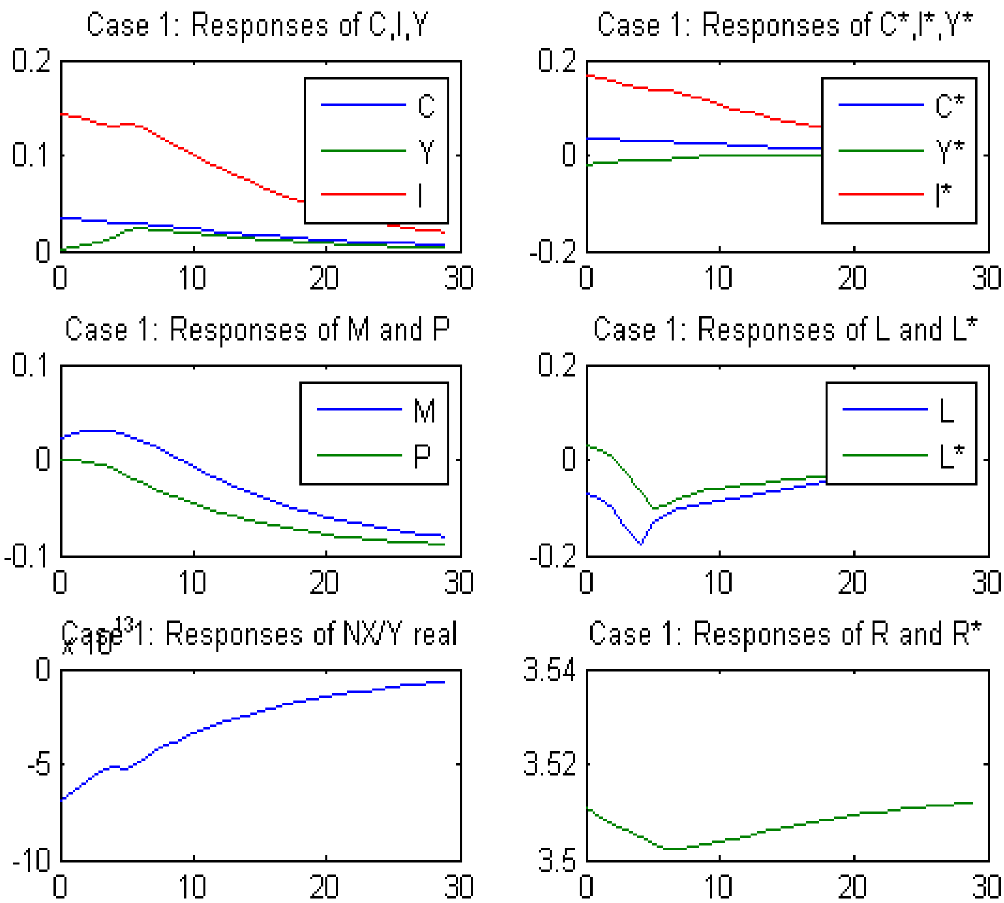
Prices of the final good fall, both in the domestic economy and in the foreign economy. Final goods price in the foreign economy decreases as a result of higher labor supply which makes the marginal utility of work decrease thus reducing marginal costs; hence, prices of intermediate goods that influence the price of the final goods also go down.

The interest rate also begins to increase after some periods, gradually lowering investment and consumption, leading to even greater reductions in prices, due to the decrease in demand. The nominal interest rate decreases in the first period because output and prices have decreased in both the foreign and domestic economy. A lower interest rate in the first period and a higher consumption level push money demand up. When the interest rate starts to increase, money demand and consumption decrease.

Exports movements depend on consumption and investment related movements. Due to the existence of complete markets, the risk sharing effect prevails and exports decrease initially. The domestic economy is borrowing resources from the foreign economy, triggering higher consumption in both economies.

The increase in the demand for intermediate goods in the domestic economy is extended to the foreign economy, so intermediate goods producers in that economy begin to produce more goods, hire more workers, and use more capital. Output in this economy also rises. When goods start being exported to the domestic economy, the surplus in the trade balance starts to decrease.

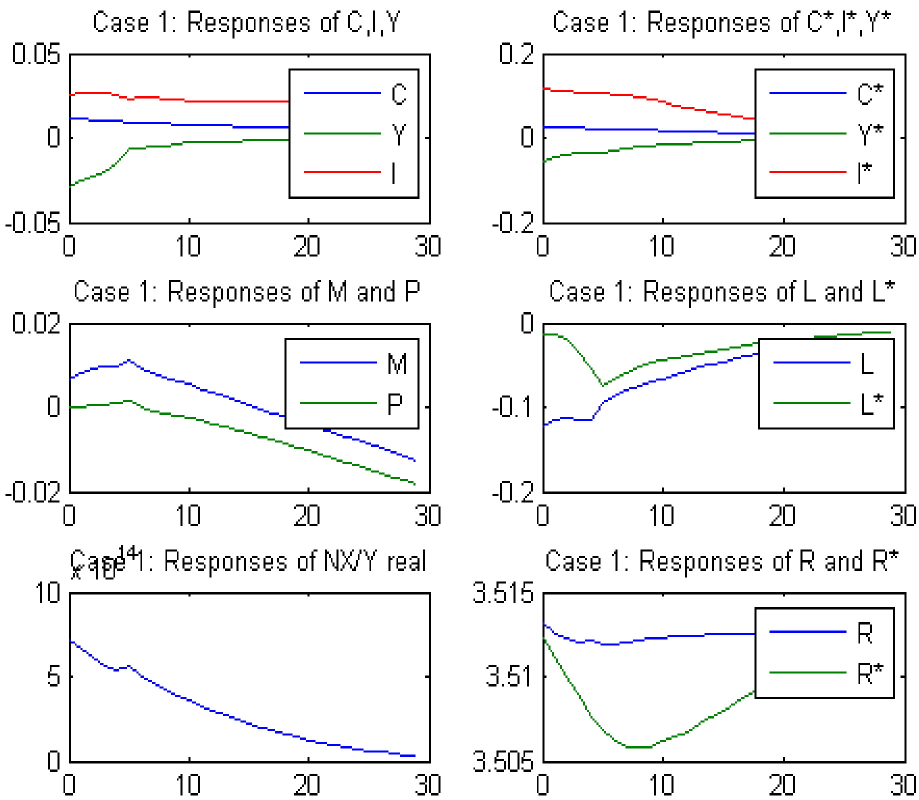
Figure 1.1: *Common Monetary Policy* - Government Shock



In the *Autonomous Monetary Policy* regime, a negative shock in government consumption has almost the same effects as in the previous regime, except in the behavior of the domestic final good price and the domestic nominal interest rate, like can be seen in Figure 1.2. Final goods producers buy intermediate goods at a higher price, so they will also charge a higher final good price. Intermediate goods producers from the foreign economy anticipate an increase in demand after output in the domestic economy starts going up again, and raise the price of intermediate goods, hence also increasing the price of the final good. They can put the price up, if the share of imports in the domestic economy is high, as it is the case for the calibration chosen, since the domestic economy is more dependent on foreign intermediate goods.

The nominal domestic interest rate falls in the first periods, because output has decreased, although prices have increased. The drop in the interest rate does not happen for as many periods as in the previous regime, because of the increase in prices in the domestic economy. The movements of domestic and foreign consumption and investment are negatively correlated because the changes in their respective nominal interest rates are the opposite, with the domestic interest rate decreasing in the final periods and the foreign rate increasing.

Figure 1.2: *Autonomous Monetary Policy* - Government Shock



1.3.2 Technological Shocks

The difference between *Common Monetary Policy* and *Autonomous Monetary Policy* regarding technological shocks relies mainly in the behavior of net exports, as can be seen in Figures 1.3 and 1.4 below. In the first regime net exports increase, while falling in the second regime. In the first regime H is selling goods to F, since output in the foreign economy increases slightly, because the common nominal interest rate decreases in response to the negative domestic technological shock, increasing demand for both domestic and foreign intermediate goods.

When monetary policy is governed by the National Central Bank, the domestic nominal interest rate decreases by more when the negative domestic technological shock occurs and decreases domestic output, since it responds more to the conditions of the domestic economy. Domestic consumption and investment increase more in this regime and the domestic economy is borrowing resources from the foreign economy.

A negative technological shock affects significantly the behavior of labor, that increases, contrary to what happens in the negative government consumption shock. Labor behavior depends on the substitution and income effects. As a result of diminishing wages, leisure becomes a cheaper good which means that workers trade work for leisure due to the substitution effect. On the other hand, the income effect leads to a labor increase because workers' purchasing power has fallen. Given the choice of parameters for this model, labor increased because the income effect is greater. Employees go to work more to compensate their lost income. The loss of productivity and the increase in labor make both marginal costs and prices increase slightly, when the shock hits the economy.

Figure 1.3: *Common Monetary Policy* - Technological Shock

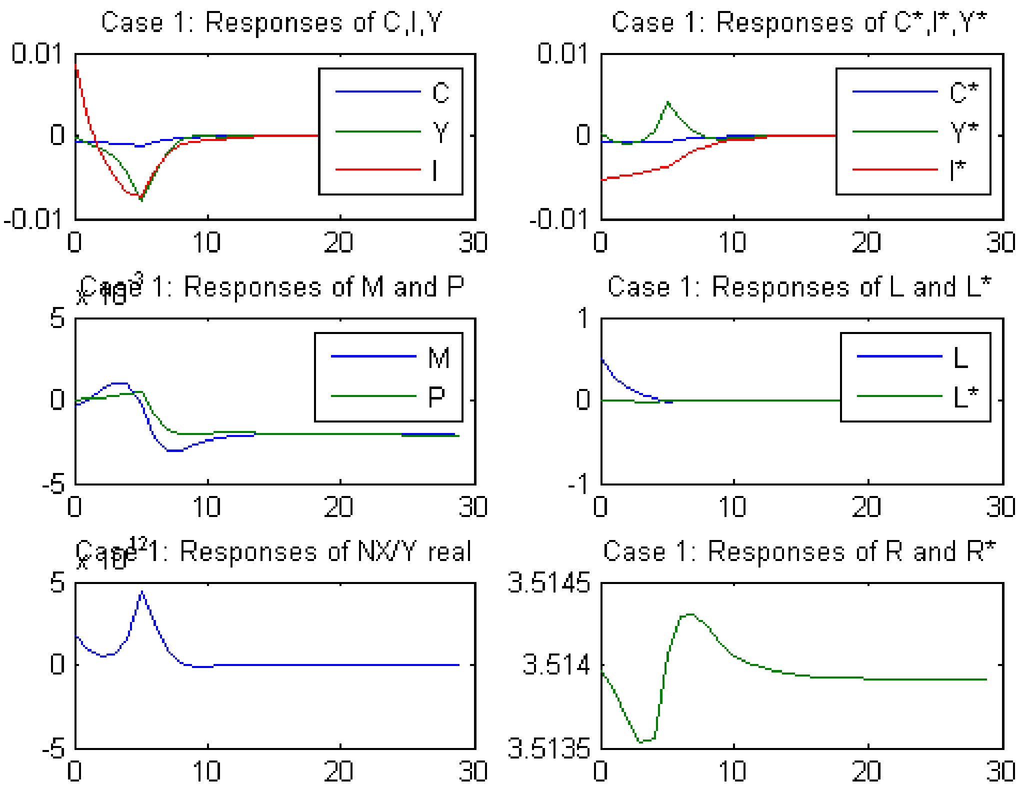
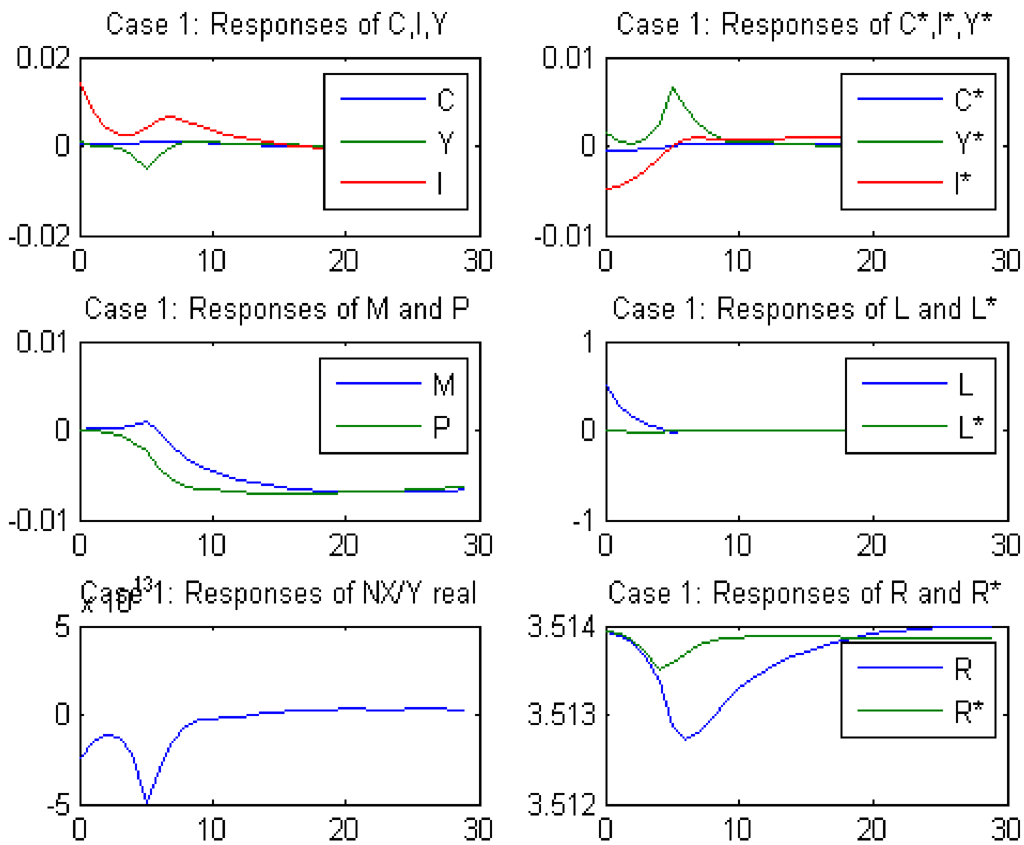


Figure 1.4: *Autonomous Monetary Policy* - Technological Shock

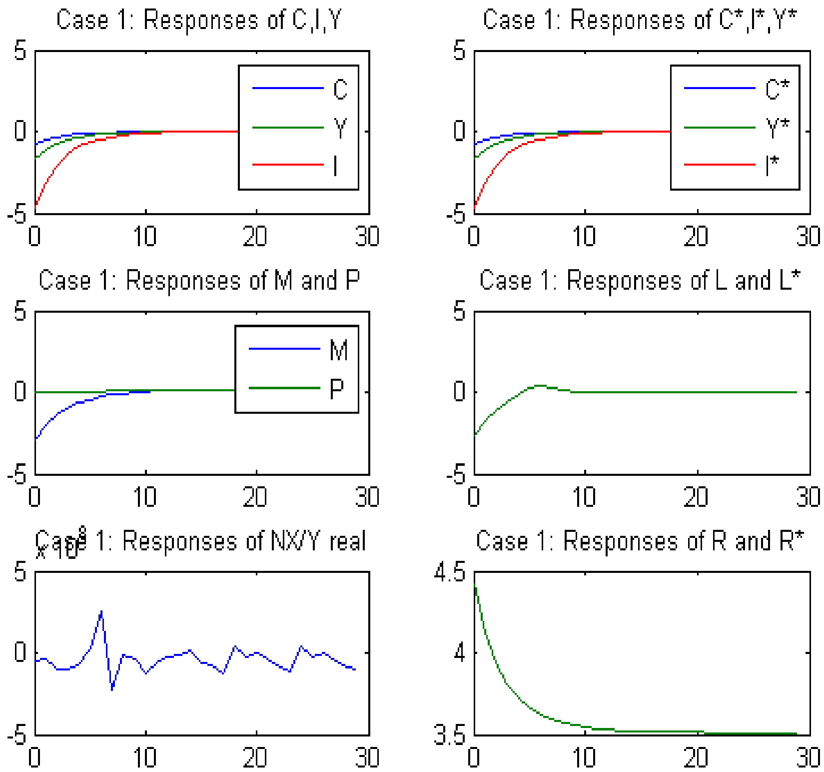


1.3.3 Monetary Policy Shocks

A positive monetary policy shock represents an increase in the nominal interest rate. In the *Common Monetary Policy* regime, pictured in Figure 1.5, both foreign and domestic nominal interest rate increase, leading to a decrease in consumption and investment and hence a decrease in the demand for the final good. Since consumers want to spend less of their income and firms are paying lower wages to compensate the decrease in demand, labor must also decrease. Real money balances also fall. Since $r^* = r$, movements in consumption, investment, labor and output in the foreign economy are similar to those of the domestic economy.

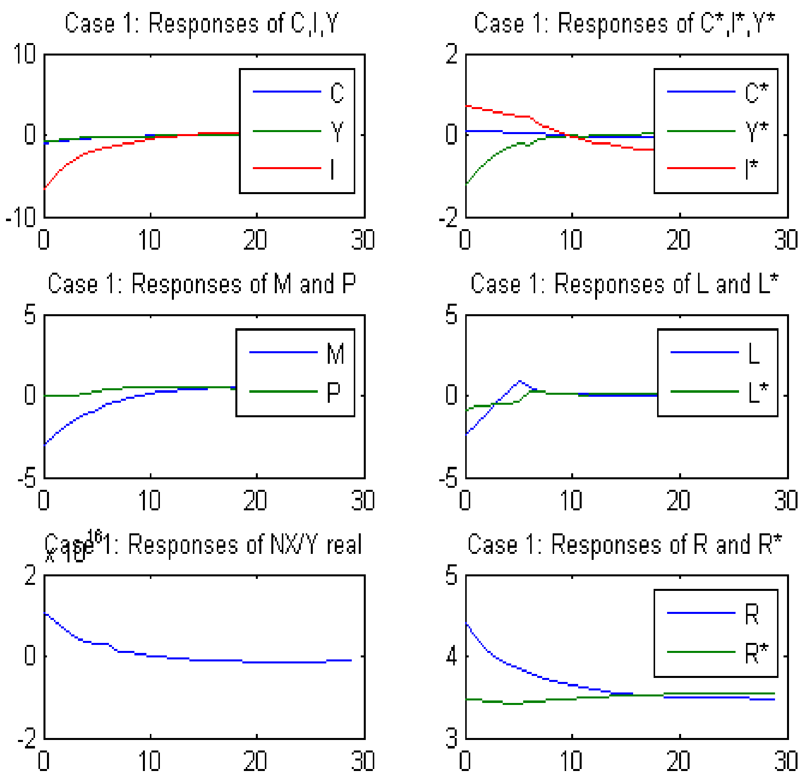
An increase in the nominal interest rate also makes mark-ups higher; as this increases monopoly power, it makes output decrease.

Figure 1.5: *Common Monetary Policy* - Monetary Shock



In the *Autonomous Monetary Policy* regime, which can be seen in Figure 1.6, a positive monetary policy shock occurs in the domestic economy. While the effects in the domestic economy are qualitatively the same as in the *Common Monetary Policy* regime, the effects on the foreign economy change substantially; because when the nominal interest rate increases at home making consumption and investment decreases, and hence output decrease, these movements also lead to an increase in the balance of trade, because the domestic economy is lending resources to the foreign economy, since domestic investment decrease due to the increase in the nominal interest rate. Initially, output in the foreign economy falls but investment initially increases. Labor decreases initially due to the decreasing domestic and foreign demand.

Figure 1.6: *Autonomous Monetary Policy* - Monetary Shock



1.4 Discussion

In this chapter we build a two country dynamic stochastic general equilibrium model which allows for different monetary policy regimes. In one regime the domestic country belongs to the Eurozone, and the ECB policy rule responds to a weighted average of the economic conditions, mainly, of the inflation rate and output gap of the Eurozone members. The other monetary policy regime is one where the home country is autonomous of the Eurozone and decides on its monetary policy through its National Central Bank. The first monetary policy regime is a theoretical innovation in this type of models and a more realistic way to model the policy rule of the ECB.

This model with these two different monetary policy regimes is being used in the next chapter to quantify the economic cost of the loss of monetary policy flexibility. In order to assess the fitness of this model for the stated purpose, we analyzed impulse response functions of the model regarding government consumption, technological and monetary policy shocks, in the two different monetary policy regimes. The model behaves as expected regarding the analyzed shocks and it seems reasonable to use for the purpose of the next chapter.

One of the shortcomings of this work concerns the fact that we are working with a two country model with symmetric economies. The economies of the member states of the Eurozone are very different from each other, so in the Eurozone context it would be more interesting to work with a model with asymmetric economies and heterogeneous agents; for example, different calibrations for the countries in the model. Also, the introduction of a third country in the model would permit the differentiation between economies in terms of its economic weight and economic structure. With this heterogeneity it would be interesting to apply common and specific shocks to all economies in the model, to analyze the differences of behavior of those economies. These seem good avenues for future research.

1.5 Appendix A - First Order Conditions

1.5.1 Consumers

In each period $t = 0, 1, ...,$ consumers choose consumption, labor, real money balances, and bond holdings to maximize their utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, l_t, M_t/P_t\right)$$

subject to the consumer budget constraints:

$$\begin{aligned} & P_t c_t + M_t + E_{t+1} Q_t B_{t+1} \\ \leq \quad & P_t W_t l_t + M_{t-1} + T_t + Q_{t-1} B_t + \Pi_t \end{aligned}$$

The first order conditions for the consumer can be written as:

$$-\frac{U_t^l}{U_t^c} = W_t$$

$$\frac{U_t^m}{P_t} - \frac{U_t^c}{P_t} + \beta E_{t+1} \frac{U_{t+1}^c}{P_{t+1}} = 0$$

$$Q_{t-1} = \beta E_{t-1} \frac{U_t^c}{U_{t-1}^c} \frac{P_{t-1}}{P_t}$$

where U_t^c, U_t^l and U_t^m are the derivatives of the variables of the utility function. We can define the nominal interest rate, r^N, from the last first order condition:

$$\frac{1}{1 + r^N} = \beta E_{t+1} \frac{U_{t+1}^c}{U_t^c} \frac{P_t}{P_{t+1}}$$

The foreign consumer faces a similar problem to that of the domestic consumer, namely to maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t^*, l_t^*, M_t^*/P_t^*\right)$$

subject to the following budget constraints:

$$P_t^* c_t^* + M_t^* + E_{t+1} Q_t^* B_{t+1}^{F^*} + E_{t+1} Q_t B_{t+1}^{H^*} / e_t$$
$$\leq \; P_t^* W_t^* l_t^* + M_{t-1}^* + T_t^* + Q_{t-1}^* B_t^{F^*} + Q_{t-1} B_t^{H^*} / e_t + \Pi_t^*$$

where B^{H^*} and $B^{F^*}$are respectively, the foreign's holdings of home and foreign country bonds. The first order conditions are similar to the ones for the domestic consumer, and the first order conditions with respect to bonds are:

$$Q_{t-1} = \beta E_{t-1} \frac{U_t^{c^*}}{U_{t-1}^{c^*}} \frac{P_{t-1}^*}{P_t^*} \frac{e_{t-1}}{e_t}$$

$$Q_{t-1}^* = \beta E_{t-1} \frac{U_t^{c^*}}{U_{t-1}^{c^*}} \frac{P_{t-1}^*}{P_t^*}$$

If we equate the first order condition for the domestic bonds holdings for the foreign consumer and the first order condition for the domestic bonds holdings of the domestic consumer, we get:

$$\frac{U_t^c}{U_{t-1}^c} \frac{P_{t-1}}{P_t} = \frac{U_t^{c^*}}{U_{t-1}^{c^*}} \frac{P_{t-1}^*}{P_t^*} \frac{e_{t-1}}{e_t}$$

With this expression and defining the real exchange rate as

$$q_t = e_t P_t^* / P_t$$

we get:

$$q_t = \xi U_t^{c^*} / U_t^c$$

by iterating back to 0, where ξ is the real exchange rate at time 0, times the ratio of the marginal utilities at time 0.

1.5.2 Final Goods Producers

Final goods producers operate in a competitive setting and in each period they want to maximize profits:

$$\max Py - \int_0^1 P_i^H y_i^H di - \int_0^1 P_i^F y_i^F di$$

subject to

$$y_t = \left[a_1 \left(\int_0^1 (y_{i,t}^H)^\theta di \right)^{\frac{\rho}{\theta}} + a_2 \left(\int_0^1 (y_{i,t}^F)^\theta di \right)^{\frac{\rho}{\theta}} \right]^{1/\rho}$$

The first order conditions of the maximization problem for the final goods producers, with respect to y_i^H and y_i^F, respectively are:

$$y_i^H = \left[\frac{a_1 P y^{1-\rho} \left(\int (y_i^H)^\theta di \right)^{\frac{\rho}{\theta}-1}}{P_i^H} \right]^{\frac{1}{1-\theta}}$$

$$y_i^F = \left[\frac{a_2 P y^{1-\rho} \left(\int (y_i^F)^\theta di \right)^{\frac{\rho}{\theta}-1}}{P_i^F} \right]^{\frac{1}{1-\theta}}$$

raising the expression to the power θ, integrating across i, solving for $\int (y_i^H)^\theta di$, and substituting these expressions in the FOC stated above, we get the factor demand functions:

$$y_{i,t}^H = \frac{[a_1 P_t]^{\frac{1}{1-\rho}} \overline{P}_{t-1}^H {}^{\frac{\rho-\theta}{(1-\rho)(\theta-1)}}}{P_{i,t-1}^H {}^{\frac{1}{1-\theta}}} y_t$$

$$y_{i,t}^F = \frac{[a_2 P_t]^{\frac{1}{1-\rho}} \overline{P}_{t-1}^F {}^{\frac{\rho-\theta}{(1-\rho)(\theta-1)}}}{P_{i,t-1}^F {}^{\frac{1}{1-\theta}}} y_t$$

where $\overline{P}_{t-1}^H$ is the average price of inputs and is equal to:

$$\overline{P}_{t-1}^H = \left(\int_0^1 P_{i,t-1}^H {}^{\frac{1}{1-\theta}} di \right)^{\frac{\theta-1}{\theta}}$$

and $\overline{P}_{t-1}^F$ is equal to:

$$\overline{P}_{t-1}^F = \left(\int_0^1 P_{i,t-1}^F {}^{\frac{1}{1-\theta}} di \right)^{\frac{\theta-1}{\theta}}$$

since all producers behave competitively, their economic profit is zero, and the final good price is given by:

$$P_t = \left(a_1^{\frac{1}{1-\rho}} \overline{P}_{t-1}^{H \frac{\rho}{\rho-1}} + a_2^{\frac{1}{1-\rho}} \overline{P}_{t-1}^{F \frac{\rho}{\rho-1}} \right)^{\frac{\rho}{\rho-1}}$$

which is independent of period t shocks.

The problem for foreign final goods producers is equal and by solving it we get:

$$y_{i,t}^{F*} = \frac{[a_1 P_t]^{\frac{1}{1-\rho}} \overline{P}_{t-1}^{F* \frac{\rho-\theta}{(1-\rho)(\theta-1)}}}{P_{i,t-1}^{F* \frac{1}{1-\theta}}} y_t^*$$

$$y_{i,t}^{H*} = \frac{[a_2 P_t^*]^{\frac{1}{1-\rho}} \overline{P}_{t-1}^{H* \frac{\rho-\theta}{(1-\rho)(\theta-1)}}}{P_{i,t-1}^{H* \frac{1}{1-\theta}}} y_t$$

$$P_t^* = \left(a_1^{\frac{1}{1-\rho}} \overline{P}_{t-1}^{F* \frac{\rho}{\rho-1}} + a_2^{\frac{1}{1-\rho}} \overline{P}_{t-1}^{H* \frac{\rho}{\rho-1}} \right)^{\frac{\rho}{\rho-1}}$$

1.5.3 Intermediate Goods Producers

The domestic intermediate goods producers choose prices $P_{i,t-1}^{H}$ and $P_{i,t-1}^{H*}$, production factors $l_{i,t}$, $k_{i,t}$, and $I_{i,t}$ to maximize:

$$\max E_0 \sum_{t=0}^{\infty} Q_t [P_{i,t-1}^{H} y_{i,t}^{H} + \\ + e_t P_{i,t-1}^{H*} y_{i,t}^{H*} - P_t W_t l_{i,t} - P_t I_{i,t}]$$

subject to the following production function:

$$y_{i,t}^{H} + y_{i,t}^{H*} = F\left(k_{i,t-1}, A_t l_{i,t}\right)$$

and to the input demands derived from the final goods producers problem.

