CENTRAL BANK &
FINANCIAL SERVICES
AUTHORITY OF IRELAND
EUROSYSTEM

13/RT/09 November 2009

Research Technical Paper

The United States as a growth leader for the Euro Area - A multi-sectoral approach

Kieran McQuinn and Geraldine Slevin*

Economic Analysis and Research Department
Central Bank and Financial Services Authority of Ireland
P.O. Box 559, Dame Street, Dublin 2, Ireland
http://www.centralbank.ie

*E-mail: kmcquinn@centralbank.ie and geraldine.slevin@centralbank.ie. The views expressed in this paper are our own, and do not necessarily reflect the views of the Central Bank and Financial Services Authority of Ireland or the ESCB. We would like to acknowledge comments by Karl Whelan UCD and participants at a CBFSAI seminar on an earlier draft. All remaining errors are our own.

Abstract

In this paper we examine the role played by technology spillovers between the United States and the Euro area. We explicitly assume that the United States acts as a growth leader for Europe and that the Euro area is constantly converging to US total factor productivity (TFP) levels. As a result, a growing divergence in the level of US TFP vis-à-vis that of Europe results in an increase in the growth rate of Euro area TFP. The model is applied to TFP data from 26 subsectors of both economies. The role of greater ICT adoption in increasing Euro area TFP is also explored.

Non Technical Summary

The relationship between Europe and the United States has become an area of increasing interest. In particular many studies have focused on labour market and business cycle developments. This paper differs in that we explicitly examine the long-run relationship between both areas by examining the possibility of technology spillovers. In particular, we assess whether there is a relationship between the rate of total factor productivity (TFP) growth in different industry sub-sector categories in the US and their counterparts in Europe. In our modelling framework we assume that the United States acts a growth leader for the Euro area. This methodology implies that the greater the difference in levels between TFP in the United States and Europe, the greater the growth rate of European TFP. Given the possibility of heterogeneity across the different sectors of the economy we estimate a fixed effects regression model which yields plausible and significant results. We modify our model to address the role played by ICT in increasing European TFP growth both directly and indirectly. Our results indicate that ICT has a positive impact on productivity growth in Europe. We also find that increased use of ICT increases the convergence of EU TFP levels to US TFP levels. The data suggests that over the sample a change took place in the respective performances of both economies, therefore we examine and detect for the possibility of structural breaks. We conduct a series of recursive estimation in order to analyse how the rate of convergence between the Euro area and the United States has changed over time as a result.

1. Introduction

From the outset, the economic performance of the Euro area has frequently been compared with that of the United States. Living standards in Europe had, for most of the post-war era, been converging to those of the United States due mainly to the relative improvement in European labour productivity. And, while, of late, this convergence process has been somewhat diminished, many studies of European economic performance center on the performance of the Euro area vis-à-vis that of the United States. Studies such as Blanchard (2004), Gordon (2004), Dew-Becker and Gordon (2006), van Ark, O'Mahony and Timmer (2008) and McQuinn and Whelan (2008) compare, across both regions, the relative performance of key economic concepts, particularly, those in the labour market.

A related, emerging, literature has begun to examine the possibililty of a more, formal, relationship between the Euro area and the United States - business cycle developments in the Euro area are explicity related to movements in the United States (Dées, di Mauro, Pesaran and Smith (2007), Giannone, Lenza and Reichlin (2008) and Dées and Saint-Guilhem (2009) being notable examples). Implicit in such an approach is the notion of the United States being a growth leader with economic regions such as the Euro area constantly converging to higher levels of US income, primarily through learning and adopting technologies originally advanced in the US economy.

Our paper contributes to this recent literature by explicitly examining technology spillovers between the United States and the Euro area. In particular, we address whether there are spillovers between the rate of total factor productivity (TFP) growth in different industry subsector catergories in the US and their counterparts in the Euro Area. Using a relatively straightforward model of technology transfer, we assume that TFP growth across the different sectors of the Euro area economy is mainly a function of the difference in TFP levels between the United States and the Euro area. If this gap increases i.e. US TFP levels become greater than those in the Euro area, than the growth rate of TFP in the Euro area increases.

While most of the studies formally examining the relationship between the US and the Euro area have focussed on the linkages between output or output per capita levels, our focus on TFP as the main growth channel between the two regions is motivated, to a large extent, by the recent reknewed emphasis on the underlying assumptions of the original Solow growth model - (see, for example, the special edition of the *Oxford Review of Economic Policy* Vol. 23, Number 1, 2007). As noted in McQuinn and Whelan (2007a) and (2007b), the Solow model specifies that, in the long run, the growth rate of the steady-state path of an economy is determined only by technological efficiency. Therefore, if some long-run economic relationship exists between the United States and the Euro area, underpinning this must be some relationship between the rates of

TFP in both regions.

Using our model, we find strong evidence of technology spillovers from