The law of motion for capital used in the production of the intermediate good i is:

$$k_{i,t} = (1-\delta)\, k_{i,t-1} + I_{i,t} - \phi\left(\frac{I_{i,t}}{k_{i,t-1}}\right) k_{i,t-1}$$

and the constraints on prices are:

$$P^H_{i,t-1} = P^H_{i,t} = ...P^H_{i,t+N-1}$$
$$P^H_{i,t+N} = P^H_{i,t+N+1} = ...P^H_{i,t+2N-1}$$
$$.$$
$$.$$
$$.$$
$$P^{H^*}_{i,t-1} = P^{H^*}_{i,t} = ...P^{H^*}_{i,t+N-1}$$
$$P^{H^*}_{i,t+N} = P^{H^*}_{i,t+N+1} = ...P^{H^*}_{i,t+2N-1}$$
$$.$$
$$.$$
$$.$$

The derivatives of the Lagrangian with respect to $P^H_{t-1}$and $P^{H^*}_{t-1}$ are:

$$\sum_{\tau=t} E_\tau Q_\tau \left\{ \theta {P^H_{i,t-1}}^{\frac{1}{\theta-1}} \Lambda^H_\tau - \zeta_\tau {P^H_{i,t-1}}^{\frac{2-\theta}{\theta-1}} \Lambda^H_\tau \right\} = 0$$

$$\sum_{\tau=t} E_\tau Q_\tau \left\{ \theta e {P^{H^*}_{i,t-1}}^{\frac{1}{\theta-1}} \Lambda^{H^*}_\tau - \zeta {P^{H^*}_{i,t-1}}^{\frac{2-\theta}{\theta-1}} \Lambda^{H^*}_\tau \right\} = 0$$

The derivative with respect to $l_{i,t}$ is:

$$-P_t W_t + \zeta_t F^l_{i,t} = 0$$

The derivative with respect to $I_{i,t}$ is:

$$-P_t + \lambda_t \left[1 - \phi' \left(\frac{I_{i,t}}{k_{i,t-1}} \right) \right] = 0$$

and finally the derivative with respect to $k_{i,t}$ is:

$$-\lambda_t + E_{t+1} Q_{t+1} \left\{ \zeta_{t+1} F^k_{i,t+1} + \lambda_{t+1} \left[1 - \delta - \phi \left(\frac{I_{i,t+1}}{k_{i,t}} \right) + \acute{\phi} \left(\frac{I_{i,t+1}}{k_{i,t}} \right) \frac{I_{i,t+1}}{k_{i,t}} \right] \right\} = 0$$

Substituting the expressions for the multipliers ζ and λ and using the first order conditions for $l_{i,t}$ and $I_{i,t}$ we get:

$$P_{i,t-1}^{H}=\frac{\sum_{\tau=t}^{t+N-1} E_{\tau}Q_{\tau}P_{\tau}v_{i,\tau}\Lambda_{\tau}^{H}}{\theta\sum_{\tau=t}^{t+N-1} E_{\tau}Q_{\tau}\Lambda_{\tau}^{H}}$$

$$P_{i,t-1}^{H^*}=\frac{\sum_{\tau=t}^{t+N-1} E_{\tau}Q_{\tau}P_{\tau}v_{i,\tau}\Lambda_{\tau}^{H^*}}{\theta\sum_{\tau=t}^{t+N-1} E_{\tau}Q_{\tau}e_{\tau}\Lambda_{\tau}^{H^*}}$$

$$\frac{U_t^c}{1-\phi_{i,t}^{'}} = \beta E_{t+1}U_{t+1}^c\left\{v_{i,t+1}F_{i,t+1}^k + \frac{1}{1-\phi_{i,t+1}^{'}}\left[1-\delta-\phi_{i,t+1}+\phi_{i,t+1}^{'}\frac{I_{i,t+1}}{k_{i,t}}\right]\right\}$$

where $v_{i,t}$ is the real unit cost which is equal to the wage rate divided by the marginal product of labor, $W_t/F_{i,t}^l A_t$ and:

$$\Lambda_t^H=[a_1P_t]^{\frac{1}{1-\rho}}\,\overline{P}_{t-1}^{H}{}^{\frac{\rho-\theta}{(1-\rho)(\theta-1)}}y_t$$

$$\Lambda_t^{H^*}=[a_2P_t^*]^{\frac{1}{1-\rho}}\,\overline{P}_{t-1}^{H^*}{}^{\frac{\rho-\theta}{(1-\rho)(\theta-1)}}y_t^*$$

Chapter 2

The Welfare Cost of the Loss of Autonomy of Monetary Policy

2.1 Introduction

In this chapter we make use of the model built in the previous one, and use it to perform a welfare analysis for some countries, currently outside the Eurozone. The Czech Republic, Hungary, and Poland will have to join the European and Monetary Union (EMU) sometime in the future.[1] On the other hand, Denmark, Sweden, and the UK have repeatedly refused to join the EMU. Surprisingly, there is very little work on the welfare consequences of the loss of monetary policy flexibility for these countries. Discussions are usually focused on the social and political consequences of the Euro, despite of the existence of a possible economic loss. This chapter fills this void by providing a quantitative evaluation of the economic costs of joining the EMU, specifically, by investigating the economic implications of the loss of monetary policy flexibility associated with EMU for each country at study.

We calibrate models specifically for each economy and use the model described in the previous chapter to perform simulations and calculate, through a welfare analysis, the economic costs of the loss of the monetary policy flexibility. By calculating a welfare analysis, the comparison of the two monetary policy regimes, i.e., to be outside or inside the Eurozone, aims, to assess whether or not consumers prefer a National Central Bank concerned with the effects of shocks in a given economy. We have never seen this done in

[1] These three transition countries were chosen because they are the biggest of the economies that joined the European Union (EU) in May 2004.

the literature and for the purpose stated above.

Our focus is the loss of autonomy of monetary policy and its implications *vis-a-vis* business cycle synchronization. Business cycle synchronization is an important decision factor for joining EMU. It is often argued that it is not a good decision to join the euro, if a country's economic cycle is not synchronized with that of other remaining members as monetary policy may actually accentuate economic fluctuations. In the studies of Chamie, DeSerres, and Lalonde (1994) and Gros and Hefeker (2002) asymmetric shocks are discussed and also the level of asymmetry between regions. Both works compare the EU with the USA. Results show that the USA presents a higher level of symmetry between regions than the EU. This supports the fact that some European countries are going to suffer more than others from joining the Euro. Also, in face of shocks, European economies do not seem to converge or be symmetric in their responses, in fact they diverge.

Related literature for this topic and for transition countries is very recent. For the transition countries at study in this paper, Holtemöller (2005) calculated for the Czech Republic, Hungary, and Poland an optimum currency area index (OCA) to measure the economic consequences of joining the EMU, and uses a Taylor Rule similar to the one we use for the European Central Bank, but in a different economic framework. The author compares national monetary policy with monetary union in a two country new-keynesian model, but does not apply a general equilibrium framework. The OCA index measures the relative loss in terms of output gap and inflation variability in the two regimes stated above. He concludes that both the Czech Republic and Hungary can reduce the volatility of inflation and of the output gap if they join the monetary union. Results for Poland are inconclusive.

Fidrmuc and Korhonen (2003) have done calculations of correlations of supply and demand shocks between the accession countries and the Eurozone. They conclude that EMU accession would be easy for Hungary, and have mixed results for Poland and Czech Republic. They also present some review of literature of business cycle synchronization between Central Europe and Eastern Countries (CEECs) and the EMU.

Brigden and Nolan (2002) in the context of a new-keynesian model study the variability of a country's output and inflation if it decides to join a monetary union. They find that the EMU increases the volatility of output and inflation and that loosing the ability to stabilize the domestic economy is less costly if supply shocks are small. They estimate that the UK stabilization cost for joining the EMU is equivalent to a permanent reduction in GDP of between 0.6% and 2%.

In the next section we present some calculations regarding the proportion of the business cycle explained by idiosyncratic factors. We show that for the developed countries at study, the specific component of the cycle is very high, but has been declining. On the other hand, Stock and Watson (2005) show that UK business cycle is less synchronized with the European business cycle and more with the North-American one, over the 1984-2002 period. They also concluded that the percentage of the business cycle that it is explained by country specific factors is increasing, contrary to other related literature, that points to the opposite result. This is also one of the five economic tests that the British Government analyzes from time to time in order to evaluate the benefits and costs of joining the EMU. Fidrmuc and Korhonen (2003) and Angeloni and Dedola (1999) are also relevant references for UK, Sweden, and Denmark for this topic.

In section 2.2 we present empirical evidence regarding synchronization and convergence for the economies at study. In section 2.3 we show the calibration procedure and reference values for the six countries. Section 2.4 discusses the methodology and sections 2.5 and 2.6 analyze results for the welfare cost of the loss of monetary policy flexibility and sensitivity analysis for transition countries. Sections 2.7 and 2.8 do the same for the developed countries and section 2.9 concludes and presents a discussion of the results, some limitations of this work, and suggestions for future research. Sections 2.10 to 2.13 present some additional information about data, calibration, business cycles statistics, and welfare results.

2.2 Empirical Evidence

Czech Republic, Hungary, and Poland are the largest countries to have joined the EU in May 2004 and they are scheduled to join the European Monetary Union at some time in the future, because, unlike the United Kingdom and Denmark, they do not have an opt-out clause.

Hungary plans to join the Euro in 2010 and join the European Exchange Rate Mechanism II (ERM II) as soon as convergence criteria are met. Its currency is currently pegged to the Euro with a wide band of 15%. Poland plans to join the Euro in 2011; despite this goal, it has no target date for joining ERM II and its currency is currently floating. The Czech Republic has not yet set a date for joining the Euro but aims to join the ERM II when convergence criteria are achieved. Its currency is on a managed float.

The economic conditions of these countries do not differ much from those of Portugal and Greece, the poorest of the European Union economies, at the time of their accession, as we can see in Table 2.1. GDP *per capita* in these economies resembles the levels, at the time of accession, for Portugal and Greece. These countries are also small open economies like Portugal and Greece, but much more open to trade. This makes them specially vulnerable to shocks and highly dependent on foreign trade partners.[2]

Table 2.1 - Comparison of GDP *per capita* and Degree of Openness in the Accession Year

Countries (Year of Accession)	GDP *per capita* in PPP (EU-15=100)	Degree of Openness
Greece (1981)	63%	27.2%
Portugal (1986)	53%	28.7%
Czech Republic (2004)	65%	71.3%
Hungary (2004)	56%	65.1%
Poland (2004)	45%	38.5%
Data Source: NewCronos		

Unlike the referred three countries, Denmark, Sweden, and the United Kingdom have repeatedly refuse to join the Euro. These are developed economies, with GDP *per capita* comparable to, or even higher than Germany and France, values that are shown in Table 2.2. Their situation is opposite of the one of the transition countries, by the time of the introduction of the Euro, in 1999. Denmark and Sweden are more open than Germany and France, but the UK has roughly the same degree of openness. These countries are however, relatively less dependent on foreign trade than the transition countries at study.

[2]Degree of Openness is calculated as [(exports+imports)/2]/GDP*100. The variables are in nominal terms. EU-15 is the European Union with the former fifteen member countries.

Table 2.2 - Comparison of GDP *per capita* and Degree of Openness in 1999

Countries (Year of Accession)	GDP *per capita* in PPP (EU-15=100)	Degree of Openness
Germany (1957)	103%	29%
France (1957)	103%	25.1%
Denmark (1973)	115%	38.2%
Sweden (1995)	107%	39.4%
UK (1973)	101%	27.3%
Data Source: NewCronos		

Business cycle synchronization is also an important decision factor to join the EMU. If business cycles are not synchronized, the impact of a common monetary policy is different for each country and may hurt the economy of the country. The ECB considers only the average economic condition of the Eurozone when setting monetary policy. Table 2.3 shows results for the cross-country correlations between the countries at study and the Eurozone.[3] We can see that Poland has a significative positive correlation with the Eurozone for output (Y) and investment (I) and a slightly lower positive correlation with labor (L), and consumption (C). Hungary has a strong positive correlation with the Eurozone output and a lower positive correlation for investment and labor. Consumption does not appear to be correlated. Synchronization does not exist between the Czech Republic and the Eurozone, with all the correlations for the variables being negative. Data for obtaining the statistics for these countries is very time limited, so results must be read with care.

For developed countries output, investment, and labor correlations are positive for all countries. Consumption correlation of Denmark and of the UK is negative, but of Sweden is significantly positive. Correlations between the UK and the Eurozone are the weakest ones and Sweden has the strongest degree of comovement with the Eurozone.

Table 2.3 - Cross-Country Correlations between the Countries and the EMU

	CZ	HU	PL	DK	SE	UK
(Y, Y^*)	-0.15	0.65	0.52	0.53	0.67	0.19
(C, C^*)	-0.49	-0.003	0.23	-0.03	0.72	-0.02
(I, I^*)	-0.18	0.29	0.72	0.38	0.72	0.22
(L, L^*)	-0.36	0.22	0.06	0.51	0.70	0.26

[3] See Appendix C for details on empirical data and methodological issues. The superscript $*$ identifies foreign variables.

Also important is the proportion of the economic cycle of each country that is explained by an idiosyncratic component *vis-a-vis* a common component with the Eurozone.[4] If the idiosyncratic component is very high that could be a problem for EMU accession, because the lower the correlation between the economic cycle of a country and the Eurozone, the bigger could be the welfare loss of giving up monetary policy. For the sake of comparison we also present results regarding the common component with the USA. Results for the countries at study are presented in Tables 2.4 and 2.5.

Table 2.4 - % of the Variability of the Specific Component in the Total Variability of the Cycle

	1992-2004	
	Eurozone	USA
Czech Republic	0.38	0.39
Hungary	0.13	0.16
Poland	0.15	0.21

Table 2.5 - % of the Variability of the Specific Component in the Total Variability of the Cycle

	1960-1978		1979-2004		1960-2004	
	Eurozone	USA	Eurozone	USA	Eurozone	USA
Denmark	0.53	0.91	0.48	0.60	0.56	0.78
Sweden	0.60	0.71	0.30	0.47	0.58	0.64
United Kingdom	0.73	0.80	0.40	0.42	0.59	0.58

As we can see, the weight of the specific component is small in the three transition countries, but specially small in Hungary and Poland. The proportion of the specific component is higher when we calculate for the USA, meaning that the proportion of the economic cycle explained by the Eurozone economic cycle is higher.

For developed countries, data availability allows us to divide the period between 1960 until 2004 in sub-periods. We choose to divide the data in the year 1979 because it is the starting year of the European Monetary System. The weight of the specific component has been declining over time, however the specific component in these countries is much bigger that the one of the transition countries. Denmark, Sweden, and the UK are bigger economies and much less open to trade, hence less affected by comovements of other countries. The specific component of business cycle of the UK is more or less the same

[4]See Appendix A for details on the estimations. This method was also use in Barbosa et al. (1998).

regardless whether we use the Eurozone or the USA, reflecting the strong relation between the UK and the USA, despite the accession to the European Union.

2.3 Calibration

The calibration of the model developed in the previous chapter is made in order to reproduce the long term properties of the economies at study. Parameter values for these countries are presented in Appendix B. We follow the calibration procedure of Cooley (1995).

2.3.1 Preferences

The functional form of the utility function is:

$$U\left(c, L, \frac{M}{P}\right) = \frac{\left[\frac{c^{(1-\kappa)}}{(1-\kappa)} + \frac{w\left(\frac{M}{P}\right)^{\frac{\eta-1}{\eta}}}{\frac{\eta-1}{\eta}} + \varphi\frac{(1-l)^{(1-\gamma)}}{1-\gamma}\right]^{1-\sigma}}{1-\sigma} \tag{2.1}$$

whose arguments are real consumption (c), labor (l) and a real money aggregate (M/P). The discount factor β is equal to $\frac{1}{(1+r^{LT})}$, where r^{LT} is the real long term interest rate for government bond yields. The value for σ is 0.0001 for all countries at study and κ is the relative risk aversion coefficient (or the inverse of the elasticity of intertemporal substitution). The value for this parameter found in the literature, can vary between 1 and 20. Because this parameter is one of the most difficult values to estimate empirically, we perform a sensitivity analysis to the value of this parameter. In order to have a balanced growth we impose $\gamma = \sigma$.[5] The value for φ, the weight on leisure, is calculated in order to match the time that families dedicate to work to empirical data.

[5] In the market sector suppose that technology for each intermediate good producer is given by $F(k_t, A_t l_t)$, where A_t grows at a constant rate A. In the nonmarket sector suppose that technological progress increases the productivity of time destined to nonmarket activities, so that an input of $(1-l_t)$ units of time out of the market, produces $A_t(1-l_t)$ units of leisure services. With these kind of preferences, if c_t and m_t grow at a A_t rate and if l_t is constant, then $-\frac{U_{lt}}{U_{ct}} = k\frac{(1+A)^{(1-\gamma)t}}{(1+A)^{-\sigma t}}$ where k is a constant. Along a balanced growth path wages grow at the same A rate, so in order for the economy to have a balanced growth path, we must have $\gamma = \sigma$.

Parameters concerning money demand are estimated according to the first order condition for a nominal bond, which costs one euro at t and pays $(1 + r^N)$ euros in $t + 1$:

$$\log \frac{M_t}{P_t} = -\eta \log \frac{w}{1-w} + \log c_t - \eta \log \left(\frac{r^N}{1+r^N} \right) \tag{2.2}$$

we estimated a regression with quarterly data, where $M1$ is used for money, the GDP deflator for P, private consumption at constant prices for c, and the three month interest rate of the money market for r^N, where r^N is the nominal interest rate. In the estimation we obtained the value for η, the interest elasticity of real money demand. The value for w is residual and we set the value equal to 0.0076 for all countries.

2.3.2 Technology for the Final Goods Producers

The elasticity of substitution between home and foreign goods was defined as $\frac{1}{(1-\rho)}$. Some studies, like the one by Whalley (1985), found this elasticity to be in a range between 1 and 2, being lower for Japan and Europe than for the USA. The value found for this elasticity is calculated by using the expression of the first order condition for the demand functions of the input intermediate goods:

$$\log \frac{IMP}{D} = b_0 + b_1 \log \frac{PD}{PIMP} + b_2 \log Y \tag{2.3}$$

where IMP are imports at constant prices, D is national production subtracted of exports at constant prices, $PIMP$ is the imports deflator, PD is the deflator for D, and Y is national income at constant prices.

Shares for the model are calculated assuming that there are only two countries in the world, each one of the countries and the Eurozone. y^h and y^f represent the share of imports from the Eurozone in percentage of GDP and the share of national production in percentage of GDP, respectively. To calculate a_1 and a_2, representing respectively the weights of domestic and imported goods, in their steady state values, the following relation is established: $y^h/y^f = [a_1/a_2]^{\frac{1}{1-\rho}}$.

2.3.3 Technology for the Intermediate Goods Producers

The production function for intermediate producers is a Cobb-Douglas with constant returns to scale:

$$F(k, Al) = k^{\alpha} (Al)^{1-\alpha} \tag{2.4}$$

for the technology parameters we calculated the share of capital used in the production of the good, α, using empirical data for the capital income share of the private sector. The depreciation rate for capital, δ, was calculated implicitly by the following formula:

$$k_t = (1 - \delta) k_{t-1} + I_t \tag{2.5}$$

We tried to adjust the adjustment cost parameter b in equation (1.9) in order to achieve the volatility of investment relative to output of the empirical data.

In order to calculate the value for the markup parameter, we need to define several variables. First, we define the markup of price to marginal cost as $P^H/P_v = 1/\theta$. Then we need to define profit as $\Pi = y - vy$, where v is the unit cost. In steady state $v = \theta$, so $\Pi/y = 1 - \theta$. To obtain a estimate of Π/y we follow Domowitz, Hubbard, and Petersen (1986) and define the price-cost margin as $(value\ added - payroll)/(value\ added + cost\ of\ materials)$. In the steady state of the model the numerator of the former equation equals $\Pi + (r + \delta) k$. We calculate the denominator as Jorgenson, Gollop, and Fraumeni (1987), assuming that the value for the cost of materials is similar to the value added. We then calculate the steady state values for $r + \delta$ and k/y. The previous calculations imply the value for Π/y. Using the last value, we find the markup, which implies the value for θ.

We choose the number of periods that prices stay fixed for each group of producers, based on Gali, Gertler, and Lopez-Salido (2001) estimates that the number of quarters that price stay fixed in Europe to be about six, so we use this value for all countries.

2.3.4 Technological Shocks

We estimate a $VAR[1]$ for each one of the economies and the Eurozone, to obtain the values for ρ^A, σ^A, and also for the cross-country correlation of these shocks, corr(ε^A,ε^{A^*}).

2.3.5 Government Consumption Shocks

We estimate a $VAR[1]$ for each one of the economies and the Eurozone, to obtain the values for ρ^g, σ^g, and also for μ^g.

2.3.6 Monetary Policy Shocks

The theoretical debate about the policy rule of the Central Bank is very extensive. In this model the National Central Bank follows a Taylor Rule, represented by equation (1.15) of the previous chapter. For all countries the rule of the National Central Bank exhibits a positive correlation of 0.1 with foreign monetary shocks.

The policy rule of the ECB is characterized by equation (1.16). For the European Central Bank the parameters for ρ^r, ρ^π, and ρ^O are always the same regardless of the country at study, since its monetary policy rule does not change, only the weights of the countries in that rule and the volatilities of this rule differs between simulations for each country. We kept a fixed exchange rate in the simulation *Common Monetary Policy*. In all simulations, we choose the value for the variance of the shocks in order to reproduce the total variance of the output.

Parameter values for the countries at study are presented in Tables 2.6 and 2.7 below. Table 2.6 presents parameter values for the UK and shows the deviations relative to those values for Denmark and Sweden. Table 2.7 presents parameter values for the Czech Republic and shows the differences for Hungary and Poland relative to the first country.

Table 2.6 - Calibration Values for the Three Developed Countries at Study

	UK	DK	SE
Preferences			
β	0.996	-0.009	0
φ	201	+89	+149
η	0.34	-0.23	-0.22
κ	3.95	-0.95	+0.37
Final Good Technology			
ρ	0.145	+0.86	+0.14
a_1	0.87	-0.04	-0.05
a_2	0.13	+0.04	+0.05
Intermediate Good Technology			
α	0.378	-0.019	0
δ	0.99	+0.16	+0.09
θ	0.951	+0.024	0
b	65	-55	0
Taylor Rule National Bank			
ρ^r	0.92	n.a.	-0.1
ρ^π	1.08	n.a.	-0.03
ρ^o	0.29	n.a.	+0.03
σ^r	0.0046	n.a.	+0.004
Technological Shocks			
ρ^A	0.659	-0.206	-0.059
σ^A	0.007	-0.003	+0.002
$corr(\varepsilon^A, \varepsilon^{A^*})$	0.21	+0.17	+0.25
Government Consumption Shocks			
ρ^g	0.97	+0.02	+0.01
σ^g	0.007	+0.012	+0.002
μ^g	0.11	+0.01	+0.01

Table 2.7 - Calibration Values for the Three Transition Countries at Study

	CZ	HU	PL
Preferences			
β	0.996	+0.003	-0.005
φ	350	-150	0
η	0.11	+0.12	+0.07
κ	3.5	-0.7	0
Final Good Technology			
ρ	0.24	+0.2	+0.36
a_1	0.66	-0.02	+0.01
a_2	0.34	+0.02	-0.01
Intermediate Good Technology			
α	0.39	0	+0.01
δ	1.15%	0	0
θ	0.95	-0.03	-0.01
b	50	-4	-19
Taylor Rule National Bank			
ρ^r	0.81	-0.01	+0.06
ρ^π	1.26	-0.06	+0.06
ρ^o	0.15	+0.21	+0.32
σ^r	0.009	-0.002	-0.003
Technological Shocks			
ρ^A	0.54	-0.03	+0.2
σ^A	0.005	+0.014	+0.005
$corr(\varepsilon^A, \varepsilon^{A^*})$	0.02	+0.32	+0.19
Government Consumption Shocks			
ρ^g	0.92	+0.05	-0.29
σ^g	0.005	+0.014	+0.005
μ^g	0.11	+0.01	-0.01

Calibration for Denmark, Sweden, and the UK exhibits some differences, as we can see in Table 2.6; namely, in Denmark monetary policy shocks are inexistent because the country follows an exchange rate peg to the Euro, so monetary policy is used to maintain that peg. Also in Denmark, government consumption shocks have a greater volatility than in the other two countries. Technological shocks in this country have a smaller persistence than in the other two. In UK the trade share with the EMU is smaller than in the other two countries, and the elasticity of substitution between domestic and imported goods is smaller.

Calibration for transition countries also exhibits some differences that are worth noting as we can see in Table 2.7 above; namely, in Poland technological shocks are more persistent than in the other two transition countries, and in the case of government consumption shocks the persistence is much greater in the Czech Republic and in Hungary. Volatilities of these several shocks are also different between these economies and are much stronger in Hungary and in the Czech Republic, than in Poland. Another significant difference is the value of the elasticity of substitution between domestic and imported goods.

These differences are going to influence the value of the results and have an important role in the decision of joining (or not). We will see why in detail in the next sections.

2.4 Methodology

The model built in the previous chapter and the calibration procedure just performed in the last section permits us to construct a detailed quantitative analysis for the behavior of the main macroeconomic variables and, more importantly, to quantify the welfare gain (or loss) associated with the various policy regimes.

The main purpose of this chapter is to formally analyze the consequences of different rules for monetary policy, in terms of consumer welfare in the countries at study. We therefore ask how much consumption consumers are willing to give (or receive) in order to remain indifferent between monetary policy defined by the European Central Bank (*Common Monetary Policy*), and monetary policy defined by the National Central Bank (*Autonomous Monetary Policy*). This corresponds to calculating the compensating variation associated to the full elimination of an *Autonomous Monetary Policy* regime in this economy. The welfare analysis follows the Lucas (1987) method:[6]

1. Two regimes were compared; in the first, the monetary policy of the domestic economy is nonexistent because it is governed by the European Central Bank whereas

[6] Clarida, Gali, and Gertler (1999) criticize this approach of measuring welfare, stating that: " If some groups suffer more in recessions than others and there are incomplete insurance and credit markets, then the utility of a hypothetical representative agent might not provide an accurate barometer of cyclical fluctuations in welfare." For the purpose of this paper, which is measuring the loss of a country of loosing the monetary policy flexibility we are going to disregard this criticism. Besides, our model does not have the features that the authors criticize.

in the second, the National Central Bank is in charge of monetary policy for the domestic economy. A simulation of 1000 periods was made in both regimes. In the *Common Monetary Policy* simulation, technological and government consumption shocks take place both in the domestic and foreign economy, whereas monetary shocks only occur in the foreign economy, representing the Eurozone. In the *Autonomous Monetary Policy* simulation, both economies suffered all three shocks.

2. Based on the simulated time series for consumption (C), labor (L), and real money aggregate($\frac{M}{P}$) we calculate the average value of the utility function for both policy regimes.

3. Given the average values for both utility functions, we calculated the compensating variation in terms of consumption in the following way:

$$U_0\left(\lambda c_0, l_0, M/P_0\right) = U_1\left(c_1, l_1, M/P_1\right) \tag{2.6}$$

Where U_0 uses the values for c, l, and M/P of the *Common Monetary Policy* simulation and U_1 uses the values of the *Autonomous Monetary Policy* simulation. The value of λ represents the average gains (or losses) of welfare in percentage of consumption.

2.5 Results for Transition Countries

In this section we first analyze the results for business cycles statistics of the simulated economies in the two monetary regimes. The values of the statistics for the simulations support some of the stylized facts found in the literature, for instance, output is more volatile than consumption, but less volatile than investment.

Variables are more volatile in the *Autonomous Monetary Policy* simulation for all three countries, where not only are there government consumption and technological shocks, but also the monetary policy shock in the domestic economy. In the *Common Monetary Policy* simulation there are no monetary policy shocks in the domestic economy, since monetary policy is established by the European Central Bank; hence, volatility is lower in this simulation. In addition, when we impose equation (1.17) the volatility of variables decrease.

Although comparisons of the behavior of autocorrelations differ from country to country and depend on the magnitude of the shocks and the comovements between them, on average persistence is higher in the *Autonomous Monetary Policy* simulation. This is a logical result, since monetary policy is oriented towards the domestic economy, which means that monetary policy stabilizes the economy more, making variables more persistent.

Analyzing the cross-country correlations we find that simulation *Common Monetary Policy* has on average the higher cross-country correlations. This happens also because of the imposition of equation (1.17), so specially for consumption and investment, these cross-country correlations are very high.

Tables C1 to C3 in the Appendix C present the results in the third and fourth column of the statistics for the *Common Monetary Policy* and *Autonomous Monetary Policy* simulations, respectively, for the domestic economy. The second column presents statistics calculated from empirical data. Table 2.8 presented below, shows the results for welfare analysis, which are discussed after the referred table.

Table 2.8 - Welfare Results for Transition Economies - Benchmark Simulations

	C	L	M/P	U	λ
Czech Republic					
Common Monetary Policy	100.16	100.25	100.71	99.99	-0.26%
Autonomous Monetary Policy	100	100	100	100	
Hungary					
Common Monetary Policy	100.27	100.25	100.73	99.99	-0.18%
Autonomous Monetary Policy	100	100	100	100	
Poland					
Common Monetary Policy	100.05	100.23	100.34	99.97	-0.25%
Autonomous Monetary Policy	100	100	100	100	

Consumers are willing to give up consumption in order to live in an economy where the monetary policy is established by the National Central Bank in all three countries. The behavior of labor explains why consumers prefer the *Autonomous Monetary Policy* regime. Labor in this simulation is on average lower; as a result there is more leisure and consumers are better off, even though consumption is higher in the *Common Monetary*

Policy regime, because nominal interest rates in this regime are on average lower.

Values for consumption are on average smaller in the *Autonomous Monetary Policy* simulation, because we have a more aggressive inflation parameter in the Taylor Rule for the National Central Bank for all three countries. As a result, for example when prices increase, the interest rate response is higher, bringing about a higher drop in average consumption. Therefore, on average labor has to rise by less in order to satisfy the increase in consumption and also to satisfy output demand.

The main differences between simulations within each country are the volatility of the monetary policy shocks, the parameters of the Taylor rules, and the difference between who runs the monetary policy (i.e., Taylor Rule, with or without economic weights). Monetary policy shocks dominate the behavior of economies more than technological and government consumption shocks.

The different welfare results for each country are explained obviously by different parameters, but most importantly by differences regarding the magnitude of technological, government consumption, and monetary policy shocks.

2.6 Sensitivity Analysis for Transition Countries

In this section we analyze the robustness of the model in terms of the benchmark welfare value (λ) computed above. For simplicity we restrict our discussion to the most significant parameters in the model.[7] All simulations follow the procedure described before. Table 2.9 summarizes the results for each of the three transition countries. It shows that our key results are quite robust across these three economies. In particular, for most combinations of parameters we find that all three countries prefer to remain outside the EMU and retain an autonomous monetary policy.[8]

[7] We increase the correlations of monetary policy shocks to 0.5, the relative risk aversion coefficient (κ) to 25% more of its value, and decrease the weight of imported goods from the Eurozone to 25% less of its initial value.

[8] Detailed results for robustness can be found in Appendix D, Tables D1 to D3.

Table 2.9 - Results for Sensitivity Analysis - Transition Countries

CZ	HU	PL
Benchmark		
-0.26%	-0.18%	-0.25%
No Technological Shocks		
-0.26%	-0.18%	-0.21%
No Government Consumption Shocks		
-0.29%	-0.44%	-0.25%
Correlation of the monetary policy shocks		
-0.10%	-0.03%	-0.25%
Relative Risk Aversion Coefficient		
-0.29%	-0.20%	-0.25%
Weight of imported goods from the Eurozone		
-0.33%	-0.33%	-0.26%

Generally we find that changes in the values of the import share, of the relative risk aversion coefficient, and of the correlation of monetary policy shocks seem to have the biggest impact in the change of the welfare value. The exception is Poland where technology shocks are the only variable that has a visible effect on our welfare calculations. This is probably due to the smaller persistence of government shocks and lower volatility of monetary policy shocks for Poland as well as its smaller trade share with the EMU (15%).

Conversely, Czech Republic and Hungary have significantly larger trade shares with the Eurozone and demand shocks play a more important role. For these countries we find that decreases in trade volume with the Eurozone increases the costs of adopting a common monetary policy. This finding is consistent with the theory of the endogeneity of optimum currency areas (Frankel and Rose, 1998) and for much the same reasons. A low trade volume increases the domestic economies exposure to idiosyncratic shocks and makes a common monetary policy less desirable.

Results for the relative risk aversion coefficient are also quite intuitive and suggest that when agents are more risk averse, they strongly prefer a world with relatively less volatility in economic aggregates. As a result they prefer a more autonomous monetary authority that is more actively engaged in stabilizing the domestic economy. Again this is particularly so in the case of Hungary and the Czech Republic where the easier to stabilize spending shocks play a more important role.

Results for the experiment on government consumption shocks depend on the impact of these shocks in the interest rate rule. Czech Republic and Hungary have strong government consumption shocks, significative government consumption shares but also a strong preference for present consumption, since the intertemporal discount factor is high, so the impact of the removal of the shock is bigger than in the other countries. Without government spending shocks, consumption and the level of demand are on average higher, thus increasing the price level in these countries. Given this increase in prices, consumers in this country prefer a more autonomous monetary policy rule, since it is able to stabilize more the economy. As noted above technological shocks do not change much the results, except in the case of Poland, where they are significantly more persistent. Predictably Poland would find the Eurozone somewhat more attractive if technology shocks were not important.

Finally, changes in the correlation of the monetary policy shocks also seem important, specially in Czech Republic and in Hungary. This is intuitive since increasing the correlation of monetary policy shocks in simulation *Autonomous Monetary Policy* makes domestic and foreign nominal interest rates react in a similar way. As two policies become more alike, consumers become more indifferent between the two monetary regimes.

2.7 Results for Developed Economies

The values of the statistics for the simulations support some of the stylized facts found in the literature, for instance, output is more volatile than consumption and net exports, but less volatile than investment. Autocorrelations are usually persistent as in the data.

In the simulation *Common Monetary Policy* there are not monetary policy shocks in the domestic economy, since monetary policy is established by the European Central Bank, so volatility is lower in this simulation. We modelled the monetary policy of the Danish Central Bank as an exchange rate peg to the euro, so the policy rule does not follow a Taylor Rule, hence there is not any volatility at all for these shock, making variables in this country less volatile in simulation *Autonomous Monetary Policy.*

Comparisons of the behavior of autocorrelations differ from country to country, and depend of the magnitude of the shocks and the comovements between them, but persistence is on average higher in simulation *Autonomous Monetary Policy.* This is a logical result, since monetary policy is oriented towards the domestic economy, hence monetary policy stabilizes more the domestic economy, making variables more persistent.

Analyzing the cross-country correlations we find that simulation *Common Monetary Policy* has on average the higher cross-country correlations. This happens because of the imposition of equation (1.17), so specially for consumption and investment, these cross-country correlations are very high and seem to dominate the pattern of cross-country correlations.

Denmark has a different behavior from the other countries in the cross-country correlations of output, investment and labor in simulation *Common Monetary Policy*, because the volatility of the interest rate shock is insignificant. This simulation is then dominated by the stronger shock present in the simulation, the government consumption shock and restriction (1.17). The restriction imposes a strong correlation between consumption in the two economies. The government consumption shock makes correlations between output, investment, and labor negative. If we think of a negative consumption shock; output, labor, and investment in these economy decrease, but consumption increases. Net exports movements depend on consumption and investment relative movements. Due to the existence of complete markets the risk sharing effect prevails and net exports increase initially. The domestic economy is lending resources to the foreign economy, making consumption higher in both economies. Because consumption has increased, output increases and because the economy needs more factors of production, so does investment.

Tables C4 to C6 in Appendix C present the results of the statistics for simulations *Common Monetary Policy* and *Autonomous Monetary Policy*, for the domestic economy in all three developed countries. Table 2.10 shows the results for welfare analysis, that are discussed below.

Table 2.10 - Welfare Results for Developed Economies - Benchmark Simulations

	C	L	M/P	U	λ
Denmark					
Common Monetary Policy	100.68	101.46	100.24	99.74	-5.44%
Autonomous Monetary Policy	100	100	100	100	
Sweden					
Common Monetary Policy	100.09	100.33	100.62	99.94	-0.54%
Autonomous Monetary Policy	100	100	100	100	
UK					
Common Monetary Policy	100.13	100.31	102.03	99.96	-0.54%
Autonomous Monetary Policy	100	100	100	100	

Consumers are willing to give up consumption in order to live in an economy where the monetary policy is established by the National Central Bank in all three countries. Results are higher than the ones for transition countries, although the explanation for these results is the same as for the referred economies. Specifically, in the case of Denmark because monetary policy shocks are absent from simulation *Autonomous Monetary Policy*, hence don't produce volatility, and because consumers dislike volatility, the preference for not joining the EMU is substantially higher than in the other two countries.

2.8 Sensitivity Analysis for Developed Countries

In this section we analyze the robustness of the model in terms of the benchmark welfare value (λ) for the three developed countries.[9] Results are presented in Table 2.11 below, for each of the three developed countries. It shows, as it was the case in transition countries, that our key results are robust across these three economies.[10]

[9] We increase the correlations of monetary policy shocks to 0.5; the relative risk aversion coefficient (κ), and the weight of imported goods from the Eurozone to 25% more of their initial value.

[10] Detailed results for sensitivity analysis can be found in Appendix D, tables D4 to D6.

Table 2.11 - Results for Sensitivity Analysis - Developed Countries

DK	SE	UK
Benchmark		
-5.44%	-0.54%	-0.54%
No Technological Shocks		
-6.73%	-0.53%	-0.54%
No Government Consumption Shocks		
0.0185%	-0.25%	-0.46%
Correlation of the monetary policy shocks		
n.a.	-0.45%	-0.77%
Relative Risk Aversion Coefficient		
-2.48%	-0.47%	-0.6%
Weight of imported goods from the Eurozone		
-5.20%	-0.43%	-0.55%

Generally we find that changes in the values of the import share, of the relative risk aversion coefficient, and of the correlation of monetary policy shocks seem to have the biggest impact in the change of the welfare value. Technology shocks have a negligible impact on the welfare results, except in Denmark. In this country we model the *Autonomous Monetary Policy* regime as an exchange rate peg to the euro, and remove monetary policy shocks from this simulation. When we remove technological shocks, volatility in this simulation decreases even more, leaving risk averse consumers even better in this regime.

These three developed countries have a smaller trade share with the Eurozone than transition countries, but demand shocks also play an important role like in the other three countries. For Denmark and Sweden we find that increases in the trade volume with the Eurozone decreases the costs of adopting a common monetary policy. This finding is consistent with the theory of the endogeneity of optimum currency areas (Frankel and Rose, 1998) and for much the same reasons. The UK prefers marginally more not to enter when trade shares are high, because consumers in this country have a high value for risk aversion relative to the other countries. Higher trade shares increase the exposure of the country to foreign shocks and also increase volatility in the economy, making risk averse consumers, less willing to enter the Eurozone and more willing to have a National Central Bank able to stabilize the economy.

Consumers are more indifferent between the two regimes, when demand shocks are removed. Volatility in both simulations are reduced and the need to stabilize domestic spending shocks disappears, making consumers more willing to join the EMU. As previously mentioned, technological shocks are not very important to the results, except in Denmark.

Changes in the correlation of the monetary policy shocks also seem important, and make consumers in Sweden more indifferent to the choice of regime. This is intuitive since increasing the correlation of monetary policy shocks in simulation *Autonomous Monetary Policy* makes domestic and foreign nominal interest rates react in a similar way. As two policies become more alike, consumers become more indifferent between the two monetary regimes. Conversely, in the UK consumers are finding the idea of joining the Eurozone less appealing, when we increase the correlation of the monetary policy shocks. The monetary policy rule of the domestic central bank in this country has a higher degree of interest rate smoothing than the rule for the ECB. The interaction between this parameter and the increase in the correlation of monetary policy shocks decrease the volatility of the variables in this simulation, hence increasing the costs of joining the EMU.

Sweden and Denmark are more willing to enter the Eurozone when risk aversion is higher. In Denmark, monetary policy of the National Central Bank is not used as a stabilization tool, since the country has its currency pegged to the euro. When risk aversion is higher, consumers dislike volatility even more, and the need to stabilize the economy increases, so consumers in Denmark prefer to enter the Eurozone and to have some possibility of stabilization. The monetary policy rule in Sweden has a very low parameter of interest rate smoothing in comparison with the ECB. When the Swedish Central Bank acts to stabilize the economy, the intervention is quicker but may upset the volatility of the variables, making risk averse consumers more willing to enter the Eurozone. In the UK, risk averse consumers prefer the monetary policy of their National Central Bank and its ability to stabilize the economy without upsetting the volatilities of the variables.

2.9 Discussion

The use of this model for these countries illustrates in an explicit way the main result of this chapter: consumers are willing to give up part of their consumption in order to stay in an economy where the monetary policy is conducted on a national level. As a result, on average EMU membership can be a costly decision for these countries in terms of the loss of monetary policy. We must emphasize the fact that these results were obtained in the context of a complete markets model, making them even more important, because, even in a situation where consumers share the risk across countries, they are on average not willing to join the Eurozone.

Detailed analysis of the results shows that the loss of monetary policy flexibility is more or less costly depending on several factors. In the case of transition countries, the decision to enter is more costly when technological shocks are stronger, when correlation of the monetary policy shocks is weaker, when consumers are more risk averse, and when the import share between the countries under study and the EMU is lower. Government consumption shocks do not present clear results about the decision to join the EMU, depending on the interaction between these shocks and the interest rate rule of the monetary authority.

For developed countries, the decision of entering is more costly when technological shocks and government consumption shocks are stronger, except for the first ones in the case of Denmark. The other analyzed variables present mixed results, depending on the country's specific key parameters.

Besides discussing the costs of belonging to a Monetary Union, optimum currency area theory also discusses the benefits. It seems proper in this work to compare the results of the loss of independence of monetary policy with some of the benefits.

One of the most important benefits of joining the EMU is the elimination of transaction costs. For transition countries some studies try to assess the benefit of loosing the exchange rate transaction cost. For Poland, Wojcik (2000) found that the country could gain 0.1% of GDP every year by eliminating transaction costs. Estimates for this benefit from the National Bank of Poland (2004) reached a value of 0.2% of GDP per year.

The National Bank of Hungary reached a value for Hungary between 0.18-0.3% of GDP (Csajbók, Csermely, Eds. (2002)).

For the other countries at study there are also several studies that try to assess the benefit of loosing the exchange rate *vis-a-vis* the other EMU members. For the UK, the European Commission (EC) in 1990 estimate this value to be 0.1% of GDP, and 0.4% of GDP for the average of the European Union. In 1996, a study by IFO, claim that the last value had increased to 1% of GDP. Calmfors et al. (1997) found a 0.3% of GDP benefit for Sweden. In countries which have a poorly developed financial system, the gains from eliminating transaction costs are higher, since they have fewer financial products to defend themselves from exchange rate risk, contrary to countries that have a sophisticated financial system like Denmark, Sweden, and the UK.

Converting our benchmark results to percentage of GDP, we find that in the three developed countries at study, consumers are willing to give up between 0.2 and 2.6% of their consumption in percentage of GDP to live in an economy with an autonomous Central Bank; while for transition countries, the percentage is between 0.1 and 0.2%. The cost of loosing monetary policy flexibility is higher for the three developed countries. Their economies are bigger and their trade share with the EMU is smaller. Of course that the calculation of some benefits and costs are excluded, but on average, the values found in this work for the costs of the loss of monetary policy flexibility, are close to the benefits associated with the disappearance of transaction costs.

2.10 Appendix A - Some Further Business Cycle Calculation

The data was taken from AMECO database, an online annual database of the European Commission. We estimated an OLS regression based on the following expression:

$$\begin{aligned} y\_cic_t &= \beta_1 y\_cic_{t-1} + \beta_2 y\_cic_{t-2} + \beta_3 y\_cic^*_t + \\ &\quad \beta_4 y\_cic^*_{t-1} + \beta_5 y\_cic^*_{t-2} + \varepsilon_t \end{aligned} \tag{2.7}$$

where y_cic is the cyclical component of real GDP of the domestic economy and y_cic^* is the cyclical component of real GDP of the foreign economy. ε_t can be regarded as the idiosyncratic component of the domestic economy fluctuations, i.e., the part of the domestic economy cycle that is not explained by the Eurozone business cycle (or alternatively the USA) nor by the past behavior of the country cycle. The variables were detrended using H-P filter with a value of 100. For each country we try several estimations in order to achieve the best possible fit. This means that whenever variables were not statistical significant, they were removed.

Our purpose with these calculations was to assess the proportion of the business cycle explained by idiosyncratic shocks in each of the countries. This proportion is calculated in the following way: $\frac{\sigma_{\varepsilon_t}}{\sigma_{y\_cic_t}}$, where σ_{ε_t} is the standard deviation of the idiosyncratic component of the cycle and $\sigma_{y\_cic_t}$ is the total standard deviation of the cycle in the domestic economy. So, the bigger the value of this ratio, the bigger the proportion of the business cycle is due to specific country shocks. Our aim was also to compare the importance of the Eurozone and the USA in explaining the economic cycle of these countries, which is why we made two estimations for each country: one where the foreign economy is the Eurozone, and another where the foreign economy is the USA.

2.11 Appendix B - Calibration Values for the Economies at Study

We use annual and quarterly data from several sources, namely OECD, from its database OLISNET; EUROSTAT, from its database NewCronos, and European Commission, from its database AMECO. Whenever needed we remove seasonality from quarterly data using the X12-ARIMA procedure. Data was detrended by using the Hodrick-Prescott filter, using lambda with values of 100 and 1600 for annual and quarterly data, respectively.

2.11.1 Consumers

- The discount factor β is calculated using annual data, later turned into quarterly values, from EUROSTAT (NewCronos). For Denmark, Sweden, and the UK we use data for r^{LT} for the period between 1985 and 2002. For transition countries the period is 1999-2003. This variable was deflated using the consumer price index for the same periods stated above.

- The value for φ, the weight on leisure, is calculated in order to make the time that families dedicate to work equal to a value that matches estimates from OECD (Employment Outlook) for the 1997-2001 period for developed countries, and between 1995 and 1998 for transition countries.

- The money demand regression was estimated with quarterly data for the period 1993:01-2003:02, 1993:01-2003:02, 1988:04-2003:02, 1994:01-2002:01, 1995:01-2002:03 and 1996:01-2002:02, respectively for Denmark, Sweden, the UK, Czech Republic, Hungary, and Poland.

2.11.2 Final Goods Producers

- Regressions to estimate the elasticity of substitution between home and foreign intermediate goods use annual data, from the Annual National Accounts of EUROSTAT. Estimations for Denmark, Sweden, the UK, Czech Republic, Hungary, and Poland were respectively for the following periods: 1966-2002, 1980-2002, 1970-2002, 1990-2002, 1991-2002 and 1992-2002.

- For the weights of domestic and imported goods, we used annual data of bilateral trade of CHELEM data base, which is managed by CEPII - Centre D'Etudes Prospectives et D'Information Internationales. The period used for developed countries is 1967-2001. For Hungary and Poland we use 1991-2001 data, and for Czech Republic the period is 1993-2001.

2.11.3 Intermediate Goods Producers

- We used OECD statistics (Economic Outlook) for the capital income share of the private sector for the period between 1987-2000 for developed countries and between 1994-2000 for the Czech Republic. We assume the same value than the one of the Czech Republic for Hungary, since we could not find any available data for this country. The value for Poland was taken from Zienkowski (2000).

- The data series for the capital stock and gross fixed capital formation (GFCF) was taken from AMECO, an European Commission data base, for the 1960-2002 period for developed countries. Since we could not find available data for the capital stock for transition countries we assume that these countries are going to converge to the steady-state values of the European Union, and hence we use data of this economic bloc to calculate the depreciation rate for these countries. We turn the annual values used to quarterly ones.

- For the markup parameter we used data taken from the NewCronos database for the 1970-2001 period for developed countries, and for transition countries the period used is 1992-2002.

2.11.4 Technological Shocks

- We use quarterly data for the gross domestic product at 1995 prices, from the National Accounts and data on total employment, all from EUROSTAT (NewCronos), for the period between 1991:02 and 2004:01 for developed countries and between 1995:01-2004:01 for transition countries. Solow residuals were estimated using labor data only, because data on capital stock either is not available or it is a unreliable time series.

2.11.5 Government Consumption Shocks

- We use quarterly data for the final consumption expenditure of general government at 1995 prices from the National Accounts, EUROSTAT (NewCronos), for the period between 1991:01-2004:02 for developed countries, and between 1995:01-2004:02 for transition countries.

2.11.6 Monetary Policy Shocks

- For the European Central Bank the parameters for ρ^r, ρ^π and ρ^O are respectively 0.86, 1.12 and 1.03. The volatilities of this rule differs between simulations for each country, being respectively 0%, 0.97%, 0.975%, 1.14%, 0.64%, and 0.695% for Denmark, Sweden, the United Kingdom, the Czech Republic, Hungary, and Poland. In the same order, their economic weights, ϖ, are 2.5%, 3.6%, 16%, 0.8%, 0.7%, and 2.1%.

- The growth rate of prices mu is respectively 1.13, 1.3, and 1.19 for Czech Republic, Hungary, and Poland, implying inflation rates respectively of 2.6, 6.8, and 4.4% for these countries.

- The growth rate of prices mu is respectively 1.04, 1.13 and 1.13 for Denmark, Sweden, and the United Kingdom, implying inflation rates respectively of 1.0%, 3.1%, and 3.1% for these countries.

- We kept a fixed exchange rate in the simulation *Common Monetary Policy,* calibrating with the most recent values from the *Financial Times* online database.

- The Taylor Rule for the ECB was taken from Hayo and Hoffman (2006). Policy rules for UK and Sweden were based on Clarida, Gali, and Gertler (1998) and Knutter (2004), respectively. Policy rules for the Czech Republic and for Hungary, and Poland were based on Laxton and Pesenti (2003) and Mohanty and Klau (2004), respectively.

- We changed the inflation parameter for these rules because it was smaller than one, leading to problems of multiple equilibria.

- Denmark follows an exchange rate peg to the Euro, so we modelled the policy for this country in a different way. The monetary policy rule for Denmark was modelled as an exchange rate peg, so we fixed the exchange rate of the Danish Krone to the Euro with a value of 7.43. Denmark is currently inside the European Exchange Rate Mechanism II (ERM II), so the Taylor Rule was not used for this country.

Parameter values for the countries at study are presented in the Tables B1 to B6 below. The calibration method followed was described in section 2.3.

Table B1 - Parameter values for Czech Republic

Benchmark Model	
Preferences	β=0.996, φ=350, σ=γ=0.0001
	η=0.108, ω=0.0076, k=3.48
Final Good Technology	ρ=0.2366, a_1=0.656, a_2=0.344
Intermediate Good Technology	α=0.385, δ=1.15%, θ=0.951, b=50, N=6
Taylor Rule National Bank	ρ^r=0.81, ρ^π=1.26, ρ^O=0.15
	var(ε^r)=var(ε^{r^*})=0.0091^2,corr(ε^r,ε^{r^*})=0.1
Technological Shocks	ρ^A=0.54, corr(ε^A,ε^{A^*})=0.019
	var(ε^A)=var(ε^{A^*})=0.005^2
Government Consumption Shocks	ρ^g=0.92, μ^g=0.114
	var(ε^g)=var(ε^{g^*})=0.005^2

Table B2 - Parameter values for Hungary

Benchmark Model	
Preferences	β=0.999, φ=200, σ=γ=0.0001
	η=0.23, ω=0.0076, κ=2.8
Final Good Technology	ρ=0.435, a_1=0.635, a_2=0.365
Intermediate Good Technology	α=0.385, δ=1.15%, θ=0.922, b=46, N=6
Taylor Rule National Bank	ρ^r=0.8, ρ^π=1.2, ρ^O=0.36
	var(ε^r)=var(ε^{r^*})=0.00694^2, corr(ε^r,ε^{r^*})=0.1
Technological Shocks	ρ^A=0.51, corr(ε^A,ε^{A^*})=0.34
	var(ε^A)=var(ε^{A^*})=0.019^2
Government Consumption Shocks	ρ^g=0.97, μ^g=0.12,
	var(ε^g)=var(ε^{g^*})=0.019^2

Table B3 - Parameter values for Poland

Benchmark Model	
Preferences	β=0.991, φ=350, σ=γ=0.0001
	η=0.184, ω=0.0076, κ=3.48
Final Good Technology	ρ=0.6, a_1=0.67, a_2=0.33
Intermediate Good Technology	α=0.40, δ=1.15%, θ=0.938, b=31, N=6
Taylor Rule National Bank	ρ^r=0.87, ρ^π=1.32, ρ^O=0.47
	var(ε^r)=var(ε^{r^*})=0.0057^2, corr(ε^r,ε^{r^*})=0.1
Technological Shocks	ρ^A=0.74, corr(ε^A,ε^{A^*})=0.21
	var(ε^A)=var(ε^{A^*})=0.01^2
Government Consumption Shocks	ρ^g=0.63, μ^g=0.10
	var(ε^g)=var(ε^{g^*})=0.01^2

Table B4 - Parameter values for Denmark

Benchmark Model	
Preferences	β=0.987, φ=290, σ=γ=0.0001
	η=0.108, ω=0.0076, κ=3.0
Final Good Technology	ρ=0.231, a_1= 0.8256, a_2=0.1744
Intermediate Good Technology	α=0.359, δ=1.15%, θ=0.975, b=10, N=6
Taylor Rule National Bank	Denmark follows an exchange rate peg to the euro. Taylor Rule was not used.
Technological Shocks	ρ^A=0.453, corr(ε^A,ε^{A^*})=0.38
	var(ε^A)=var(ε^{A^*})=0.004^2
Government Consumption Shocks	ρ^g=0.99, μ^g=0.121
	var(ε^g)=var(ε^{g^*})=0.0186^2

Table B5 - Parameter values for Sweden

Benchmark Model	
Preferences	β=0.996, φ=350, σ=γ=0.0001
	η=0.125, ω=0.0076, κ=3.58
Final Good Technology	ρ=0.2857, a_1=0.8232, a_2=0.1768
Intermediate Good Technology	α=0.378, δ=1.08%, θ=0.951, b=65, N=6
Taylor Rule National Bank	ρ^r=0.82, ρ^π=1.05, ρ^O=0.32
	var(ε^r)=var(ε^{r^*})=0.0085^2,corr(ε^r, ε^{r^*})=0.1
Technological Shocks	ρ^A=0.6, corr(ε^A,ε^{A^*})=0.46
	var(ε^A)=var(ε^{A^*})=0.009^2
Government Consumption Shocks	ρ^g=0.98, μ^g=0.12
	var(ε^g)=var(ε^{g^*})=0.0085^2

Table B6 - Parameter values for UK

Benchmark Model	
Preferences	β=0.996, φ=201, σ=γ=0.0001
	η=0.34, ω=0.0076, κ=3.95
Final Good Technology	ρ=0.1453, a_1=0.8707, a_2=0.1293
Intermediate Good Technology	α=0.378, δ=0.99%, θ=0.951, b=65, N=6
Taylor Rule National Bank	ρ^r=0.92, ρ^π=1.08, ρ^O=0.29
	var(ε^r)=var(ε^{r^*})=0.0046^2,corr(ε^r, ε^{r^*})=0.1
Technological Shocks	ρ^A=0.659, corr(ε^A,ε^{A^*})=0.21
	var(ε^A)=var(ε^{A^*})=0.007^2
Government Consumption Shocks	ρ^g=0.97, μ^g=0.11
	var(ε^g)=var(ε^{g^*})=0.007^2

2.12 Appendix C - Detailed Data Specification and Results for Business Cycle Statistics

- Data was taken from the Quarterly National Accounts of NewCronos, an electronic database of EUROSTAT. The variables used are output (y), private consumption (c), investment (I), net exports as a percentage of GDP (nx), all at constant prices, and employment (l).

- H-P filter with a lambda of 1600 was used to remove the trend and X12-ARIMA to remove seasonality. All variables are in logarithms, except net exports as a percentage of GDP.

- We used quarterly data for the Czech Republic, Hungary, Poland, and the Eurozone (Greece included) for the 1991:01-2003:04 period.

- Data for Denmark refers to the period between 1988:01-2004:01, for Sweden the period is 1980:01-2004:01, for UK is between 1964:01-2004:01, and finally for Eurozone is for 1991:01-2004:01. Statistics for private consumption were calculated after subtracting consumption on durable goods. These data were taken from the Central Statistics Offices of the respective countries, but is still compatible with data taken from EUROSTAT.

- Disaggregation for consumption between durable and non-durable goods for Eurozone and for transition countries is not available.

- The cross-country correlations are for each of the economies and the Eurozone.

Table C1 - Statistics and Stylized Facts for Czech Republic

	Data	Common Monetary Policy	Autonomous Monetary Policy
Standard Deviations			
Y	1.83	1.83	1.83
NX/Y	1.81	0.15	2.30
Standard Deviations Relative to GDP			
C	1.24	0.47	0.69
I	3.51	2.86	4.14
L	0.40	1.73	1.91
Autocorrelations			
Y	0.73	0.51	0.58
C	0.63	0.51	0.60
I	0.55	0.50	0.59
L	0.91	0.53	0.58
NX/Y	0.59	0.71	0.58
Cross-Country Correlations			
(Y, Y^*)	-0.15	1.00	0.92
(C, C^*)	-0.49	1.00	-0.12
(I, I^*)	-0.18	1.00	-0.12
(L, L^*)	-0.36	0.97	0.54
$(Y, NX/Y)$	-0.58	0.03	0.21

Table C2 - Statistics and Stylized Facts for Hungary

	Data	Common Monetary Policy	Autonomous Monetary Policy
Standard Deviations			
Y	1.16	1.16	1.16
NX/Y	1.93	0.72	1.99
Standard Deviations Relative to GDP			
C	1.91	0.47	0.82
I	8.84	2.48	4.38
L	0.80	2.65	2.81
Autocorrelations			
Y	0.49	0.53	0.51
C	0.61	0.54	0.59
I	0.30	0.50	0.57
L	0.78	0.53	0.51
NX/Y	0.50	0.72	0.62
Cross-Country Correlations			
(Y, Y^*)	0.65	0.92	0.92
(C, C^*)	-0.003	0.92	-0.29
(I, I^*)	0.29	1.00	-0.38
(L, L^*)	0.22	0.63	0.40
$(Y, NX/Y)$	-0.36	0.15	0.16

Table C3 - Statistics and Stylized Facts for Poland

	Data	Common Monetary Policy	Autonomous Monetary Policy
Standard Deviations			
Y	1.24	1.24	1.24
NX/Y	1.16	0.23	0.80
Standard Deviations Relative to GDP			
C	0.94	0.39	0.53
I	5.90	3.73	5.03
L	1.09	1.98	2.23
Autocorrelations			
Y	0.82	0.47	0.46
C	0.65	0.50	0.57
I	0.63	0.49	0.56
L	0.74	0.51	0.53
NX/Y	0.51	-0.26	0.34
Cross-Country Correlations			
(Y, Y^{*})	0.52	0.94	0.47
(C, C^{*})	0.23	1.00	-0.13
(I, I^{*})	0.72	1.00	-0.16
(L, L^{*})	0.06	0.74	0.14
$(Y, NX/Y)$	-0.54	0.06	-0.27

Table C4 - Statistics and Stylized Facts for Denmark

	Data	Common Monetary Policy	Autonomous Monetary Policy
Standard Deviations			
Y	1.10	1.16	1.10
NX	0.93	0.87	0.54
Standard Deviations Relative to GDP			
C	1.06	0.73	0.12
I	6.18	4.96	3.21
L	0.70	4.74	2.67
Autocorrelations			
Y	0.47	0.63	0.66
C	0.47	0.69	0.55
I	0.35	0.23	0.35
L	0.56	0.12	0.44
NX	0.53	0.40	0.23
Cross-Country Correlations			
(Y, Y^*)	0.53	-0.53	0.43
(C, C^*)	-0.03	0.91	0.07
(I, I^*)	0.38	-0.34	-0.09
(L, L^*)	0.51	-0.02	0.14
(Y, NX)	-0.01	-0.10	-0.23

Table C5 - Statistics and Stylized Facts for Sweden

	Data	Common Monetary Policy	Autonomous Monetary Policy
Standard Deviations			
Y	1.43	1.43	1.43
NX	0.86	0.12	0.44
Standard Deviations Relative to GDP			
C	0.91	0.55	0.64
I	5.17	2.79	3.23
L	0.71	1.92	2.10
Autocorrelations			
Y	0.59	0.52	0.54
C	0.70	0.52	0.56
I	0.67	0.52	0.55
L	0.85	0.55	0.56
NX	0.46	0.06	0.13
Cross-Country Correlations			
(Y, Y^*)	0.67	0.97	0.40
(C, C^*)	0.72	1.00	0.07
(I, I^*)	0.72	1.00	0.07
(L, L^*)	0.70	0.84	0.17
(Y, NX)	-0.20	-0.11	-0.35

Table C6 - Statistics and Stylized Facts for UK

	Data	Common Monetary Policy	Autonomous Monetary Policy
Standard Deviations			
Y	1.47	1.47	1.47
NX	0.78	0.07	0.45
Standard Deviations Relative to GDP			
C	0.93	0.46	0.54
I	4.95	2.88	3.16
L	0.82	1.81	2.23
Autocorrelations			
Y	0.62	0.52	0.58
C	0.79	0.51	0.62
I	0.64	0.51	0.61
L	0.92	0.55	0.63
NX	0.57	-0.16	-0.15
Cross-Country Correlations			
(Y, Y^*)	0.19	0.99	0.41
(C, C^*)	-0.02	1.00	0.13
(I, I^*)	0.22	1.00	0.14
(L, L^*)	0.26	0.89	0.11
(Y, NX)	-0.26	-0.07	-0.22

2.13 Appendix D - Detailed Results for the Sensitivity Analysis

Table D1 - Welfare Results for Sensitivity Analysis - Czech Republic

	C	L	M/P	U	λ
Benchmark					
Common Monetary Policy	100.16	100.25	100.71	99.99	-0.26%
Autonomous Monetary Policy	100	100	100	100	
No Technological Shocks					
Common Monetary Policy	100.16	100.25	100.71	99.99	-0.26%
Autonomous Monetary Policy	100	100	100	100	
No Government Consumption Shocks					
Common Monetary Policy	100.16	100.25	100.68	99.99	-0.29%
Autonomous Monetary Policy	100	100	100	100	
Correlation of the Monetary Policy Shocks					
Common Monetary Policy	100.05	100.08	100.24	100.02	-0.10%
Autonomous Monetary Policy	100	100	100	100	
Relative Risk Aversion Coefficient					
Common Monetary Policy	100.15	100.24	100.71	99.99	-0.29%
Autonomous Monetary Policy	100	100	100	100	
Weight of the Imported Goods from the Eurozone					
Common Monetary Policy	100.21	100.23	100.70	99.99	-0.33%
Autonomous Monetary Policy	100	100	100	100	

Table D2 - Welfare Results for Sensitivity Analysis - Hungary

	C	L	M/P	U	λ
Benchmark					
Common Monetary Policy	100.27	100.25	100.73	99.99	-0.18%
Autonomous Monetary Policy	100	100	100	100	
No Technological Shocks					
Common Monetary Policy	100.27	100.25	100.73	99.99	-0.18%
Autonomous Monetary Policy	100	100	100	100	
No Government Consumption Shocks					
Common Monetary Policy	100.14	100.37	100.56	99.93	-0.44%
Autonomous Monetary Policy	100	100	100	100	
Correlation of the Monetary Policy Shocks					
Common Monetary Policy	100.20	100.12	100.45	100.02	-0.03%
Autonomous Monetary Policy	100	100	100	100	
Relative Risk Aversion Coefficient					
Common Monetary Policy	100.42	100.26	100.45	99.98	-0.20%
Autonomous Monetary Policy	100	100	100	100	
Weight of the Imported Goods from the Eurozone					
Common Monetary Policy	100.20	100.31	100.61	99.96	-0.33%
Autonomous Monetary Policy	100	100	100	100	

Table D3 - Welfare Results for Sensitivity Analysis - Poland

	C	L	M/P	U	λ
Benchmark					
Common Monetary Policy	100.05	100.23	100.34	99.97	-0.25%
Autonomous Monetary Policy	100	100	100	100	
No Technological Shocks					
Common Monetary Policy	100.11	100.19	100.38	99.98	-0.21%
Autonomous Monetary Policy	100	100	100	100	
No Government Consumption Shocks					
Common Monetary Policy	100.05	100.23	100.34	99.97	-0.25%
Autonomous Monetary Policy	100	100	100	100	
Correlation of the Monetary Policy Shocks					
Common Monetary Policy	99.95	100.18	100.08	99.96	-0.25%
Autonomous Monetary Policy	100	100	100	100	
Relative Risk Aversion Coefficient					
Common Monetary Policy	100.08	100.18	100.38	99.96	-0.25%
Autonomous Monetary Policy	100	100	100	100	
Weight of the Imported Goods from the Eurozone					
Common Monetary Policy	100.11	100.24	100.33	99.97	-0.26%
Autonomous Monetary Policy	100	100	100	100	

Table D4 - Welfare Results for Sensitivity Analysis - Denmark

	C	L	M/P	U	λ
Benchmark					
Common Monetary Policy	100.68	101.46	100.24	99.74	-5.44%
Autonomous Monetary Policy	100	100	100	100	
No Technological Shocks					
Common Monetary Policy	100.68	101.40	100.24	99.75	-6.73%
Autonomous Monetary Policy	100	100	100	100	
No Government Consumption Shocks					
Common Monetary Policy	100	100	100	100	0.0185%
Autonomous Monetary Policy	100	100	100	100	
Correlation of the Monetary Policy Shocks					
Common Monetary Policy	n.a.	n.a.	n.a.	n.a.	n.a.
Autonomous Monetary Policy	n.a.	n.a.	n.a.	n.a.	
Relative Risk Aversion Coefficient					
Common Monetary Policy	100.43	100.65	100.24	99.88	-2.48%
Autonomous Monetary Policy	100	100	100	100	
Weight of the Imported Goods from the Eurozone					
Common Monetary Policy	100.68	101.45	100.28	99.73	-5.20%
Autonomous Monetary Policy	100	100	100	100	

Table D5 - Welfare Results for Sensitivity Analysis - Sweden

	C	L	M/P	U	λ
Benchmark					
Common Monetary Policy	100.09	100.33	100.62	99.94	-0.54%
Autonomous Monetary Policy	100	100	100	100	
No Technological Shocks					
Common Monetary Policy	100.09	100.38	100.62	99.94	-0.53%
Autonomous Monetary Policy	100	100	100	100	
No Government Consumption Shocks					
Common Monetary Policy	100.14	100.22	100.74	99.99	-0.25%
Autonomous Monetary Policy	100	100	100	100	
Correlation of the Monetary Policy Shocks					
Common Monetary Policy	100	100.27	100.19	99.95	-0.45%
Autonomous Monetary Policy	100	100	100	100	
Relative Risk Aversion Coefficient					
Common Monetary Policy	100.10	100.35	100.67	99.94	-0.47%
Autonomous Monetary Policy	100	100	100	100	
Weight of the Imported Goods from the Eurozone					
Common Monetary Policy	100.09	100.31	100.65	99.96	-0.43%
Autonomous Monetary Policy	100	100	100	100	

Table D6 - Welfare Results for Sensitivity Analysis - United Kingdom

	C	L	M/P	U	λ
Benchmark					
Common Monetary Policy	100.13	100.31	102.03	99.96	-0.54%
Autonomous Monetary Policy	100	100	100	100	
No Technological Shocks					
Common Monetary Policy	100.13	100.31	102.03	99.96	-0.54%
Autonomous Monetary Policy	100	100	100	100	
No Government Consumption Shocks					
Common Monetary Policy	100.17	100.31	102.12	99.97	-0.46%
Autonomous Monetary Policy	100	100	100	100	
Correlation of the Monetary Policy Shocks					
Common Monetary Policy	99.97	100.41	100.5	99.89	-0.77%
Autonomous Monetary Policy	100	100	100	100	
Relative Risk Aversion Coefficient					
Common Monetary Policy	100.11	100.34	102.03	99.94	-0.6%
Autonomous Monetary Policy	100	100	100	100	
Weight of the Imported Goods from the Eurozone					
Common Monetary Policy	100.14	100.34	101.99	99.95	-0.55%
Autonomous Monetary Policy	100	100	100	100	

Chapter 3

Comparing Monetary Union Experiences

3.1 Introduction

Has the European Union affected the business cycle behavior of its member countries? Is its impact any different from other previous integration experiences, namely federalist experiences? And if so, does Europe need a Federation? This paper tries to answer these questions on the basis of a comparison between the European Union and some federalist countries, namely Canada, Germany, Switzerland, and the United States.

The federal economies analyzed here have already moved one step further than the EU in the integration process, i.e., political union. According to the Oxford Dictionary, "A Federal State is a system of government in which several States form a unity but remain independent in internal affairs". Thus, in order to have the full establishment of a political union, a federal constitution, a federal court and other legislative and policy-making institutions would be needed.

The introduction of the Euro brought the issue of federalism back to life, mainly due to concerns about asymmetric shocks and the lack of a monetary policy instrument to deal with these shocks. A redistribution mechanism may be needed to help regions which suffer a specific shock, i.e., money is shifted from rich to poor regions to stabilize the economy, through a federal budget. Fatás (1998) discusses the introduction of federalism in Europe and compares it with the USA. He finds that previous studies had overestimated the benefits of stabilization provided by the US federal budget and also finds evidence that national tax systems have the power to provide more than 50% of the degree of insurance that a European federation would. Moreover, the correlation between European economies is increasing, reducing the need for insurance tax instruments.

Another important tool to stabilize economies that lose the ability to use monetary policy is having a flexible labor market, and in particular labor mobility, whereby workers can move to other regions or countries when specific shocks hit the region that they are working in. These two instruments, fiscal federalism and labor mobility, are highlighted by the theory of optimum currency areas as two very important stabilization mechanisms. However, a strand of research suggests that the mere existence of a monetary union makes the optimality criterion endogenous (Frankel and Rose, 1998). If this is the case, does Europe then need to move one step closer towards integration? Or, will that step appear in a natural, endogenous way?

Using rolling windows and cluster analysis techniques, we analyze the comovements of the output gaps for the regions of Canada, Germany, Switzerland, United States, and for the member countries of the European Union. The rolling windows technique enables us to analyze the evolution of business cycle comovements and volatility.

Artis and Zhang (1997) analyze correlations between European countries and find evidence of a strong correlation between European economies after the start of the European Monetary System, with the countries shifting their comovements from the US to Germany. Fatás (1997) also finds an increasing correlation, using employment as the analyzed variable, between the EU-12 individual members and the EU-12 aggregate, and also among member countries themselves. He also analyzes correlations between German, Italian, French, and British regions and finds evidence that correlations between the regions of these countries have been decreasing, while correlations between these countries and the European Union have increased. According to the author, increasing economic integration (trade) and coordination between policies are the likely factors that caused this event. Our results of bilateral correlations for the regions of the analyzed monetary unions also indicate some decreased correlation over time.

This fact, which has also been noticed by other studies including Bordo and Helbling

(2003), suggests that global common shocks are more important than idiosyncratic shocks for explaining business cycles during the past century.

Cluster analysis, on the other hand, is a good technique to detect the existence (or not) of a core-periphery pattern in monetary unions.[1] To study whether or not we have this type of situation, it is equivalent to study the cyclical convergence between regions. Camacho, Perez-Quiros, and Saiz (2006) use a few methods, including cluster analysis, to analyze correlations of business cycles among European economies. Although European Monetary Union (EMU) has not existed for very long, the authors conclude that EMU did not change the degree of comovements a lot between member countries.

Bayoumi and Eichengreen (1993) compare data for the US States and European Union countries to analyze aggregate demand and supply shocks and detect the existence of possible core-periphery situations in Europe, although they do not use cluster analysis. Their results indicate that shocks appear more idiosyncratic in the European Union countries than in the US States, but also suggest that there is a core of countries in the European Union, governed by Germany and its closest neighbors, that exhibit shocks similar in magnitude to those hitting US States. The authors conclude that these results show the EMU to be a difficult group to manage.

Artis, Kohler, and Mélitz (1998) use a similar technique to cluster analysis to calculate the number of optimal currency areas in the world. They use data on trade share and output cyclical correlations and conclude that, among other currency areas, there is some support for the existence of the EMU. However, its size is smaller than the actual one if both criteria are considered, especially the output gap cyclical correlations that show weak correlations between some countries that already belong to the EMU. If both criteria are applied, two possible EMUs could arise: one, with German, Austria, Belgium, and the Netherlands and another with France, Italy, Spain, and Belgium. France and Germany present weaker correlations and they do not manage to be included in the same group. Moreover, the United Kingdom is eliminated from these two possible groups and there is

[1] Tsangarides and Qureshi (2006) use cluster analysis to evaluate common characteristics among regions of West Africa countries that want to form a monetary union. They use crisp and fuzzy clustering on a set of variables, including the one used here - the correlations of business cycles - to analyze a similar topic to ours: the adequacy of membership of a monetary union.

evidence of a strong Scandinavian group.

This work studies business cycle features at the regional level for five monetary unions, four of which are federalist countries, namely, Canada, Germany, Switzerland, and the USA, and one is the European Union. By using cluster analysis, we also try to detect a core-periphery pattern concerning cyclical association in these monetary unions. Our aim is to compare the EU with economies that have already moved a step further in the integration process, namely, political union, in the form of federalism.[2] In section 3.2 we provide some historical background for the analyzed monetary unions as well as information about the data used. In section 3.3 we present business cycle correlations analysis and section 3.4 analyzes cluster analysis for all the monetary unions that we studied. Section 3.5 concludes.

3.2 A Sample of Monetary Unions

3.2.1 Historical Background

Compared with Canada, Germany, Switzerland, and the United States, the European Union is a relatively new integration experience, as we can see in Table 3.1 below.

Table 3.1 - Historical Integration Processes

	Date of Formation	Common Central Bank	Common Currency
Canada	1867	yes (1935)	yes (1858)
Germany	1871	yes (1876)	yes (1871)
Switzerland	1848	yes (1907)	yes (1848)
The United States of America	1788	yes (1914)	yes (1788)
European Union	1957	yes (1999)	yes (1999)

European Union integration begun with the goal of establishing peace between France and Germany, by means of economic cooperation after World War II. In 1957, six countries signed the Treaty of Rome: Belgium, France, Germany, Italy, Luxembourg, and the Netherlands. Several more countries joined later, in 1973, 1981, 1986, 1995, 2004, and

[2] For this exercise, it would be preferable to have data starting before the constitution of a federation or before the constitution of a monetary union. However, regional data for these federal economies only starts after these particular historical events.

finally 2007. Moreover, further enlargement seems yet to come, given that other countries are asking to join.

The European Union evolved from an initial customs union, which was gradually set in motion and still presents some drawbacks nowadays, to an Economic and Monetary Union. Monetary Union was initialized with the Maastricht Treaty in 1992. Then, in 1999, the Euro, the European common currency, and the European Central Bank, the guardian of European monetary policy, were also set into place. European integration has not yet moved to a formal political union, there is an insufficiently large budget for stabilization purposes and federal transfers do not exist (Bordo, 2004). In 2005, a proposed European Constitution failed to be ratified in France and the Netherlands, an act that some people believe to be a sign of a general lack of belief in the European construction process.

Canadian Federation was established in 1867, under the British North American Act. The Federation was built against fears of an American invasion. The government in charge of ruling the Federation was also in charge of issuing currency and supervising the banking sector. The designation of the Canadian currency was established as the dollar, a designation that has prevailed since 1858 under the Currency Act. This year marks the effective year of a distinctive Canadian currency, although others currencies were also allowed to be circulated in the country. During the decade after the establishment of the Constitution, the Canadian government made an effort to remove all other foreign currencies from circulation, including American dollars and British pounds. The country has two official languages, English and French, remaining historical signs of the previous English and French occupations (Powell, 2005).

Germany has been a Federation since 1871, born out of a fear of Prussia and the existing German Confederation with their neighbour Austria. The Federation has held a common currency since that date, and a Central Bank was established in 1876. Before 1871 a customs union was already functioning. The current Constitution was formally enforced in 1949. From the end of World War II until 1989, Germany was divided between Western and Eastern Länders. After German reunification, the sixteen Länders were joined again, although a very different Germany arose from this event, with strong disparities between the West and the East (Valério, 2005).

Switzerland became a federal state in 1848 when a constitution, replacing the old laws, turned a Confederation into a Federation, i.e., they changed from an association of sovereign entities, to a group of entities that share a common central authority. The constitution abolished trade restrictions between Cantons and established a single currency, with the federal authorities in charge of enforcing these policies. The Swiss National Bank was established in 1907. This country has twenty-six regions called Cantons and four official languages, namely, German, French, Italian, and Romanisch. Since the implementation of the constitution, the Cantons no longer have the right to leave the Federation (Church and Dardanelli, 2005).

The federation of the United States of America was formed in 1776, although the US Federal Constitution was ratified later, in 1788. The Federation evolved from the initial thirteen colonies in 1776 to an eventual 50 states, with Alaska and Hawaii joining in 1959. The USA was born out of the desire of the thirteen colonies for independence from Britain, as they came to realize that individually they had a smaller chance of survival. Since 1788 a single currency has been circulating in the economy, but it took until 1914 for the Federal Reserve to appear and until the 1930s for federal fiscal transfers to achieve an important role. Federal institutions, such as the Federal Reserve, arose from the need to solve some specific problems and not as part of a well defined plan. This is a big contrast from the construction of the European Union (Bordo, 2004).

3.2.2 Samples

The variable used in all techniques is the annual output gap. We calculated this variable by subtracting the value for potential output from the log real output for each region. We used the Hodrick-Prescott filter with a lambda parameter of 100 to calculate potential output. The variable used for each region and monetary union is not always the gross domestic product (GDP) since it is not available for every country.[3] Ideally, to fully assess issues of endogeneity of optimum currency area criteria, data starting before the constitution of a monetary union in these countries would be needed. However, regional data for these monetary unions has not existed for long enough. Thus this study was

[3] See Appendix A for details about the data, data sources and other methodological issues.

restricted to the longest available time series for each country.

The monetary unions under analysis have different lengths for their regional time series.[4] In Canada, data for current provincial personal income is available between 1926 and 2005. The country is composed of ten provinces and three territories, but in this analysis we have excluded the Yukon, Nunanut, and Northwestern Territories. Their weight in Canada is almost residual, so the loss of this data is negligible. Data is available for US States between 1929 and 2005 and it is also for current state personal income. For the twenty six Cantons of Switzerland, data is available for the Net National Income at factors cost and current prices between 1978 and 2004. For these three countries we did not have deflators at the regional level, so we used the national private consumption deflator, to deflate regional output. Previous studies facing the same problem have used this same method, e.g., Sala-i-Martin (1996).

For the sixteen Länders of Germany, data for gross domestic product at 1995 prices is available between 1991 and 2004. In addition, we have data between 1970 and 2004 for the eleven Western Länders, although data for West Berlin is only available until 1990. For the European Union, the longest period available was 1960-2005, and the variable that we use is gross domestic product at 2000 prices. We use this period for most of the current members of the European Union, but Eastern and Central European Countries usually only have data beginning in the early nineties.

3.3 Business Cycles

3.3.1 Methodology

We analyzed the dynamics of the correlations for the output gap between regions in each monetary union using rolling windows analysis. Rolling-window analysis works like a moving sample, when some specified number of observations is dropped from each window and others are added in; with each window always having the same length.

To perform rolling windows analysis, we specified a window length of ten years, usually

[4] In Appendix B we have available a list of regions and maps for each of the monetary unions. The list of regions for each monetary union also provides its accession date, the abbreviation of its name, and its relative weight in the union's total output. The base year for this calculation is the last year available in the sample for each monetary union.

the average duration of a complete business cycle.[5] The window is moved forward by an increment of one year. So we began by using observations 1 to 10 of the data, then using observations 2 to 11, and so on. The following equation was used to apply the rolling windows technique to the calculation of the correlations coefficients between region i and j ($r_{i,j}$) in each window of ten years[6]:

$$r_{i,j} = \frac{\sum_{n=1}^{k}(X_{i,n} - \bar{X}_i)(X_{j,n} - \bar{X}_j)}{\sqrt[2]{(\sum_{n=1}^{k}(X_{i,n} - \bar{X}_i)^2)(\sum_{n=1}^{k}(X_{j,n} - \bar{X}_j)^2)}} \tag{3.1}$$

where $X_{i,n}$ is the value of the output gap for region i in a given period n, where $n = 1, .., k$ and k is equal to 10 for a ten-year rolling window, and $\bar{X}_i$ is the average value for the output gap for region i for a given ten-year rolling window. The same applies to region j. The number of regions varies according to the monetary union being studied.

In each window we calculated the bilateral correlation matrix between the regions of the monetary unions being studied. Thus, given Z regions for a given monetary union, in each window we calculate $\frac{Z(Z-1)}{2}$ bilateral correlations, and compute their average and standard deviation. In the figures presented below, we called these values "bilateral average" and "standard deviation (bilateral)", respectively.

We also calculated a vector $(Z \times 1)$ of correlations of the regions with the union and obtained the average and standard deviations of these correlations. In the figures presented below, we designated these values as "national average" and "national standard-deviation", respectively.

The figures presented in the text are for the rolling windows analysis of ten years length. Because the choice of the optimal period of time for a rolling window is not yet a consolidated topic in the literature, we also performed calculations with different periods of time, using periods of fifteen and/or twenty years, depending on the length of the sample for each monetary union. We also did fifteen-year rolling windows analyses for

[5] Sorensen and Whitta-Jacobsen (2005) and the seminal work of Burns and Mitchell (1946) are good references of studies about business cycles length.

[6] Notice however, that computation of the output gap was performed only once, using the full sample.

both Germany and Switzerland, since their data series are shorter than the ones of the other monetary unions being studied.[7]

3.3.2 Results

Canada

The analysis for the entire period tells us that most of the provinces exhibit strong bilateral correlations, and that there are also high correlations between the provinces and the whole of Canada. The province of Newfoundland and Labrador exhibits a weaker correlation with the other provinces and a lower standard deviation. However, this province joined Canada in 1949, long after the others. Although entering in 1905, the Saskatchewan province exhibits substantially higher standard deviations than the remaining provinces and weaker bilateral correlations.

We performed rolling windows of ten and twenty years to analyze the dynamics of the correlations. Figures 3.1 and 3.2 show results for average and standard deviations of the correlations, respectively. Correlations at the beginning of the analyzed period were high, but the data presents a trend of decreasing average correlation, except in the 1970s and 1990s. By contrast, the standard deviations of the correlations were low at first, and show an upward trend, except in the 1970s. The standard deviations also increased in the years after the province of Newfoundland and Labrador joined the Federation.

These conclusions are valid for both periods of rolling windows analysis, although, the values for the ten-year period show a lot of significant changes. The increasing standard deviations and decreasing average correlations point to a possible development of a core-periphery pattern in this country, since the provinces seem to be experiencing some degree of divergence.

[7] See Appendix C for results of rolling windows of 15 and 20 years for the monetary unions being studied. In these cases k will be 15 and 20 respectively, in the equation (3.1) above. Some specific results for certain regions and monetary unions are not presented in the text but are available upon request from the author.

Figure 3.1: Average Correlations between Canadian Provinces and with Canada

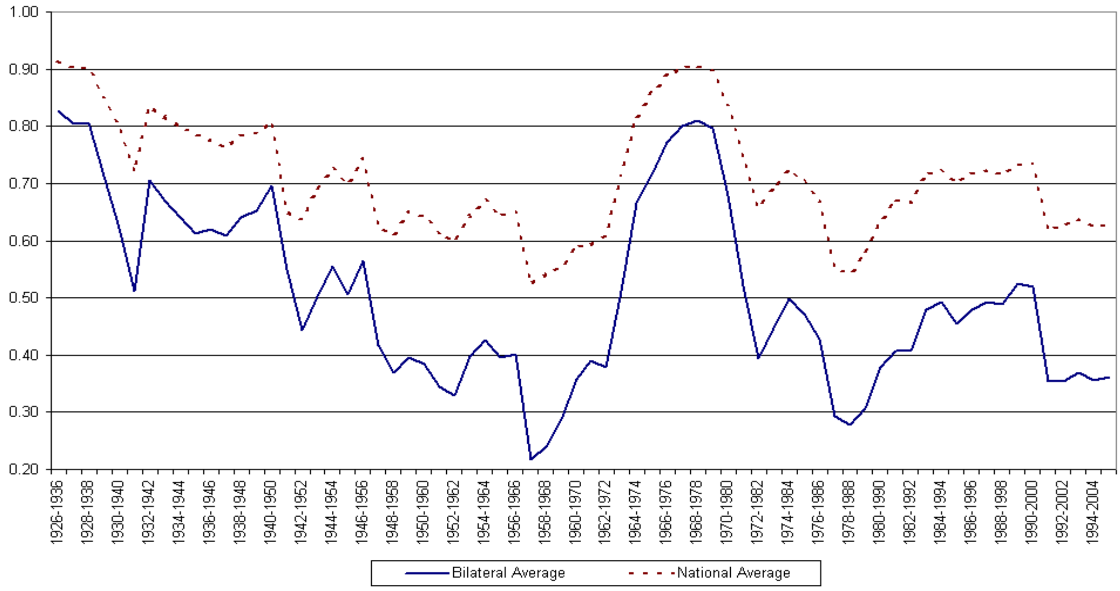
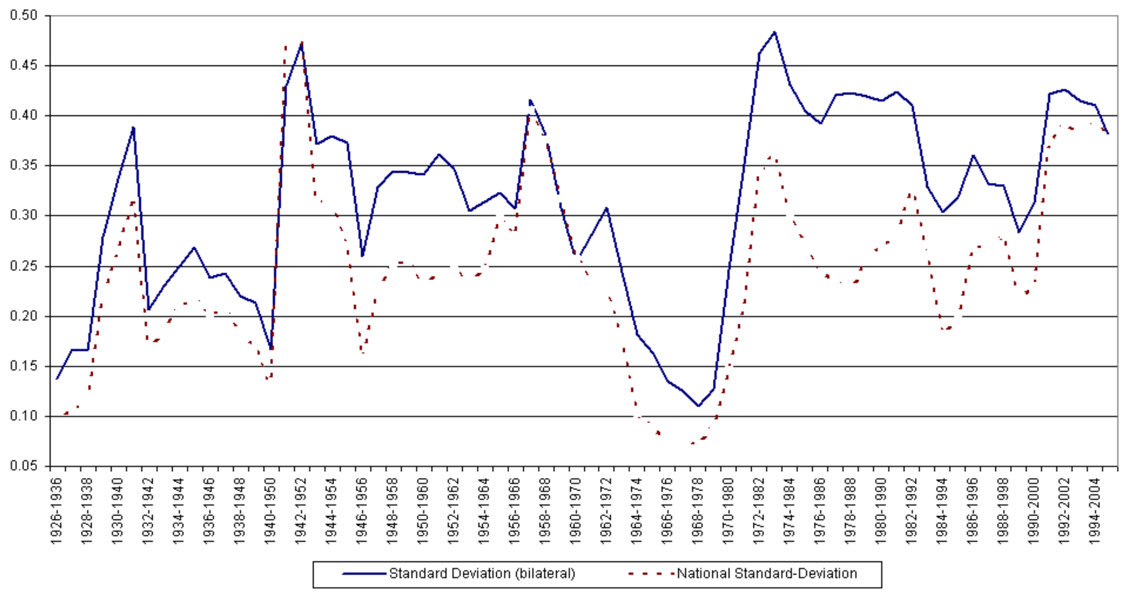


Figure 3.2: Standard-Deviations of the Correlations for the Canadian Provinces

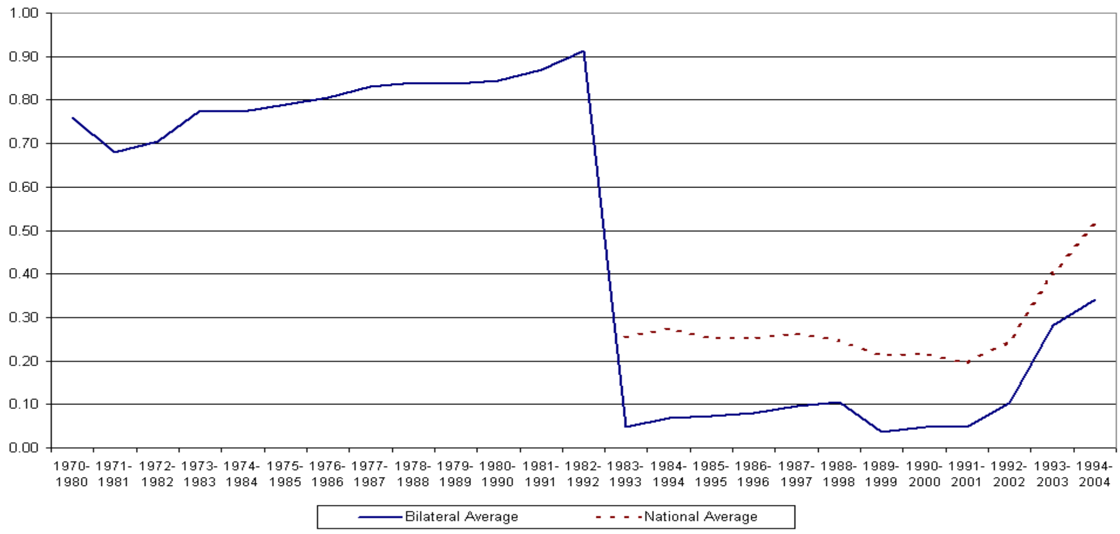


Germany

Looking at the business cycles data for the entire period, we can see that the Eastern Länders have higher standard deviations than Western Länders. Their economies are smaller and experiencing a period of transition from a socialist to a market economy. On average, Eastern Länders exhibit negative correlations with Germany and also with Western Länders. For Western Länders, correlations increased in the period between 1991 and 2004, in comparison with the entire period of 1970 to 2004.

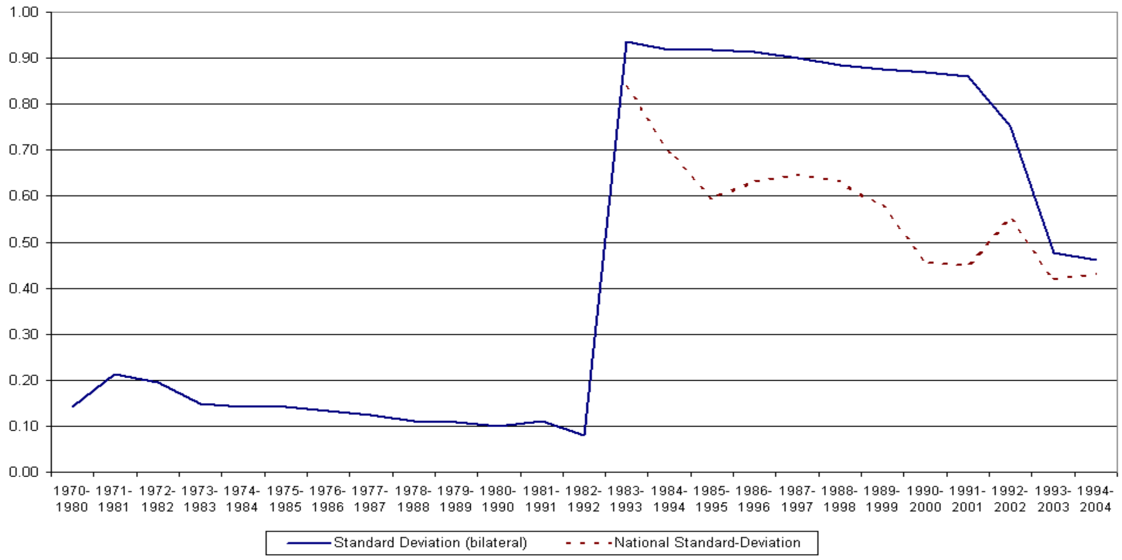
We performed rolling windows analysis of ten, fifteen, and twenty years for Germany. Figures 3.3 and 3.5 show that the average correlations between Western Länders were very high in the period before unification, but also that the average correlations between all Länders after unification are very low, although they are increasing. Figure 3.4 shows that the standard deviations for all Länders substantially increased due to the reunification process, but have exhibited a declining trend afterwards, clearly demonstrating the strong impact of the reunification on the country.[8]

Figure 3.3: Average Correlations between German Länders and with Germany



[8]The calculation of average correlations and standard deviations for Germany as whole, as seen in Figures 3.3 and 3.4, with the sixteen Länders, is only possible after 1991, when data for all Länders is available.

Figure 3.4: Standard-Deviations of the Correlations for the German Länders



Standard deviations of the correlations between Western Länders, however, present a declining trend. This, of course, demonstrates a substantial difference between the Western and Eastern parts of Germany, and indicates the presence of two distinct groups in this country, as can be seen by comparing Figures 3.4 and 3.6. The figures shown below give results only for the Western Länders between 1970 and 2004, excluding West Berlin.[9]

[9] In Figures 3.5 and 3.6, Germany was computed as the sum of the ten Western Länders, excluding West Berlin.

Figure 3.5: Average Correlations between Western Länders and with Germany

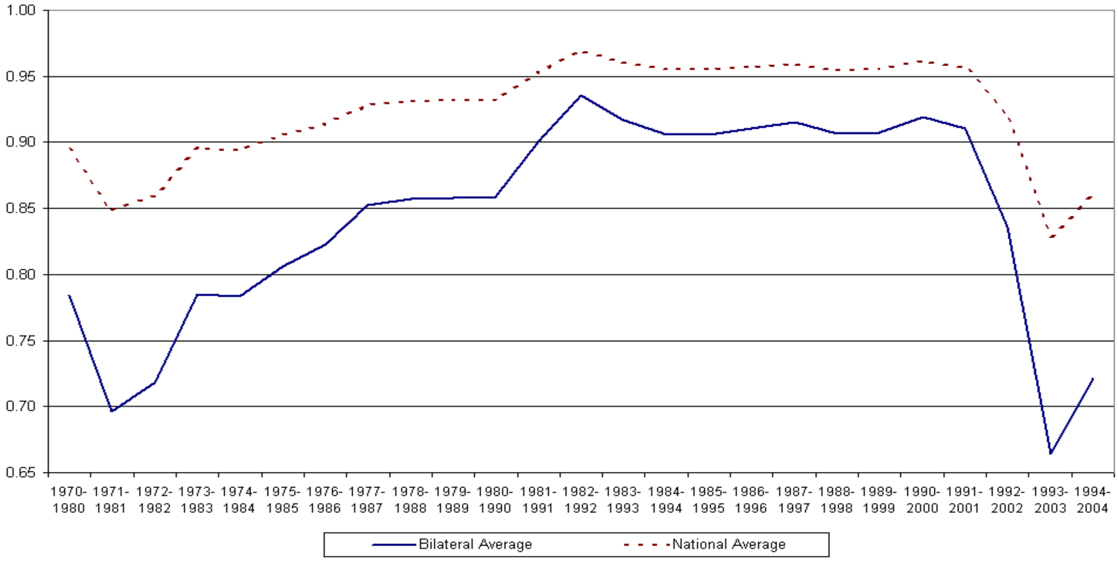
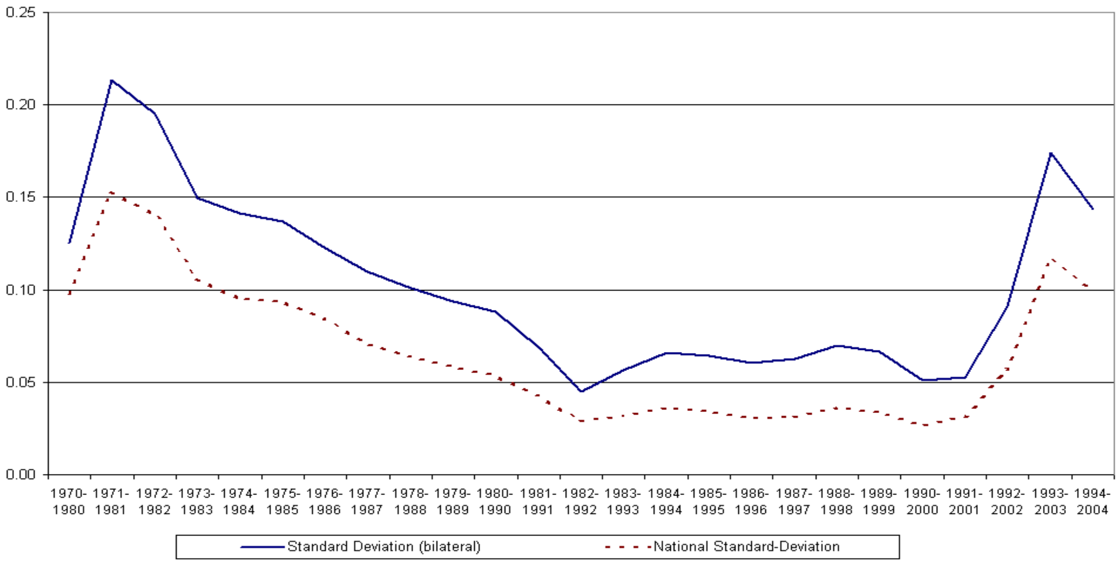


Figure 3.6: Standard-Deviations of the Correlations for the German Western Länders



Switzerland

Switzerland presents weaker positive correlations between its regions than the other analyzed monetary unions. Several Cantons exhibit negative correlations between each other, although none has a negative correlation with the national economy.

We performed rolling windows analysis of ten, fifteen, and twenty years and analyzed the average correlations and the standard deviations of the correlations between the Cantons and the monetary union and also among the Cantons. Figure 3.7 shows that the initial value for bilateral and national average correlations was relatively high, although lower than for Canada and West Germany, and has been decreasing over time. This fact is evident in all time periods used for the calculations of rolling windows, although a smoother path was found in rolling windows with a larger length. On the other hand, the standard deviations of the correlations have been increasing, even though this evidence is clearer in the ten-year period rolling windows, as can be seen in Figure 3.8. This seems to be evidence of some loss of convergence between the Cantons.

Figure 3.7: Average Correlations between Swiss Cantons and with Switzerland

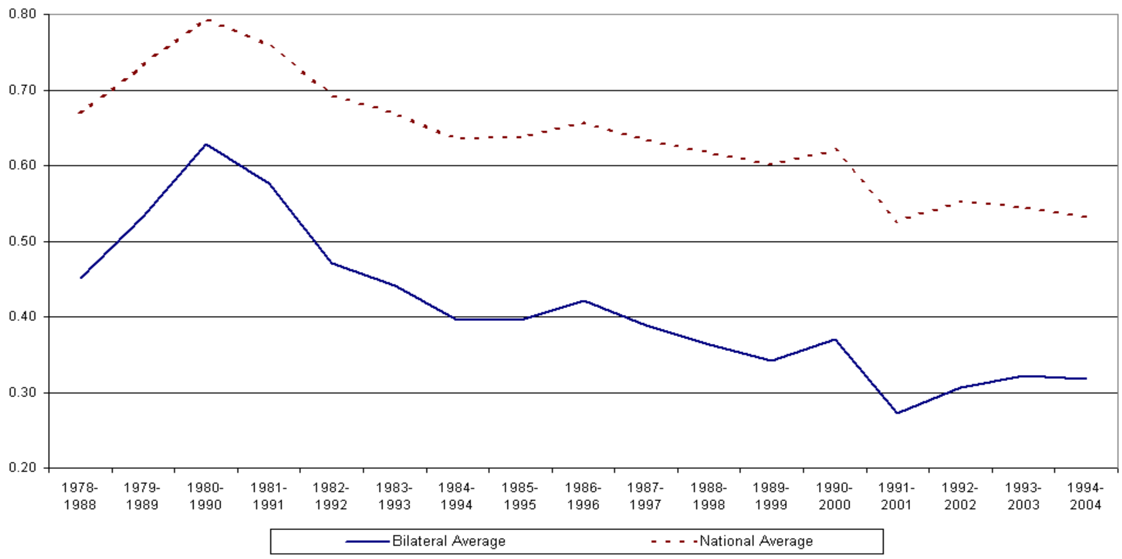
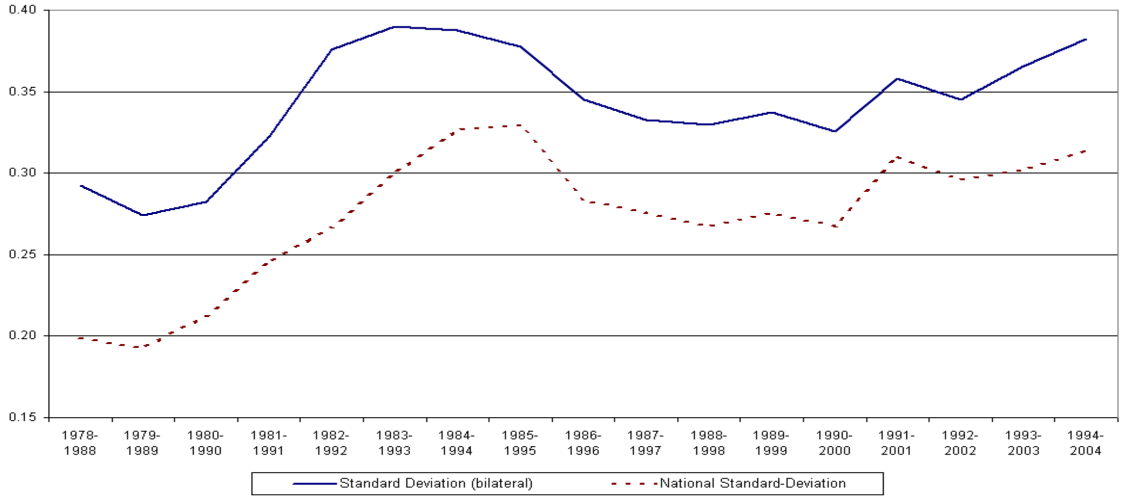


Figure 3.8: Standard-Deviations of the Correlations for the Swiss Cantons



United States of America

Some facts appear in the analysis for the entire period for the USA, namely that most average bilateral correlations between US States are positive and significantly high. However, correlations between Alaska, Hawaii, and some other US States are negative, and positive correlations with other States are weak. Alaska and Hawaii only joined the Federation in 1959, so a possible explanation for these results could be the shorter accession time of these States to the Federation.

The behavior of the variables for the USA is somewhat similar to Canada, i.e., correlations start with an initial high value, but show a decreasing average correlation, except in the 1970s and at the end of the 1990s, for the ten-year rolling windows, as show in Figure 3.9. The twenty-year rolling windows show that after the 1970s, average correlations have remained relatively stable.

Figure 3.10 shows that the initial value for the standard deviations of the correlations was low, but shows an increasing trend, except in the 1970s. The standard deviations of the correlations also increased in the years after the States of Alaska and Hawaii joined the Federation. The main conclusions are valid for both lengths of rolling windows analysis.

Figure 3.9: Average Correlations between USA States and with the USA

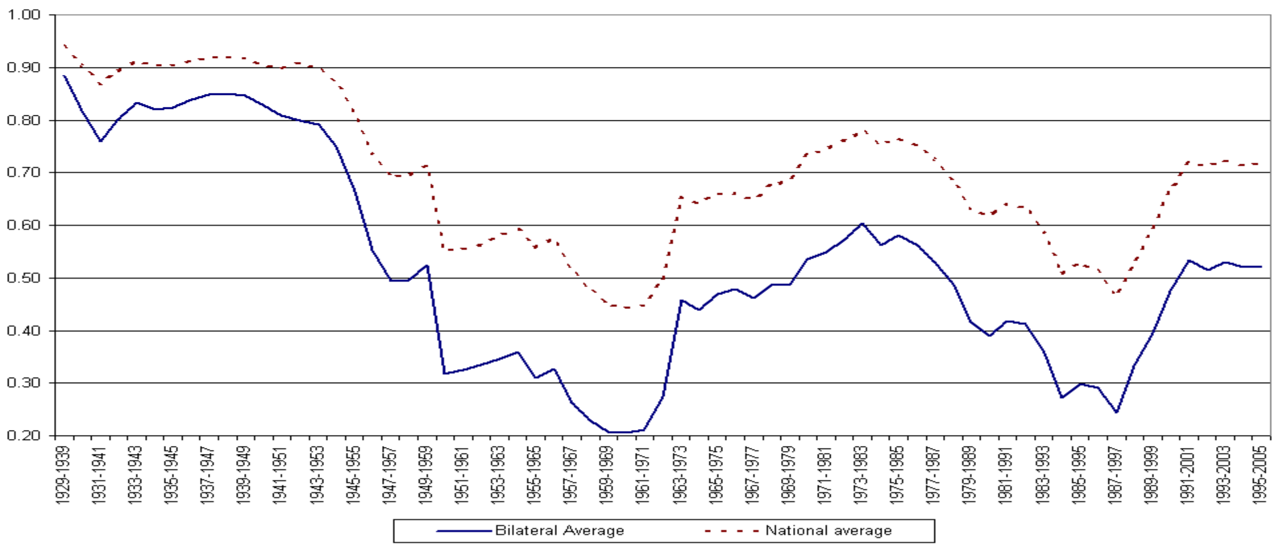
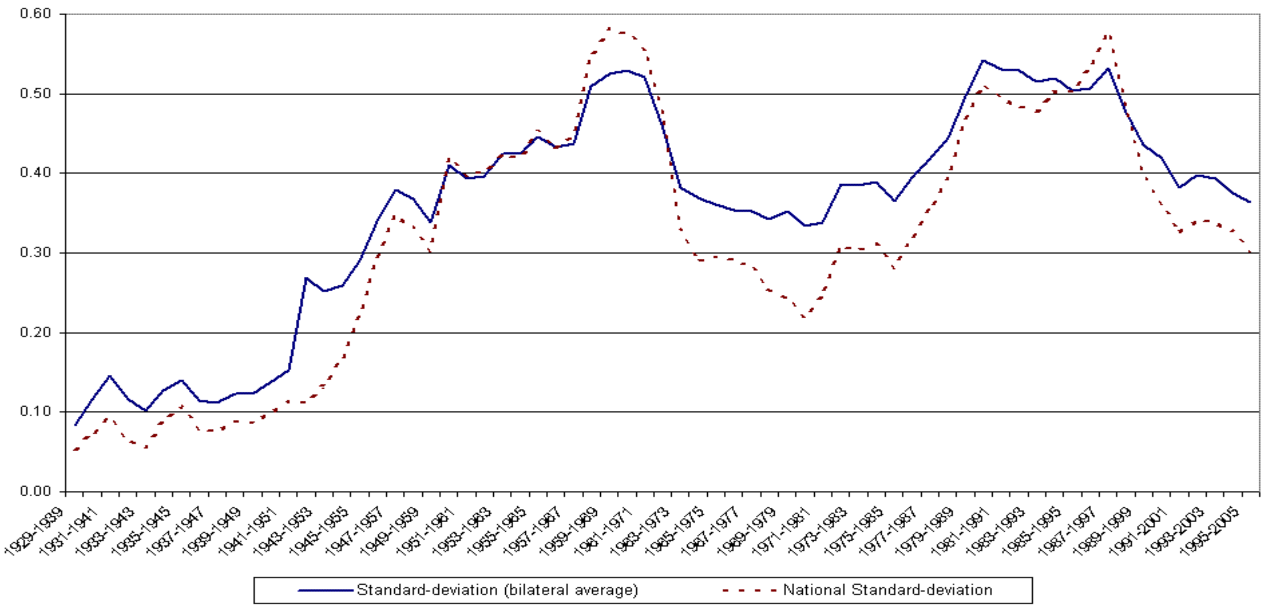


Figure 3.10: Standard-Deviations of the Correlations for the USA States



The European Union

Standard deviations are usually higher in transition countries, such as the former communist countries that joined the EU, and correlations are negative between new members of Eastern Europe and old members of Western Europe. Transition countries are catching up and are not synchronized with their neighbouring countries. Strong positive correlations between old member countries are significative. The UK, Denmark, and Sweden present lower correlations than countries inside the Eurozone. Countries with strong GDP growth rates in the 1990s, such as Ireland and Finland, also have lower correlations.

The results for rolling windows analysis show broadly stable average correlations, except in the 1990s, when the Central and Eastern countries joined the sample, as can be seen in Figure 3.11. From that point on, when the European Union became a regional bloc with twenty five members, correlations began to decrease. We also can see in Figure 3.12 that standard deviations of the correlations show an increasing trend, both between the member countries and the European Union and between the member countries themselves, especially after the Central and Eastern countries joined the sample. The main conclusions are valid for both periods of rolling windows analysis used.

Figure 3.11: Average Correlations between the EU Countries and with the EU

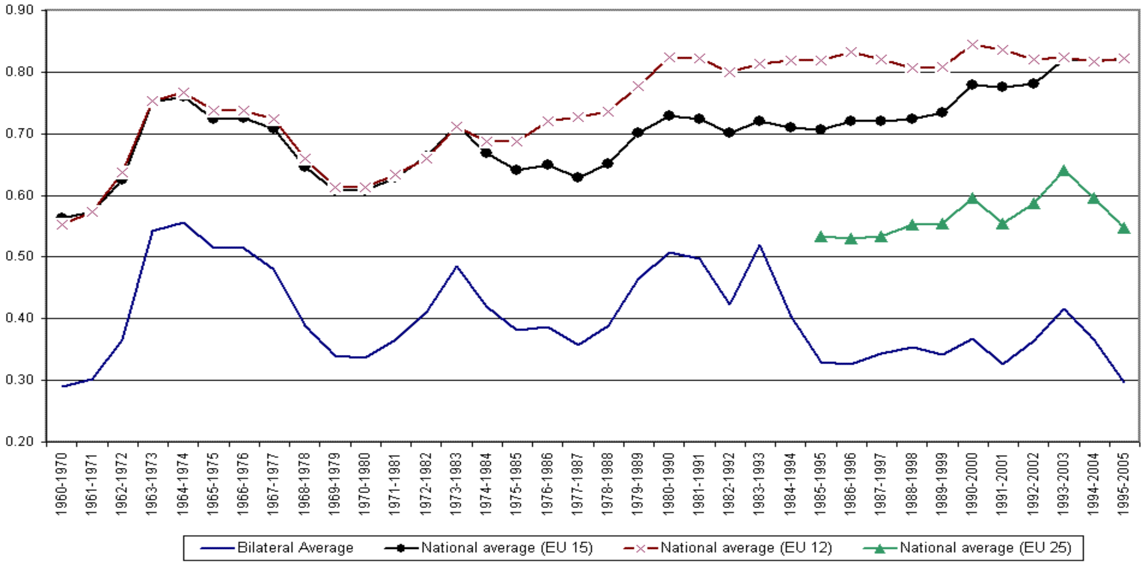
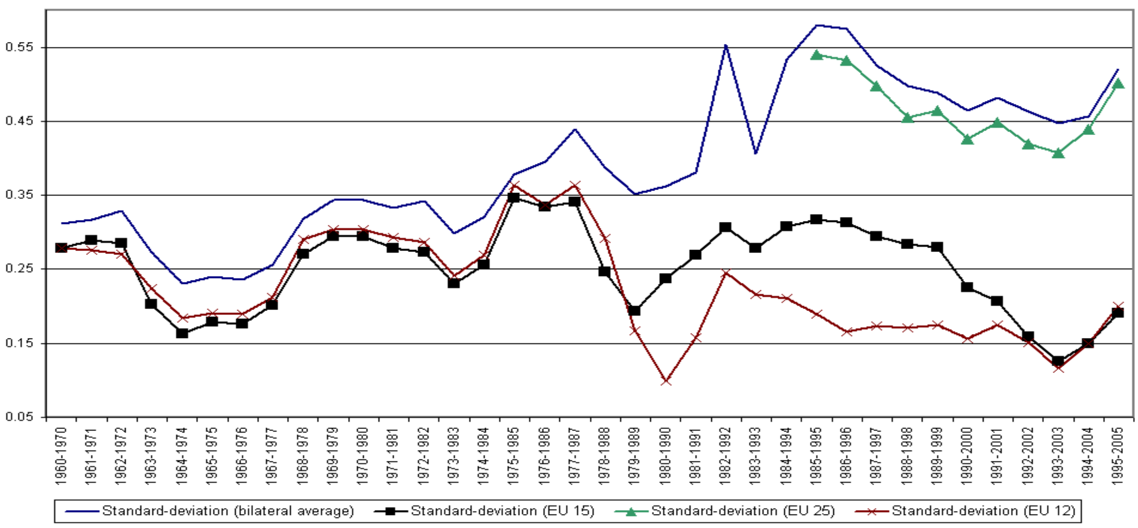


Figure 3.12: Standard-Deviations of the Correlations between EU Countries



We also analyzed rolling windows correlations between members of the Eurozone (EU-

12) and between members of the EU-15. Figures 3.13 to 3.16 show results for these groups. Both groups show an increasing positive correlation between member countries, both in the ten-year and in the twenty-year rolling windows analysis, but the Eurozone presents a smoother evolution of correlations over time than the other groups. Standard deviations exhibit a somewhat similar behavior for each group for the ten-year rolling windows analysis. For the twenty-year rolling windows analysis, the EU-15 shows an increasing trend in standard deviations, but the Eurozone presents a smoother trend.

Figure 3.13: Average Bilateral Correlations between EU-15 Countries

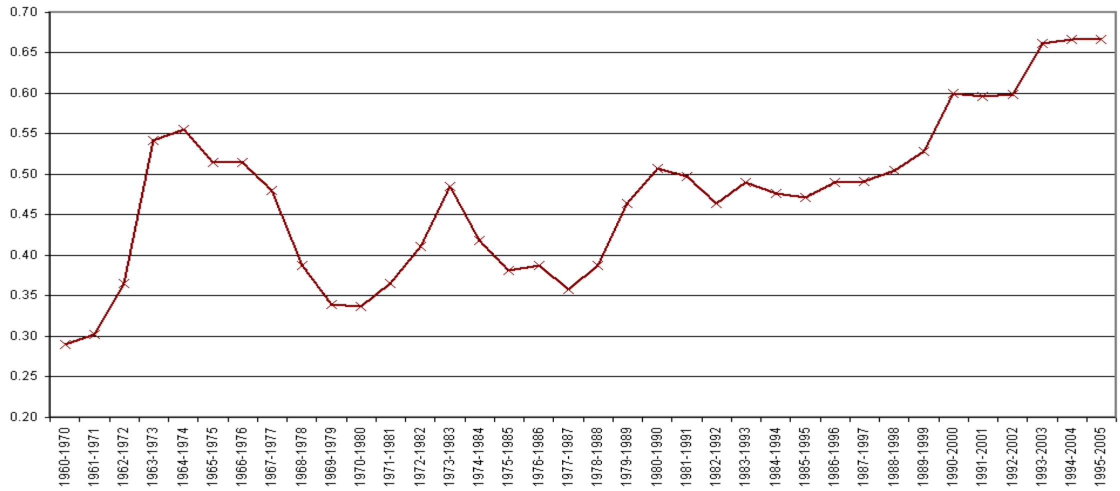


Figure 3.14: Standard-Deviations of the Bilateral Correlations between EU-15 Countries

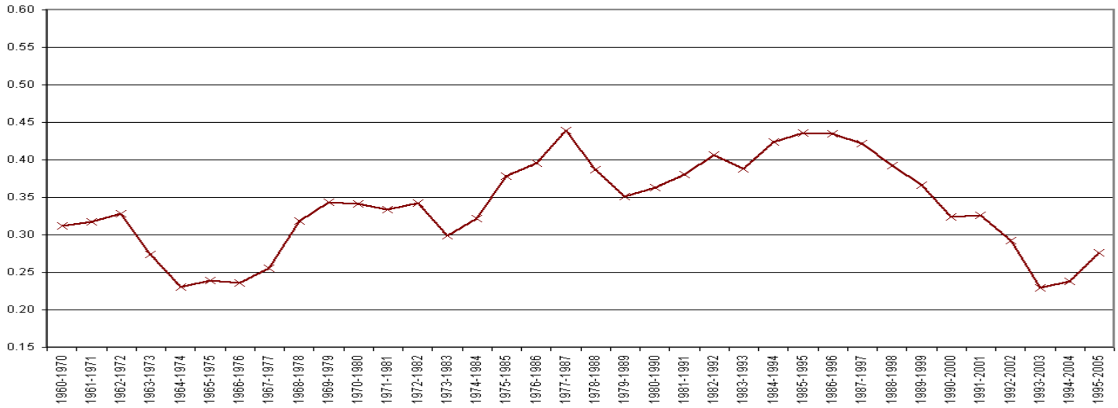


Figure 3.15: Average Bilateral Correlations between Eurozone Countries

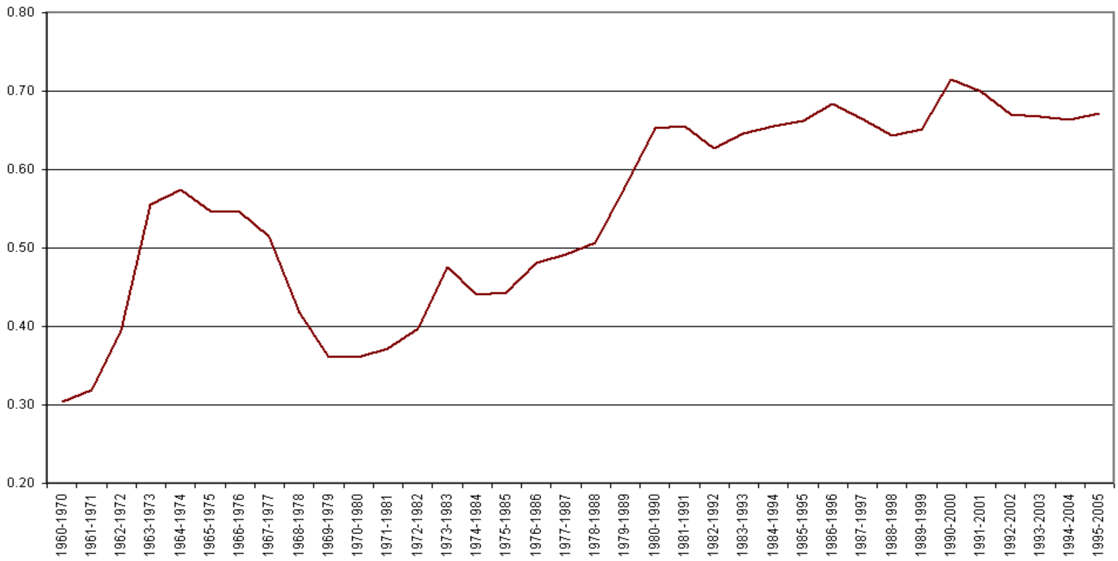
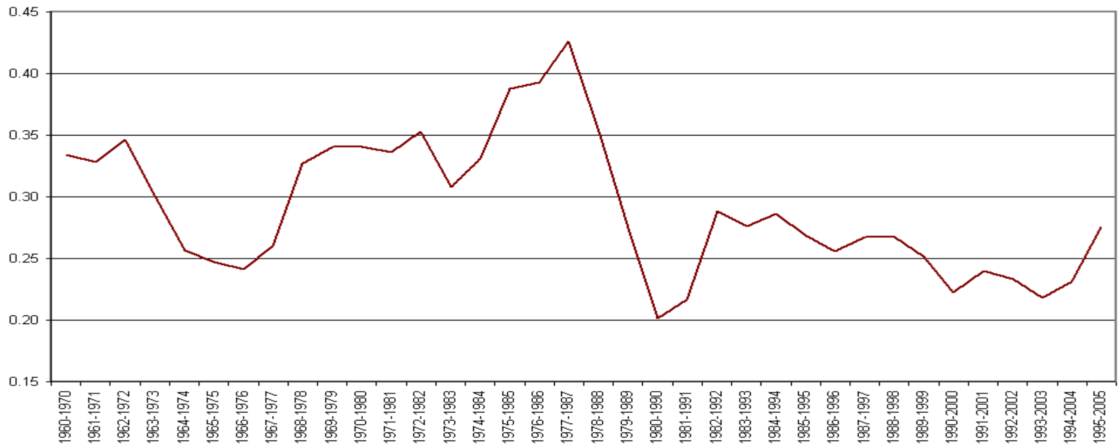


Figure 3.16: Standard-Deviations of the Bilateral Correlations between Eurozone Countries



3.4 Regional Clusters

3.4.1 Methodology

We performed cluster analysis to analyze convergence between regions and monetary unions for each monetary union, respectively.[10] Since the standard deviations of the output gap correlations have often been increasing, as we have seen in the last section, this may be a consequence of an increasing difference between regions. Maybe some regions are becoming closer to each other in terms of comovements and others are getting farther apart. This in turn, may lead to the formation of a core-periphery situation in the analyzed monetary unions.

As in the previous section, the output gap was used as the variable. Cluster analysis was performed for the evolutions of the output gaps, using a ten-year span for each cluster analysis, using the statistical software SPSS. This time span was also used as a benchmark in the previous section, so, for comparison reasons it was also used here. The entire time span for some monetary unions is not very long, so conclusions must be drawn with care.

[10] See Appendix B for a description of regions and their abbreviations for each monetary union.

The hierarchical agglomerative cluster method was used, i.e., a method which begins with each individual region being a single cluster and ends with all the regions in the same cluster, if not stopped earlier. In order to use this method, an aggregation (or desegregation) criterion must also be chosen, and in this case the complete linkage method was chosen. With this method the distance between two groups is defined as the distance between its least similar members. Given two groups (l, j) and (k), the distance (d) between them is the biggest distance between their members:

$$d_{(l,j)k} = \max\{d_{lk}; d_{jk}\}$$

The Pearson correlation coefficient was chosen as a distance measure. This distance measure was chosen so that it would be possible to compare between these results and the results from the previous section. The first cluster that is formed tends to be the most homogeneous, i.e., the one that presents the highest correlations between its members.[11]

We decided to stop cluster formation before the correlation coefficient goes below the average bilateral correlations of the regions for each monetary union. These values were obtained in the previous section. With this method, the number of clusters in each period can be obtained. Sensitivity analysis was also performed on the hypothesis for cluster formation, in order to check if the results change substantially with the change in the criterion. Thus, in this last exercise it was decided to stop cluster formation before the correlation coefficient went below the value for average bilateral correlations plus half a standard deviation of those bilateral correlations.[12]

3.4.2 Results

Canada

The evolution of cluster formation in Canada between 1926 and 2005 does not support the existence of a strong core-periphery pattern for this economy, as can be seen in Table 3.2. However, there are provinces that share a common pattern, namely, the provinces of Quebec and Newfound Land and Labrador, which always belong to the same cluster. These

[11] See Hair et all. (2006) for a good multivariate data analysis manual that includes cluster analysis.
[12] Tables for Sensitivity Analysis of Regional Clusters are available in Appendix D.

provinces are geographical close to each other, so proximity may be a good explanation in this case. This may also be true for the provinces of Nova Scotia and New Brunswick, which, with the exception of the period 1966-76, always belong to the same cluster. The province of Ontario usually belongs to the first cluster, where correlations are higher. By contrast, the province of Saskatchewan is mostly in the clusters where the correlations are lower. The provinces of Quebec, Ontario, and British Columbia, which combined added up to about 75% of Canada's economy, always belonged to the same cluster until 1966. This evidence suggests the existence of a core-periphery pattern before 1966 in the Canadian economy.

Table 3.2 - Cluster Evolution for Canada

	1926-36	1936-46	1946-56	1956-66
Cluster 1	BC, MAN, NB, NS, ONT, QUE	BC, MAN, NB, NS, ONT, QUE	BC, QUE, ONT	BC, ONT, QUE, NFD
Cluster 2	ALB, SAS	ALB	ALB, MAN, PEI, SAS	ALB, MAN, NB, NS
Cluster 3	PEI	PEI	NB, NS	PEI, SAS
Cluster 4		SAS		
Average for the Bilateral Correl.	0.83	0.62	0.56	0.40
Value for Correl. when Clust. is stopped	0.84	0.73	0.56	0.46
Value for Correl. after Clust. is stopped	0.77	0.57	0.54	-0.03

Table 3.2 - Cluster Evolution for Canada (continued)

	1966-76	1976-86	1986-96	1995-05
Cluster 1	NB, NFD, QUE	QUE, ONT, PEI, NB, NFD	NS, ONT, NB, MAN, PEI	NB, NS, ONT, PEI
Cluster 2	BC, NS, ONT, MAN	MAN, NS	ALB, QUE, NFD	NFD, QUE
Cluster 3	ALB, SAS	ALB, BC	BC	ALB, MAN
Cluster 4	PEI	SAS	SAS	BC
Cluster 5				SAS
Average for the Bilateral Correl.	0.77	0.43	0.48	0.36
Value for Correl. when Clust. is stopped	0.80	0.65	0.56	0.66
Value for Correl. after Clust. is stopped	0.76	0.41	0.30	0.35

The sensitivity analysis emphasizes the isolation of the Saskatchewan province and also reveals an isolated behavior of the province of Prince Edward Island until 1976. It also confirms the existence in the first half of the sample, of a strong core formed by British Columbia, Ontario, and Quebec, which vanished in recent decades. Other results remain similar.

Germany

The German economy was subject, in recent years, to a process of reunification of two very different economies. Cluster formation strongly highlights this fact, as shown in Table 3.3. Western Länders exhibited a strong common cycle both after and before German reunification, whilst the Eastern Länders share common business cycles characteristics and always belong to the same clusters (they are represented in bold). However, we must be careful in drawing conclusions, since the time span is too short to make robust conclusions for these economies, given that they are still on their transition paths. Results for the sensitivity analysis do not change the results significantly, especially after reunification, due to the substantial differences in correlations between the "two parts" of Germany.

Table 3.3 - Cluster Evolution for Germany

	1970-80	1980-90	1991-2001	1994-04
Cluster 1	HES, BAY, NSA, NRW BAW, RPF, HBG	BAY, NSA, BRE NRW, SAA	NRW, SHO, HBG, BAY, BRE, SAA, RPF NSA, BAW, HES,	**SAN, SAF MEV, THU BRA, BLN**
Cluster 2	BLNW, BRE	BAW, HES, RPF	**SAN,SAF,BRA MEV,THU,BLN**	NRW, SHO, HBG, BAY BRE, BAW, HES, SAA
Cluster 3	SHO	BLNW, SHO		NSA, RPF
Cluster 4	SAA	HBG		
Average for the Bilateral Correlations	0.76	0.84	0.05	0.34
Value for Correlations when Cluster is stopped	0.81	0.87	0.64	0.59
Value for Correlations after Cluster is stopped	0.68	0.79	-0.97	0.33

The German Reunification process is a very specific feature of the German economy, making the analysis hard to compare with other monetary unions. We can verify that there is a core (Western Länders) and a periphery (Eastern Länders), but this is due to a specific historical event in modern German history. To attempt to isolate this event, we performed cluster analysis for Western Germany only, which is analyzed in Table 3.4 below. This task is half achieved in the previous table, given that for the period 1970-1990 cluster formation was only for Western Länders. We extended the analysis for these regions for the period 1990-2004.

Table 3.4 - Cluster Evolution for Western Germany

	1990-2000	1994-04
Cluster 1	BRE, HBG, HES, NRW, SHO	BAY, BRE, BAW, HES, NRW, SAA
Cluster 2	BAY, NSA,	NSA
Cluster 3	BAW, RPF, SAA	RPF
Cluster 4		HBG
Cluster 5		SHO
Average for the Bilateral Correlations	0.92	0.72
Value for Correlations when Cluster is stopped	0.93	0.77
Value for Correlations after Cluster is stopped	0.85	0.70

In Western Länders a core-periphery situation does not seem evident. Strong correlations are present in every cluster, and clusters do not exhibit any type of pattern for these regions. When we tighten up the criterion for cluster formation, the Länder of Hamburg is mostly left out of cluster formation, except in the 1970-80 period. With the exception of this period, the results do not change substantially. So the existence of a core-periphery in Germany is due only to a specific historical event and did not change the pattern of synchronization of Western Germany.

Switzerland

Cluster analysis for Switzerland does not reveal a distinct division between a core and periphery, as shown in Table 3.5. Although clusters seem to be formed according to some degree of geographical proximity, the Cantons that take part in that specific cluster are not the same across the analyzed time periods.

The Cantons of Zurich and Vaud always belong to cluster 1, which is the cluster that exhibits the highest correlation between its members. These two Cantons are geographically far apart but their cyclical association is high.

Several Cantons exhibit the same movements over time, i.e., they always belong to the same cluster, namely: Fribourg with Solothurn, Valais with Jura, Thurgau with Appenzell Ausserrhoden, Geneva with Ticino, and Schaffhausen with Basel-Land. These Cantons do not share any common borders, except for Thurgau and Appenzell Ausserrhoden, and most of the time they do not even share the same language, so other factors must explain this close cyclical association.

Table 3.5 - Cluster Evolution for Switzerland

	1979-89	1989-99	1994-2004
Cluster 1	NEU, ZH, FR, SO, VS, VD, BE, JU	VD, ZH, GE, TG, JU, VS, TI, AAR	GE, TI, ZH, VD, NEU
Cluster 2	AG, NW, OW, SZ, TG, AAR, GR, UR	BE, OW, LU	AAR, TG, AG, SG, UR
Cluster 3	LU, SG,GL	AG, SG, ZG	BS, GL, ZG
Cluster 4	GE, TI	AIR, SZ, BL, BS, SH	BE, OW, LU
Cluster 5	BS, SH, BL	FR, SO, NEU, NW	SH, SZ, GR, BL, AIR, NW
Cluster 6	AIR, ZG	GR, UR	JU, VS, SO, FR
Cluster 7		GL	
Average for the Bilateral Correlations	0.53	0.34	0.32
Value for Correlations when Cluster is stopped	0.56	0.43	0.46
Value for Correlations after Cluster is stopped	0.50	0.30	0.18

Sensitivity exercise did not reveal any significant change from the conclusions stated above. Some Cantons then came out of cluster formation, but they were not always the same ones. Sometimes Cantons that were joined in the same cluster under the previous criteria were separated under sensitivity analysis. However, this does not follow a common trend. Thus, the existence of a core-periphery in the case of Switzerland does not seem plausible, even though some Cantons, as referred to above, seem to share a high degree of business cycle synchronization during the analyzed time period.

United States of America

Geographical proximity seems to play an important role in determining a positive correlation of the output gap between US States. However, cluster formation due to geographical proximity changes between time periods. Some specific features arise with the analysis of Table 3.6, namely the cluster where output gaps have a stronger correlation always includes some East Coast States including New Jersey and Massachusetts. These are two of the thirteen founding States of the Federation. Some US States, including Hawaii, Washington District of Columbia (D.C.), and Alaska, have some specific features, either due to geographic distance or to the idiosyncrasy of their role in the economy; e.g., Washington

D.C., which has a national political role.

Table 3.6 - Cluster Evolution for the USA

	1930-40	1940-50	1950-60	1960-70
Cluster1	IN,OH,MI,IL,NY, PA,VT,CT,MA,NJ	SC,VA,MD,RI,IN,OH, MA,NJ,PA,CT,MI	CT,NJ,OH,MI,NV,RI, MA,TN,PA,VT,MD, NH,,WA,IL,VA,IN	OH,WI,PA,NC,SC,IL,LA, GA,VA,MD,NJ,CT,MN,MA NY,RI,NH,WA,VT,KY,DE TX,MI, MO, CA, IN,TN
Cluster2	AL,TN,GA,SC, NC,AR,MS	GA,WA,AL,WI,KY,MO, MS,NE,CA,FL,TN,OK, NC,AR,NM,TX,LA,ID,KS	CO,UT,WV, ID,NM,WY	AL,OR,IA,DC,WV
Cluster3	AZ,TX,LA,MO,KS,KY, WI,WY,OK,NM,WV	AZ,UT,OR,ME, CO,DC,NV	GA,OR,WI,NC, AR,MS	MT,ND,NE,SD,ID
Cluster4	OR,WA,FL,CA, ME,NH	IL,NH,VT	CA,ME,OK,MO, AL,TX,LA,FL,NY	CO,WY,NM,UT
Cluster5	RI,VA,MD	MN,SD,WV	KY,SC,AK,AZ	AZ,HI
Cluster6	IA,MN,ND,SD,MT	NY	IA,NE	AR,MS,NV
Cluster7	CO,UT,NV	WY	DE,MN	AK,ME
Cluster8	DC	MT	DC,MT	FL,OK,KS
Cluster9	DE	ND	ND,SD	
Cluster10	ID	IA	KS	
Cluster11	NE	DE	HI	
Average for the Bilateral Correl.	0.82	0.83	0.32	0.21
Value for Correl. when Clust. is stopped	0.83	0.83	0.39	0.27
Value for Correl. after Clust. is stopped	0.81	0.80	0.27	0.10

Table 3.6 - Cluster Evolution for the USA (continued)

	1970-80	1980-90	1990-2000	1995-2005
Cluster1	MD,NY,MA,NJ,HI	CT,ME,VT,RI,DE,PA,FL,CA OH,IN,MI,TN,IL,SC,MN,WI DC,NY,MD,MS,IA,KY,NJ,GA, VA,MA,NH,AL,NC,MO,AR,AZ	CA,PA,MA,NJ,FL,NY VT,VA,WA,ME,RI, MD,DE,SC,CT	CA,VT,CT,MA,NJ NH,OK,CO,GA WY,FL,VA,NY,PA
Cluster2	GA,NC,VA,SC,DE, KS,ND,SD,NE,DC	NE,SD,KS,AK,ND	IN,WI,OH,NH,MN,NV KS,KY,OK,AZ,OR,UT,CO, MO,TX,MI,TN,IL,NC,GA,	MN,WA,AZ,NC,MI, TX,KS,MO,OH,WI, KY,SC,IL,IN, TN,
Cluster3	MS,TN,MT,ID,IN,MI,KY,OH, IL,PA,AL,NM,AR,IA,WI	NM,UT,CO,TX,MT	LA,MS,AR,NM,ID	MD,RI,DE,ME
Cluster4	LA,OR,UT,WV, CA,TX,NV	NV,WA,OR,WV	DC,HI	OR,UT,ID,AR, NV,MS,AL
Cluster5	AZ,CO,FL,OK,RI,VT,CT	LA,OK,WY	ND,SD,IA,NE	AK,DC,MT,WV
Cluster6	MO,NH,MN,ME	HI,ID	AK,WV,MT	NE,SD,ND
Cluster7	WA,WY		AL,WY	IA
Cluster8	AK			LA
Cluster9				NM
Cluster10				HI
Cluster11				
Average for the Bilateral Correl.	0.54	0.39	0.47	0.52
Value for Correl. when Clust. is stopped	0.58	0.39	0.56	0.53
Value for Correl. after Clust. is stopped	0.50	0.15	0.46	0.46

Sensitivity analysis placed less US States in the same cluster and isolated more States. However, no striking trend appeared in this analysis, although the isolated States seem more likely to belong to the Northwest part of the country. Once again, geographical proximity continues to play a big role in cluster formation, but in a random way.

The European Union

Along the period in which the analysis was made, the majority of countries do not seem to present strong common features, as reported in Table 3.7. However, there are exceptions, including Portugal and Spain. Since accession, these two countries belong to the same cluster. By contrast, this did not happen in Eastern and Central Europe, where countries do not all belong to the same cluster nor do they have any striking common feature.

Germany in the 1990s stepped way from the clusters that share a higher degree of correlation, because its business cycle became more idiosyncratic due to the reunification process. In addition, the sensitivity analysis reveals a greater division between the Eastern and Central European countries (in bold in the tables) and the old members of the European Union.

Table 3.7 - Cluster Evolution for the European Union

	1960-70	1970-80	1980-90	1990-2000	1995-05
Cluster 1	BE, FI, DE, LU, AT, EL	DK, DE, EL, UK	SE, UK, FI, ES, LU	BE, IT, AT, PT, **LV**, FR, ES, DE, EL, LU, **LT**	IE, PT, NL, FI, **SI,** AT, BE, UK, FR, LU, ES, SE
Cluster 2	FR,SE,DK	FR, AT, BE, LU, NL, IT, PT	BE, IT, NL, DE, EL, FR, PT	FI, **PL,SI,** UK, NL, IE, SE	EL, **HU, LV, LT**
Cluster 3	IE, IT	FI, SE	AT, IE	**CY,** DK	**CY,** DE, IT
Cluster 4	NL, PT	IE	DK	**CZ**	DK, **MT, PL**
Cluster 5	ES	ES			**CZ, EE, SK**
Cluster 6	UK				
Average for the Bilateral Correlations	0.29	0.34	0.51	0.37	0.30
Value for Correlations when Cluster is stopped	0.44	0.37	0.55	0.44	0.38
Value for Correlations after Cluster is stopped	0.22	0.05	0.44	0.20	0.06

This same analysis was undertaken for the European Union at fifteen members (EU-15), for the entire available period. Since the period between 1960 and 1990 in the last table was already for the EU-15 (because data is not available for the Eastern and Central Europe countries for this period), the cluster analysis only needed to be extended for the period 1990-2005, as shown in Table 3.8 below. The results changed a little for this period. Cluster formation was affected by the accession of the Eastern and Central countries given that in the table above all the old members, with the exception of Greece, Germany, Italy, and Denmark, were in the first cluster and now, as shown in Table 3.8, countries are more dispersed. Sensitivity analysis did not reveal any new feature to the analysis made above.

Table 3.8 - Cluster Evolution for the European Union at 15

	1990-2000	1995-05
Cluster 1	BE, IT, AT, PT, FR, ES, DE, EL, LU	IE, PT, NL, FI, AT, BE, UK,
Cluster 2	FI, UK, NL, IE, SE	FR, LU, ES, SE
Cluster 3	DK	DE, IT
Cluster 4		DK
Cluster 5		EL
Average for the Bilateral Correlations	0.60	0.67
Value for Correlations when Cluster is stopped	0.63	0.70
Value for Correlations after Cluster is stopped	0.44	0.61

3.5 Discussion

In all analyzed monetary unions, some common behavior can be seen in respect to the analysis of cyclical correlations. For example, average bilateral and national correlations have often been decreasing over time, and standard deviations for those correlations have been increasing. This trend is not so clear in the European Union, although when the Eastern and Central European countries join the EU, bilateral correlations do decrease.

These conclusions might indicate that, in the analyzed monetary unions, there are groups of regions becoming more dissimilar, possibly according to a core-periphery pattern. On the other hand, however, they might also suggest that the existence of federal transfers and internal migration does not make a federalist country and its regions very different from the European Union. Finally, the conclusions might also indicate that the international business cycle may play a role in explaining the results. This last point is clearer in the cases of the USA and Canada, which share many common features, including the increase in bilateral correlations during the 1930s and 1970s crises. Fatás (1997) finds evidence for the international business cycle playing a role in regions of countries that belong to the European Union, where synchronization between regions of a country are decreasing, but synchronization between the same regions and the EU business cycle is increasing. Because in this paper we have also found this trend in regions of non-EU member countries, our results further indicate that the international business cycle may play an important role.

With the exception of Germany, which had a process of reunification, no monetary union shows any striking specific feature. The youngest integration experience, besides Germany reunification, is the European Union, so correlations are still increasing over time. However, when a country or a group of countries joins the EU, and their business cycle is very different from the old members, there is a strong impact in terms of correlations between members and also in terms of standard deviations of those correlations. The same occurred in Germany. In fact, these conclusions are evident in Table 3.9 below. Germany and the EU present the lowest average correlations and the highest standard-deviations of the correlations for output gaps.

Table 3.9 - Values for the Entire Samples

	Canada	Germany	Switzerland	USA	EU
	(1926-2005)	(1970-2004)	(1979-2004)	(1929-2005)	(1960-2005)
Average correlation with the country	0.79	0.30	0.59	0.85	0.55
Stand. dev.of the aver. correl. with the country	0.14	0.38	0.19	0.18	0.38
Average Bilateral correlations	0.61	0.16	0.38	0.72	0.30
Stand. dev. of the bilateral correlations	0.21	0.73	0.27	0.23	0.39

Cluster analysis was used to check for the existence of a core-periphery pattern among the regions of the analyzed monetary unions, given that the previous analysis of the correlations suggested this possibility. Results of cluster analysis did not confirm this possibility because clusters seem to form in the majority of the monetary unions according to geographical proximity, and, further, since regions that belong to the same cluster are changing over time.

There are however, a few interesting facts to record about the monetary unions. Before the 1970s, the provinces of Quebec, British Columbia, and Ontario, which represent about 75% of the Canadian economy, formed a core in this monetary union, since they always belong to the same cluster. That core-periphery pattern disappears in the 1970s. The provinces of Saskatchewan and Ontario have opposite behaviours of cluster formation. Saskatchewan mostly appears isolated, while Ontario always appears in the cluster where correlations are higher. Language differences in Canada do not seem to play a big role in cluster formation. The same applies to Switzerland, where proximity is an important factor to cluster formation. However, the inclusion of Cantons in the same cluster, although close to each other in the federation, evolves with time. Nonetheless, the Cantons of Zurich and Vaud always belong to the highest correlation cluster.

For the USA, the States of New Jersey and Massachusetts, two of the thirteen founding States, always belong to the cluster with highest correlations. Some US States, including Hawaii, Alaska, and Washington D.C., have very specific behaviors, either due to their location, or to their role in the US economy. California and Florida are also mostly in the same cluster. When we perform sensitivity analysis in the US, the Northwestern States often appear isolated from cluster formation.

Germany suffered a very specific historical event: reunification. In this country, clearly there is a strong division between the West and the East. Data is longer for the former Western Germany, but does not reveal any pattern within these Länders. For the European Union in the mid nineties, there is also a clear distinction between old members and the new members from the Eastern and Central Europe. German reunification is also reflected here. However, besides these events, cluster formation does not follow any specific pattern over time.

General results of rolling windows and cluster analysis point to some suggestive conclusions. However, these must be drawn carefully, since data for these monetary unions, with the exception of the EU, does not start before each monetary union was formed. Bilateral correlations in the USA and in Canada were very high at the beginning of the sample, but in recent decades the values for bilateral correlations are similar to the values found for the European Union. Even without strong internal migration and federal transfers, the EU has similar results to these older monetary unions, which may be a good sign for the future of the European Monetary Union. Cluster analysis also supports some degree of optimism, since all monetary unions seem to lack strong evidence of a core-periphery pattern, including the European Union. Germany reunification is a specific case, and the strong evidence for the existence of a core in Canada has disappeared since the 1970s. If the European Union does not show any striking differences from the other monetary unions, this could also be a good indicator that the European project may be as good as these previous integration processes, at least as in what concerns the analyzed variables.

3.6 Appendix A - Data

Canada - Provincial data for Canada is from Statistics of Canada, Historical Statistics and Provincial Economic Accounts. Data is for Personal Income by Province at current prices.

The definition of Personal Income by Statistics Canada states that: "Personal income includes all factor incomes of persons such as wages and salaries and net incomes of unincorporated businesses; interest, dividends and various types of investment income of persons (including investment income accumulated on behalf of persons by life insurance companies, private pension funds and similar institutions); and all transfer payments received by persons from governments (such as old age pensions, mothers' and dependents' allowances, and unemployment insurance benefits) as well as transfers from corporations and non-residents. 'Persons' and the 'personal sector' are defined to include private pension plans and private non-commercial institutions such as universities, labor unions, professional organizations, fraternal societies and charitable institutions. While the national income includes all earnings of the various factors of production arising from the current production of goods and services, personal income includes only the part of the national income which is paid out to persons. It also includes large amounts of income of a transfer payment nature which is not included in the national income."

Data for the period 1926 to 1996 was kindly supplied by Marc Tomljanovich, from the paper by DeJuan and Tomljanovich (2005). Data for the period 1996-2005 was taken from "Provincial Economic Accounts, Selected Indicators", in the Statistics of Canada website (http://www.statcan.ca/start.html). Provincial deflators for the entire period were not available, and thus the consumer price index was used for the period 1926-2005 (base year 2000) at the national level, to deflate the provincial series, also taken from the Statistics of Canada website.

We excluded data from the territories of Nunavut, Yukon, and Northwestern, given that data supplied by Marc Tomljanovich excluded these regions from the analysis. Their value is residual in the total personal income of the Canadian economy, as can be seen in Table B1, and thus this exclusion has a residual impact.

Germany - Länder data for Germany was taken from the German Federal Statistics Office (Statistisches Bundesamt). Data is available from 1970 to 2004 for the former Federal Republic of Germany and from 1991 to 2004 for the former German Democratic Republic. The variable used is Gross Domestic Product by Länder at 1995 prices.

Switzerland - Cantonal data for Switzerland was obtained from the Swiss Federal Statistics Office. Data available refers to the Net National Income at factors cost and current prices, in millions of Swiss francs, for all 26 Swiss Cantons. This data has three breaks: 1978-1995, 1990-2001 and 1998-2004. Between these breaks some methodological and conceptual changes have been made, namely the substitution of the European System of National Accounts for the traditional method of national accounting, the system of 1979, and the system of 1995, respectively. Thus, a careful analysis of the results is required. Breaks were dealt with by applying the growth rates of the old accounting system to the levels of the ESA 95 data. Deflators at the Cantonal level were not available, so the deflator at the national level was used for the Gross National Income at market prices, base year 2000, taken from AMECO (Annual Macro Economic Database, from the European Commission).

United States - The variable is Personal Income by State in current prices, taken from the Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce, for the years 1929 to 2005. The State variable was deflated with the national consumer price index (base year 1982), given that price indexes by US States are not available.

European Union - The AMECO database provided data for all European Union countries for 1960-2005. Several countries did not present data for the entire period, namely the Central and Eastern Countries, Malta, Cyprus, and Germany. For the new members of the EU, data is only available from the 1990s. Data for Gross Domestic Product by country at 2000 prices was used.

Data for Germany was available from 1991 to 2005. Before this period, data was only available for the former Federal Republic of Germany, from 1960 to 1991. These breaks were dealt with by applying the growth rates of the old series for the former Federal Republic of Germany to the levels of the new data for the country. We used the same method for the deflator. In this way, a GDP series was built at constant prices for the period 1960-2005 by dividing the new series for GDP at current prices series by the new series for the GDP deflator.

3.7 Appendix B - Maps and List of Regions

Table B1 - Provinces of Canada

Canadian Provinces	Year that joined the Federation	Weight in the Country (2005)
Alberta (ALB)	1905	11.9%
British Columbia (BC)	1871	12.6%
Manitoba (MAN)	1870	3.2%
New Brunswick (NB)	1867	2%
New Foundland and Labrador (NFD)	1949	1.3%
Nova Scotia (NS)	1867	2.6%
Ontario (ONT)	1867	40.8%
Prince Edward Island (PEI)	1873	0.4%
Quebec (QUE)	1867	22%
Saskatchewan (SAS)	1905	2.7%
Northwestern Territories (NWT)	1870	
Nunavut	1999	0.5%
Yukon (YUK)	1898	

Figure 3.17: Provinces of Canada

Table B2 - Länders of Germany

German Länders	Year that Join the Federation	Weight in the Country (2004)
Baden-Württemberg (BAW)	1871	14.5%
Bayern (BAY)	1871	17.7%
Berlin (BLN)	1871	3.5%
Branderburg (BRA)	1871	2.1%
Bremen (BRE)	1871	1.1%
Hamburg (HBG)	1871	3.6%
Hessen (HES)	1871	9.1%
Mecklenburg-Vorpommern (MEV)	1871	1.4%
Niedersachen (NSA)	1871	8.5%
Nordrhein-Westfalen (NRW))	1871	22.1%
Rheinland- Pfalz (RPF)	1871	4.4%
Saarland (SAA)	1871	1.2%
Sachsen (SAF)	1871	3.7%
Sachsen-Anhalt (SAN)	1871	2.1%
Schleswig-Holstein (SHO)	1871	3.1%
Thüringen (THU)	1871	1.9%

Figure 3.18: Länders of Germany

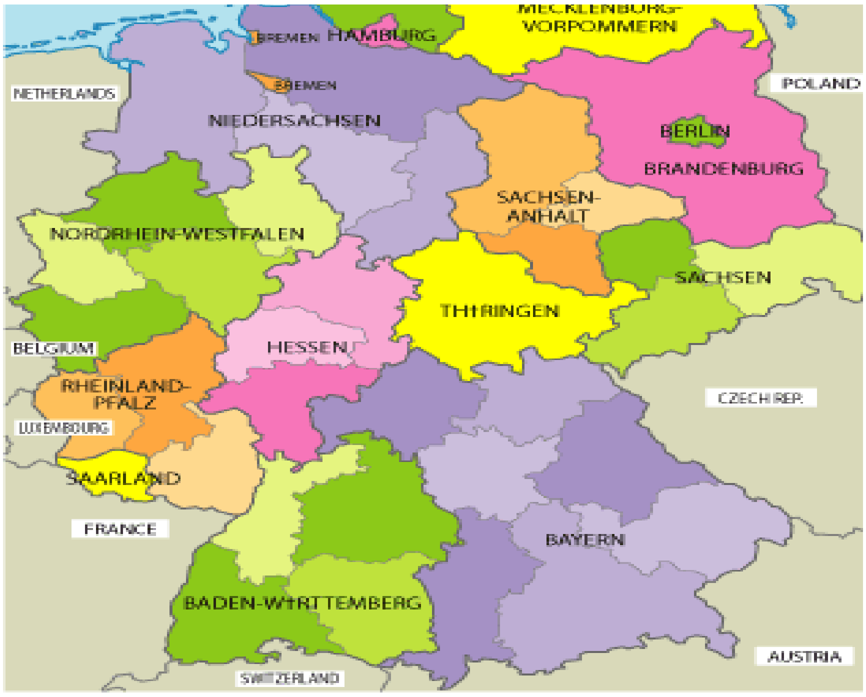


Table B3 - Cantons of Switzerland

Swiss Cantons	Year that join the Federation/Confederation	Weight in the Country (2004)
Aargau (AG)	1803	6.9%
Appenzell Innerrhoden (AIR)	1513	0.2%
Appenzell Ausserrhoden (AAR)	1513	0.6%
Basel-Landschaft (BL)	1501	3.5%
Basel-Stadt (BS)	1501	5.2%
Bern (BE)	1353	11%
Fribourg (FR)	1481	2.5%
Geneva (GE)	1815	6.7%
Glarus (GL)	1352	0.7%
Graubfünden (GR)	1803	2.2%
Jura (JU)	1979	0.7%
Luzern (LU)	1332	3.8%
Neuchâtel (NEU)	1815	2.1%
Nidwalden (NW)	1291	0.7%
Obwalden (OW)	1291	0.3%
St.-Gallen (SG)	1803	5.2%
Schaffhausen (SH)	1501	1%
Schwyz (SZ)	1291	1.7%
Solothurn (SO)	1481	2.9%
Thurgau (TG)	1803	2.6%
Ticino (TI)	1803	3.3%
Uri (UR)	1291	0.4%
Vaud (VD)	1803	8.6%
Valais (VS)	1815	2.7%
Zurich (ZH)	1351	22%
Zug (ZG)	1352	2.5%

Figure 3.19: Cantons of Switzerland

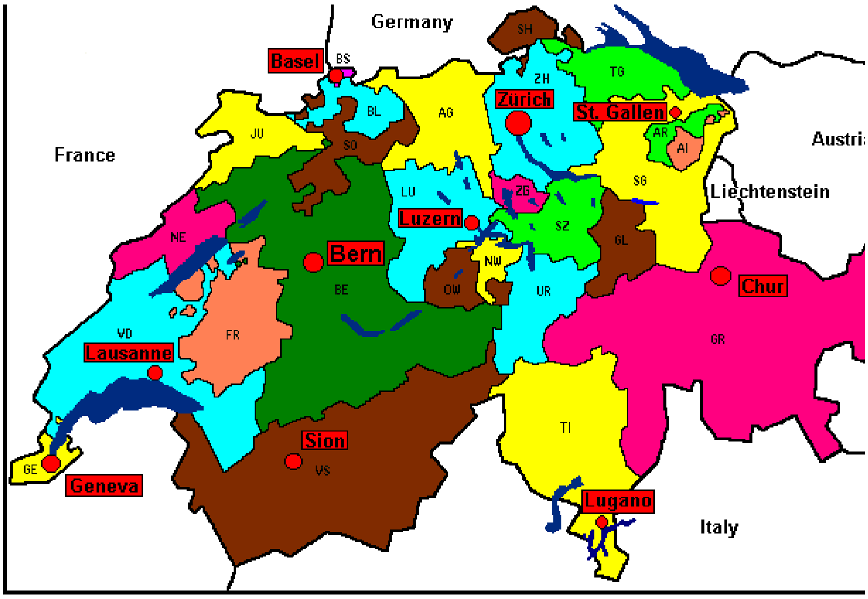


Table B4 - States of the USA

USA States	Year that join the Federation	Weight in the Country (2005)
Alabama (AL)	1819	1.3%
Alaska (AK)	1959	0.2%
Arizona (AZ)	1912	1.8%
Arkansas (AR)	1836	0.7%
California (CA)	1850	13.1%
Colorado (CO)	1876	1.7%
Connecticut (CT)	1788	1.6%
Delaware (DE)	1787	0.3%
District of Columbia (DC)	1790	0.3%
Florida (FL)	1845	5.8%
Georgia (GA)	1788	2.8%
Hawaii (HI)	1959	0.4%
Idaho (ID)	1890	0.4%
Illinois (IL)	1818	4.5%
Indiana (IN)	1816	1.9%
Iowa (IA)	1846	0.9%
Kansas (KS)	1861	0.9%
Kentucky (KY)	1792	1.2%
Louisiana (LA)	1812	1.1%
Maine (ME)	1820	0.4%
Maryland (MD)	1788	2.3%
Massachusetts (MA)	1788	2.8%
Michigan (MI)	1837	3.3%
Minnesota (MN)	1858	1.9%
Mississippi (MS)	1817	0.7%
Missouri (MO)	1821	1.8%
Montana (MT)	1889	0.3%
Nebraska (NE)	1867	0.6%
Nevada (NV)	1864	0.8%
New Hampshire (NH)	1788	0.5%
New Jersey (NJ)	1787	3.7%
New Mexico (NM)	1912	0.5%
New York (NY)	1788	7.6%
North Carolina (NC)	1789	2.6%
North Dakota (ND)	1889	0.2%
Ohio (OH)	1803	3.6%
Oklahoma (OK)	1907	1%
Oregon (OR)	1859	1.1%

Table B4 - States of the USA (continued)

USA States	Year that join the Federation	Weight in the Country (2005)
Pennsylvania (PA)	1787	4.2%
Rhode Island (RI)	1790	0.4%
South Carolina (SC)	1788	1.2%
South Dakota (SD)	1889	0.2%
Tennessee (TN)	1796	1.8%
Texas (TX)	1845	7.2%
Utah (UT)	1896	0.7%
Vermont (VT)	1791	0.2%
Virginia (VA)	1788	2.8%
Washington (WA)	1889	2.2%
West Virginia (WV)	1863	0.5%
Wisconsin (WI)	1848	1.8%
Wyoming (WY)	1890	0.2%

Figure 3.20: States of the USA

Table B5 - Member Countries of the EU

EU Members	Year of Accession	Weight in the EU (2005)
Austria (AT)	1995	2.6%
Belgium (BE)	1957	3.1%
Cyprus (CY)	2004	0.1%
Czech Republic (CZ)	2004	0.6%
Denmark (DK)	1973	2%
Estonia (EE)	2004	0.1%
Finland	1995	1.6%
France (FR)	1957	17.1%
Germany (DE)	1957	25.3%
Greece (EL)	1981	1.5%
Hungary (HU)	2004	0.6%
Ireland (IE)	1973	1.2%
Italy (IT)	1957	11.2%
Latvia (LV)	2004	0.1%
Lithuania (LT)	2004	0.1%
Luxembourg (LU)	1957	0.3%
Malta (MT)	2004	0%
Netherlands (NL)	1957	4.8%
Poland (PL)	2004	1.8%
Portugal (PT)	1986	1.3%
Slovak (SK)	2004	0.3%
Slovenia (SI)	2004	0.3%
Spain (ES)	1986	7.5%
Sweden (SE)	1995	2.9%
United Kingdom (UK)	1973	13.2%

Figure 3.21: Members of the European Union

3.8 Appendix C - Graphics for Rolling Window Analysis (Time Spans of 15 and 20 Years)

Figure 3.22: Average Correlations for the Canadian Provinces (Windows of 20 years)

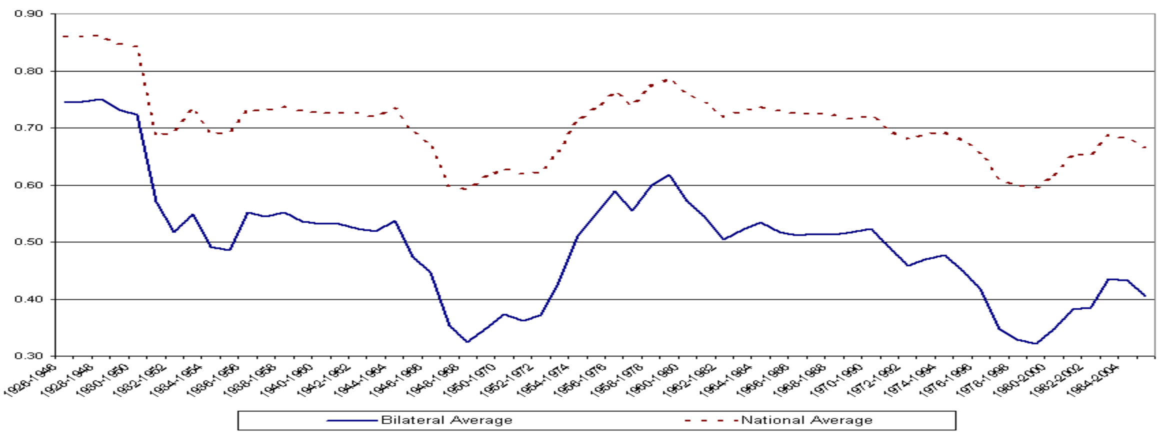


Figure 3.23: Standard-Deviations of the Correlations for the Canadian Provinces (Windows of 20 years)

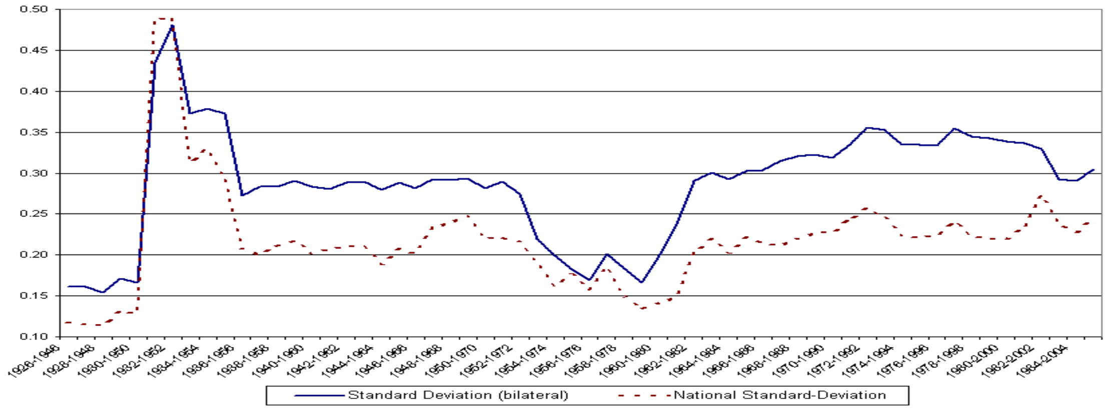


Figure 3.24: Average Correlations for the German Länders (Windows of 15 years)

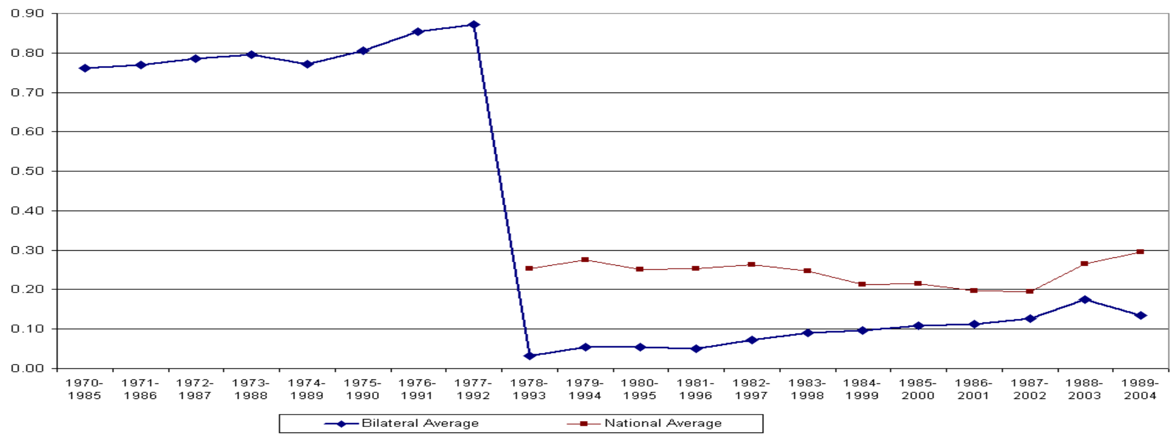


Figure 3.25: Standard-Deviations of the Correlations for the German Länders (Windows of 15 years)

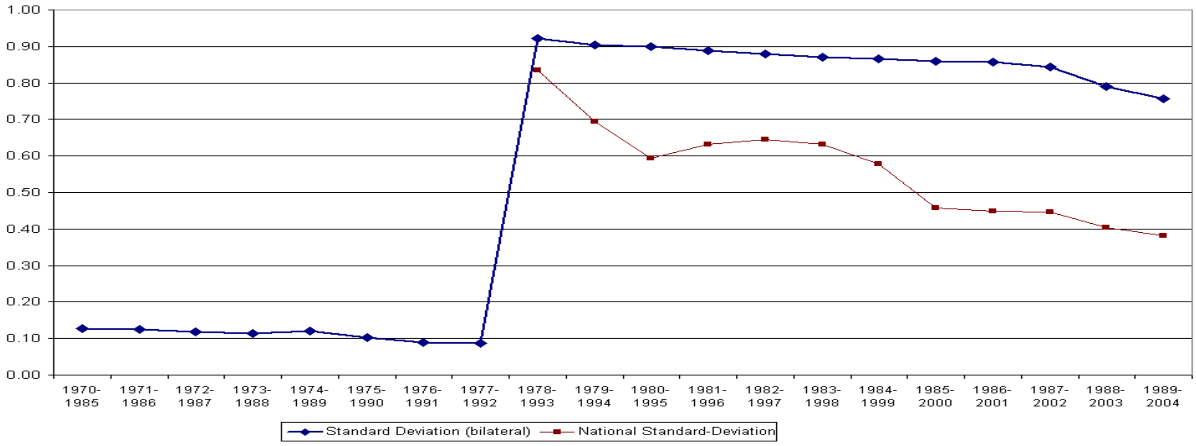


Figure 3.26: Average Correlations for the German Länders (Windows of 20 years)

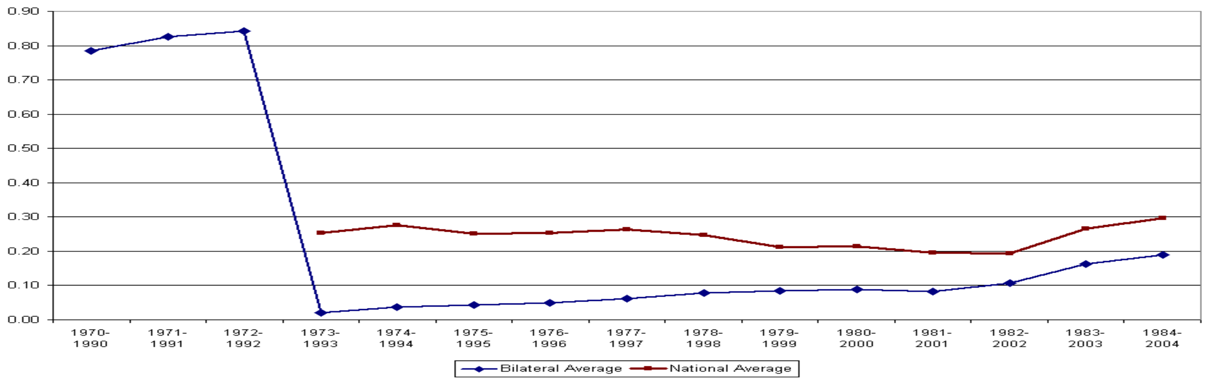


Figure 3.27: Standard-Deviation of the Correlations for the German Länders (Windows of 20 years)

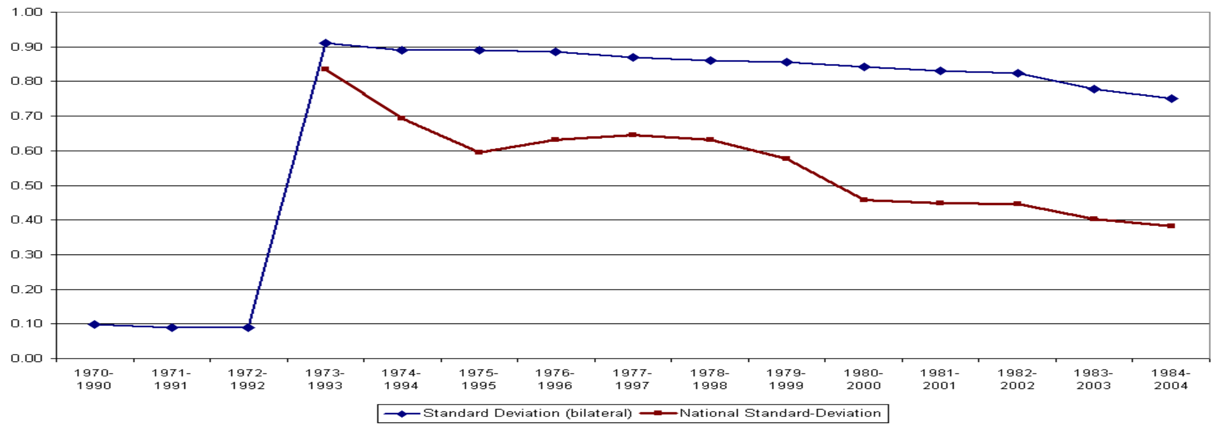


Figure 3.28: Average Correlations for the Swiss Cantons (Windows of 15 years)

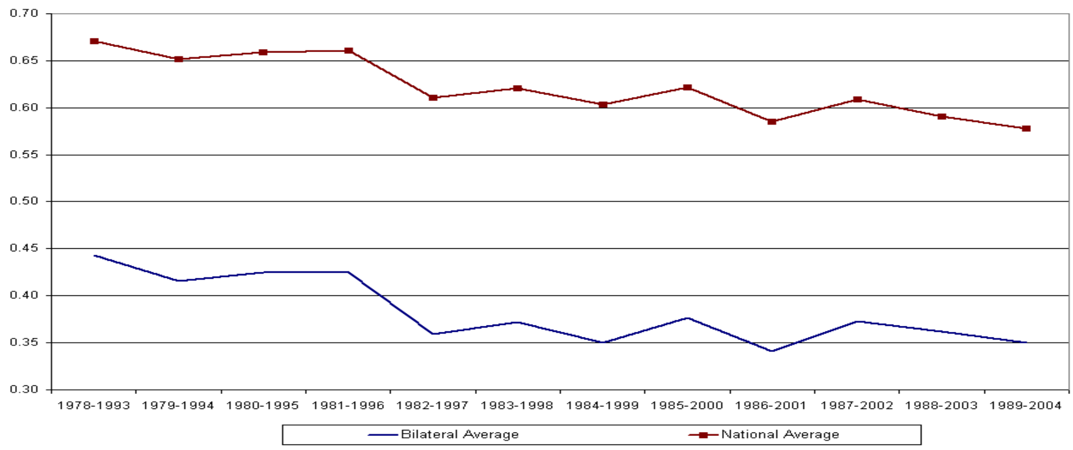


Figure 3.29: Standard-Deviations of the Correlations for the Swiss Cantons (Windows of 15 years)

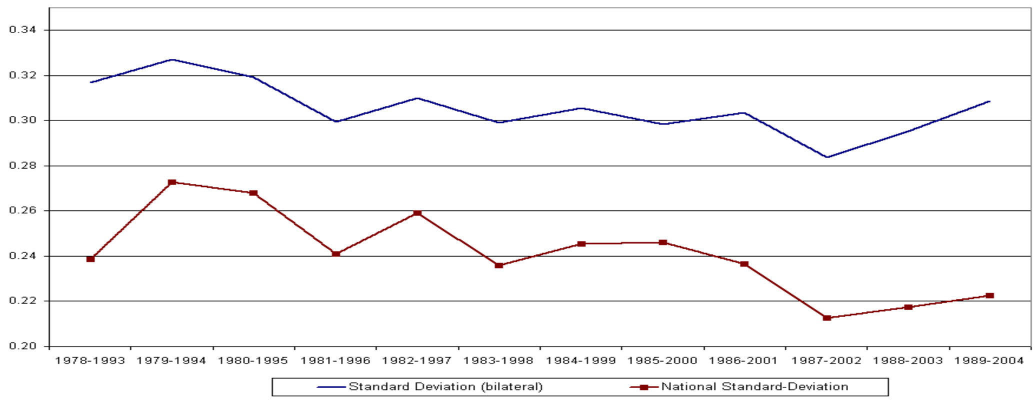


Figure 3.30: Average Correlations for the Swiss Cantons (Windows of 20 years)

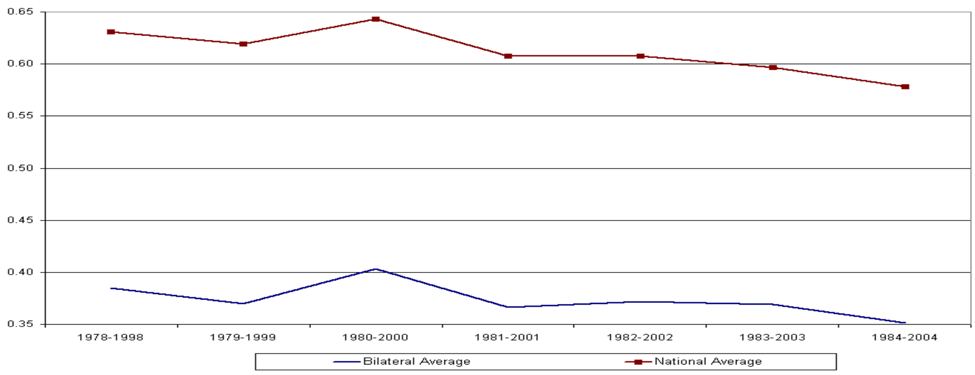


Figure 3.31: Standard-Deviations of the Correlations for the Swiss Cantons (Windows of 20 years)

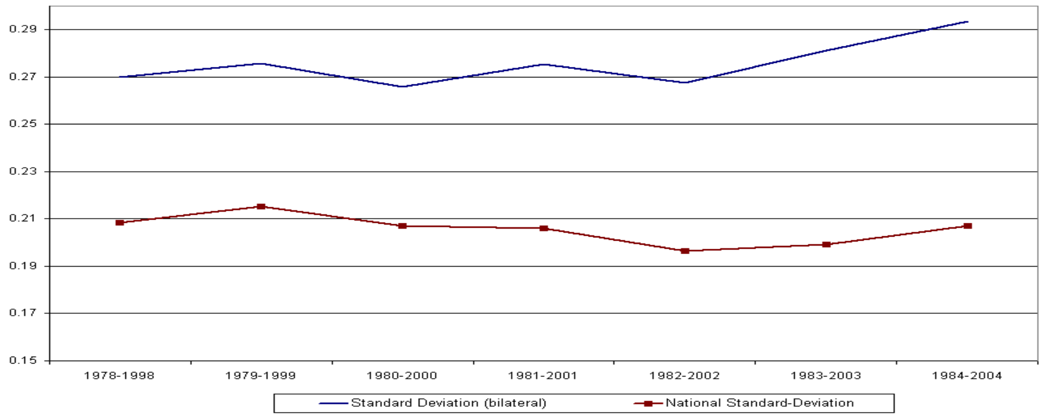


Figure 3.32: Average Correlations for the USA States (Windows of 20 years)

Figure 3.33: Standard-Deviations of the Correlations for the USA States (Windows of 20 years)

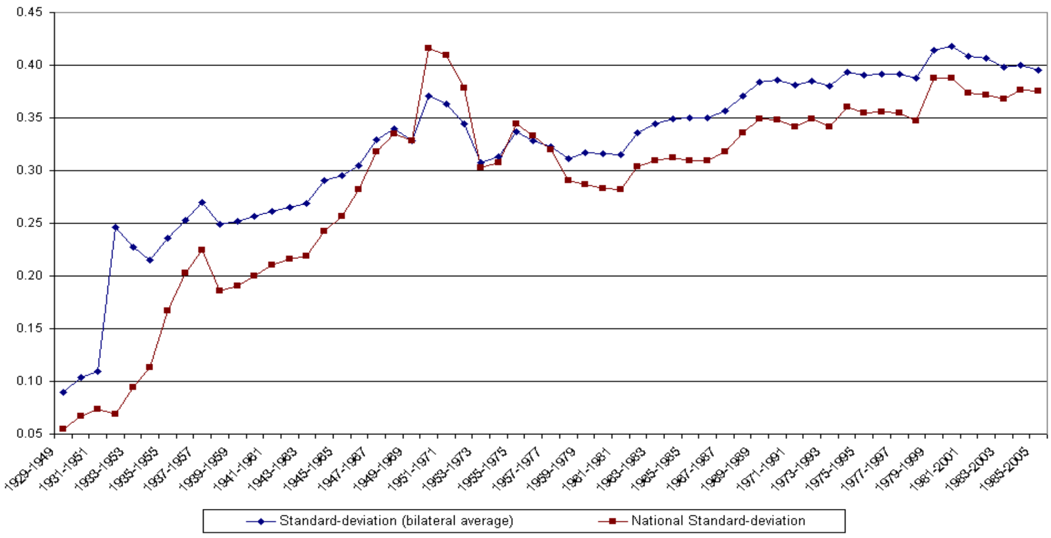


Figure 3.34: Average Correlations for the EU Countries (Windows of 20 years)

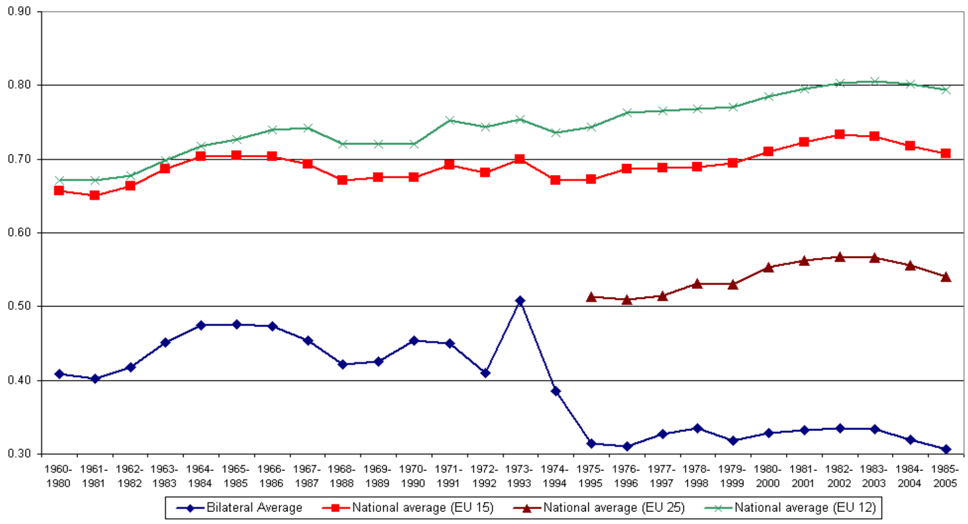


Figure 3.35: Standard-Dev. of the Correl. for EU Countries (Windows of 20 years)

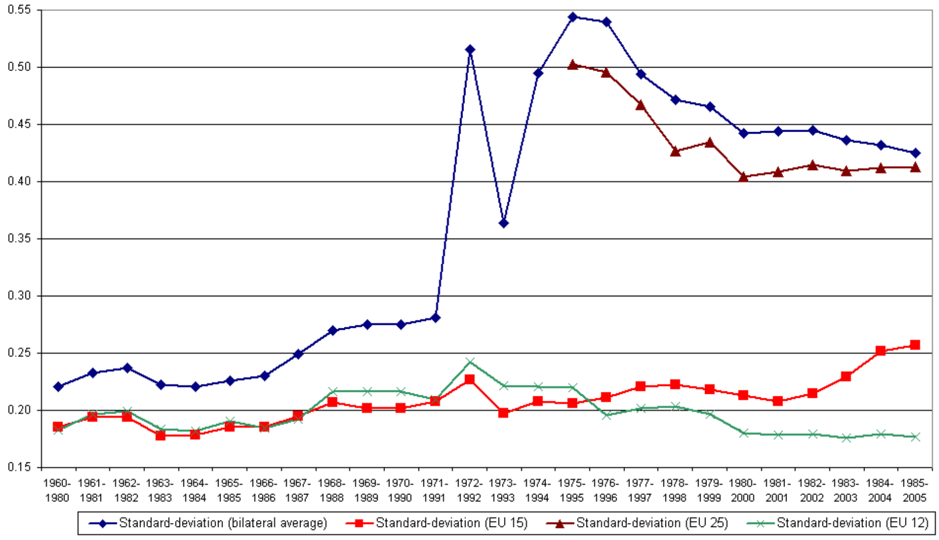


Figure 3.36: Average Bilateral Correlations for the EU-15 Countries (Windows of 20 years)

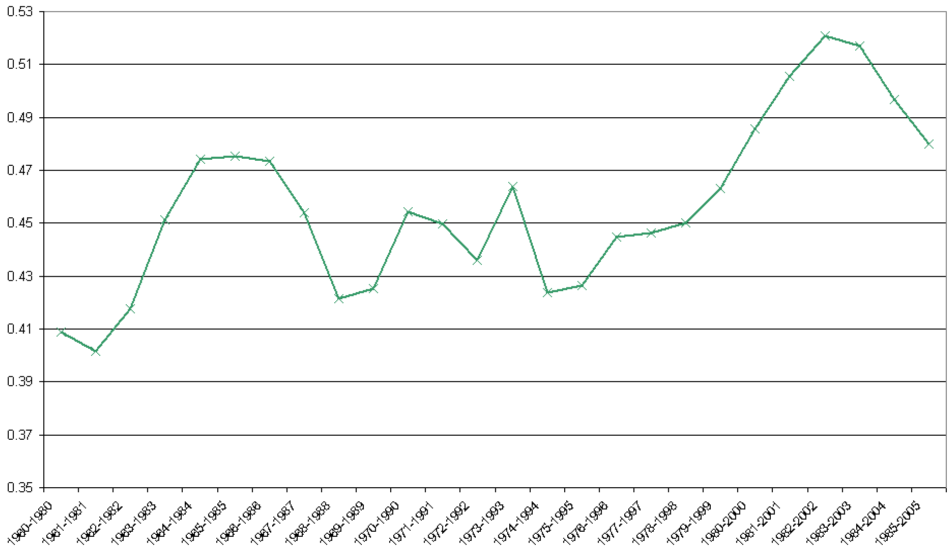


Figure 3.37: Stand.-Dev. of the Bilateral Correl. for EU-15 (Windows of 20 years)

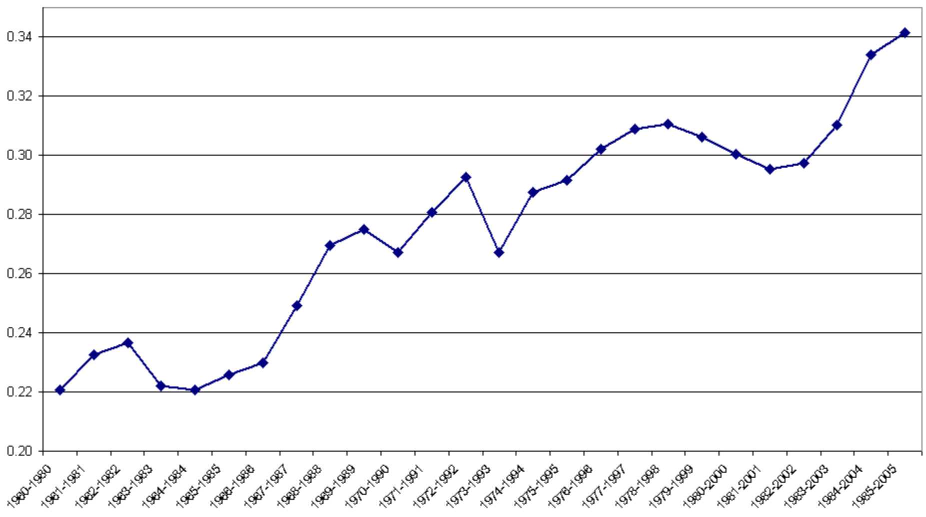


Figure 3.38: Average Bilateral Correlations for Eurozone Countries (Windows of 20 years)

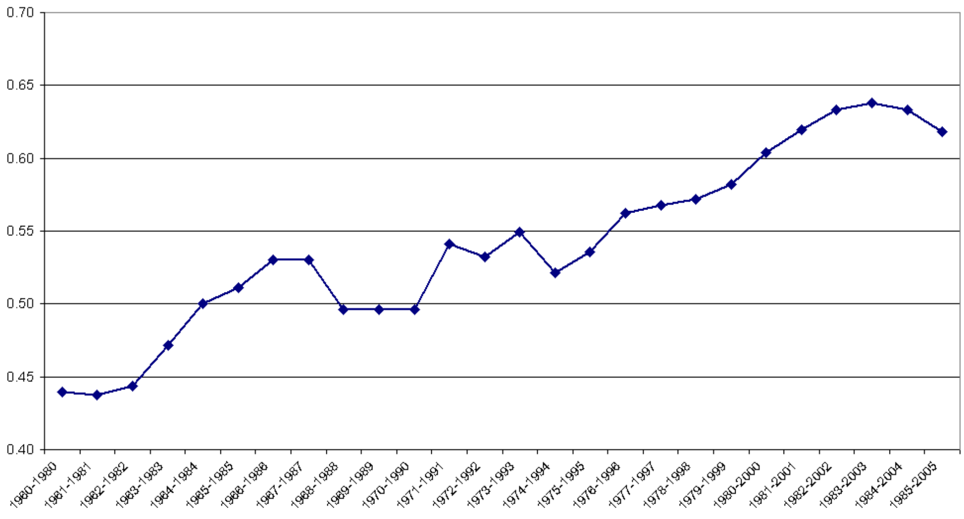
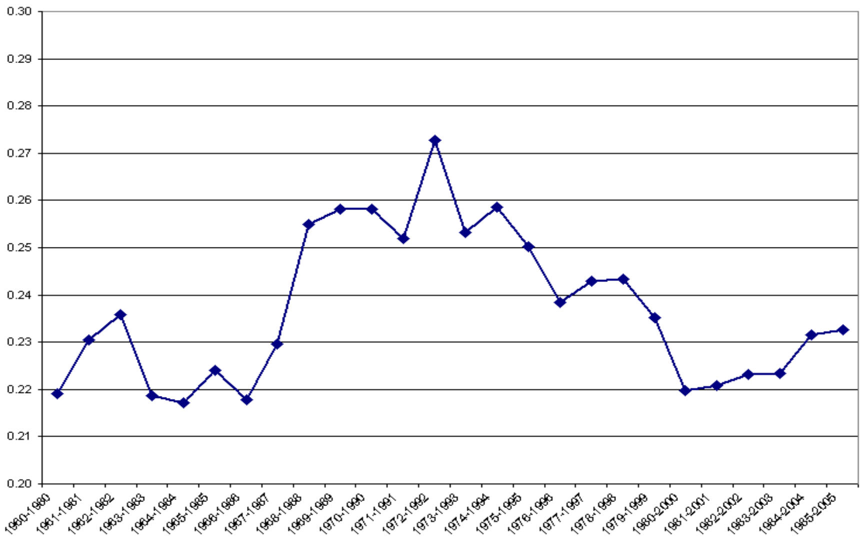


Figure 3.39: Stand.-Dev. of the Bil. Correlat. for the Eurozone (Windows of 20 years)



3.9 Appendix D - Sensitivity Analysis for Regional Clusters

Table D1 - Cluster Evolution for Canada

	1926-36	1936-46	1946-56	1956-66
Cluster 1	BC, NB, NS ONT, QUE	BC, ONT, QUE	BC, QUE, ONT	BC, QUE, ONT
Cluster 2	MAN	NS, MAN, NB	ALB, MAN	ALB, MAN,
Cluster 3	ALB	ALB	NB, NS	NB, NS
Cluster 4	SAS	PEI	PEI	NF
Cluster 5	PEI	SAS	SAS	PEI
Cluster 6				SAS
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.9	0.74	0.69	0.56
Value for Correl. when Clust. is stopped	0.95	0.83	0.81	0.61
Value for Correl. after Clust. is stopped	0.86	0.73	0.61	0.54

Table D1 - Cluster Evolution for Canada (continued)

	1966-76	1976-86	1986-96	1995-05
Cluster 1	NB, NFD, QUE	QUE, ONT, PEI, NB, NFD	NS, ONT, NB, MAN, PEI	NB, NS, ONT, PEI
Cluster 2	BC, NS, ONT	MAN, NS	ALB, QUE,	NFD, QUE
Cluster 3	ALB, SAS	ALB, BC	NFD	ALB, MAN
Cluster 4	MAN	SAS	BC	BC
Cluster 5	PEI		SAS	SAS
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.84	0.63	0.66	0.55
Value for Correl. when Clust. is stopped	0.88	0.65	0.82	0.66
Value for Correl. after Clust. is stopped	0.80	0.41	0.56	0.35

Table D2 - Cluster Evolution for Germany

	1970-80	1980-90	1991-2001	1994-04
Cluster 1	BAY, NSA, NRW RPF, HBG	BAY, NSA	NRW, SHO, HBG, BAY, BRE, SAA, RPF NSA, BAW, HES,	**SAN, SAF, MEV, THU, BLN, BRA**
Cluster 2	HES, BAW	NRW, SAA	**SAN, SAF, BRA, MEV, THU, BLN,**	NRW, SHO, HBG, BAY BRE, BAW, HES, SAA
Cluster 3	BLNW, BRE	BAW, HES, RPF		NSA, RPF
Cluster 4	SHO	BLNW, SHO		
Cluster 5	SAA	BRE		
Cluster 6		HBG		
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.83	0.89	0.48	0.57
Value for Correlations when Cluster is stopped	0.85	0.93	0.64	0.59
Value for Correlations after Cluster is stopped	0.81	0.89	-0.97	0.33

Table D3 - Cluster Evolution for Western Germany

	1990-2000	1994-04
Cluster 1	BRE, HES, NRW, SHO	BAY, BRE, BAW, HES,
Cluster 2	BAY, NSA,	NRW, SAA
Cluster 3	BAW, RPF,	NSA
Cluster 4	HBG	RPF
Cluster 5	SAA	HBG
Cluster 6		SHO
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.95	0.79
Value for Correlations when Cluster is stopped	0.96	0.83
Value for Correlations after Cluster is stopped	0.94	0.77

Table D4 - Cluster Evolution for Switzerland

	1979-89	1989-99	1994-2004
Cluster 1	NEU, ZH, FR, SO, VS, VD	VD, ZH, GE, TG, JU, VS, TI, AAR	GE, TI, ZH, VD, NEU
Cluster 2	AAR, GR, UR	BE, OW, LU	AAR, TG, AG, SG, UR
Cluster 3	AG, NW, OW, SZ, TG	AG, SG, ZG	BS, GL, ZG
Cluster 4	LU, SG,GL	AIR, SZ, BL, BS, SH	BE, OW, LU
Cluster 5	BE, JU	FR, SO, NEU, NW	SH, SZ, GR, BL
Cluster 6	GE, TI	GR	JU, VS, SO, FR
Cluster 7	BS, SH,	GL	AIR, NW
Cluster 8	AIR	UR	
Cluster 9	BL		
Cluster 10	ZG		
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.67	0.51	0.51
Value for Correlations when Cluster is stopped	0.69	0.53	0.54
Value for Correlations after Cluster is stopped	0.64	0.43	0.46

Table D5 - Cluster Evolution for the USA

	1930-40	1940-50	1950-60	1960-70
Cluster1	IN,OH,MI,IL,NY PA,VT	SC,VA,MD,RI,IN OH,MA,NJ,PA	CT,NJ,OH,MI,NV RI,NH,,WA	OH,WI,PA,NC,SC,IL MD,NJ,CT,MN,MA NY,RI,NH,WA,VT,KY MO,TN,LA,TX
Cluster2	AL,TN,GA,SC, NC	GA,WA,AL,WI KY,MO,NC,AR	CO,UT,WV,ID	AL,OR,IA,DC,WV
Cluster3	AZ,TX,LA, MO,KS,KY	AZ,UT,OR,ME,CO	IL,MA,TN,PA,VT MD,VA,IN	MT,ND,NE,SD,ID
Cluster4	OR,WA,FL,CA,	IL,NH,VT	GA,OR,WI,NC,AR,MS	CO,WY,NM,UT
Cluster5	RI,VA,MD	CA,FL,TN,OK,NM,TX,LA	CA,ME,OK,MO,NY	AZ,HI
Cluster6	IA,MN,	ID,KS, MS,NE,	KY,SC,AK,AZ	AR,MS
Cluster7	CO,UT,NV	CT,MI	IA,NE	AK,ME
Cluster8	WI,WY,OK,NM,WV	DC,NV	DE,MN	FL,OK
Cluster9	CT,MA,NJ	MN,SD,WV	DC,MT	GA,VA,CA,IN,DE,MI
Cluster10	AR,MS	NY	ND,SD	NV
Cluster11	ME,NH	WY	AL,TX,LA,FL	KS
Cluster12	ND,SD,MT	MT	NM,WY	
Cluster13	DC	ND	KS	
Cluster14	DE	IA	HI	
Cluster15	ID	DE	ND	
Cluster16	NE		SD	
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.88	0.90	0.53	0.48
Value for Correl. when Clust. is stopped	0.90	0.91	0.57	0.55
Value for Correl. after Clust. is stopped	0.88	0.90	0.50	0.42

Table D5 - Cluster Evolution for the USA (continued)

	1970-80	1980-90	1990-2000	1995-2005
Cluster1	MD,NY,MA,NJ,HI	CT,ME,VT,RI,DE,PA,FL,CA DC,NY,MD,,NJ,VA,MA,NH	CA,PA,MA,NJ,FL,NY VT,VA,WA,ME,RI, MD,DE,SC,CT	CA,VT,CT,MA, NH,OK,CO,GA WY,VA,NJ
Cluster2	GA,NC,VA,SC,DE, KS,ND,SD,NE,	AL,NC,MO,AR,AZ, OH,IN,MI,TN,IL,SC MS,IA,GA,MN,WI,KY	IN,WI,OH,OR,UT,CO KS,KY,OK,AZ, MO,TX,MI,TN,	MN,WA,AZ,NC,MI TX,KS,MO,OH,WI KY,SC,IL,IN, TN
Cluster3	MS,TN,IN,MI,KY,OH, IL,PA,AL,NM,,WI	NE,SD,KS	IL,NC,GA,NH, MN,NV	FL,NY,PA
Cluster4	LA,OR,UT,WV	NM,UT,CO,TX	LA,MS,AR,NM	MD,RI,DE,ME
Cluster5	AZ,CO,FL,OK,	NV,WA,OR	DC,HI	OR,UT,ID
Cluster6	MO,NH,MN,ME	LA,OK,WY	ND,SD	AK,DC
Cluster7	WA,WY	AK,ND	IA,NE	NE,SD,ND
Cluster8	CA,TX,NV	HI	AK,WV	AR,NV,MS,AL
Cluster9	RI,VT,CT	ID	MT	MT,WV
Cluster10	AR,IA,MT,ID	WV	AL	IA
Cluster11	AK	MT	WY	LA
Cluster12	DC		ID	NM
Cluster13				HI
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.71	0.66	0.68	0.70
Value for Correl. when Clust. is stopped	0.71	0.69	0.69	0.70
Value for Correl. after Clust. is stopped	0.67	0.63	0.64	0.63

Table D6 - Cluster Evolution for the European Union

	1960-70	1970-80	1980-90	1990-2000	1995-05
Cluster 1	BE, FI, LU, DE,	DK, DE, EL, UK	SE, UK, FI, ES, LU	BE, IT, AT, PT, FR, ES, DE, EL, LU	IE, PT, NL, FI, **SI,** AT, BE, UK, FR, LU, ES, SE
Cluster 2	FR,SE,DK	FR, AT, BE, LU, PT	BE, IT, NL, EL, DE	FI, **PL,SI,** UK, NL, IE, SE	EL, **HU**, **LV, LT**
Cluster 3	AT, EL	NL, IT,	FR, PT	**LV**, **LT**	DE, IT
Cluster 4	IE, IT	FI, SE	AT	**CY**	DK, **MT**
Cluster 5	NL, PT	IE	IE	DK	**CZ**
Cluster 6	ES	ES	DK	**CZ**	**SK**
Cluster 7	UK				**PL**
Cluster 8					**CY**
Cluster 9					**EE**
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.46	0.51	0.69	0.60	0.56
Value for Correlations when Cluster is stopped	0.52	0.53	0.76	0.61	0.61
Value for Correlations after Cluster is stopped	0.46	0.37	0.68	0.47	0.52

Table D7 - Cluster Evolution for the European Union at 15

	1990-2000	1995-05
Cluster 1	BE, IT, AT, ES, PT, FR	IE, PT, NL
Cluster 2	DE, EL,	FR, LU, ES, SE
Cluster 3	FI, UK,	AT, BE, UK
Cluster 4	NL, IE, SE	DE, IT
Cluster 5	LU	DK
Cluster 6	DK	EL
Cluster 7		FI
Av. Bilat. Correl. + $\frac{1}{2}$ St. Dev. Bilat. Correl.	0.60	0.67
Value for Correlations when Cluster is stopped	0.63	0.70
Value for Correlations after Cluster is stopped	0.44	0.61

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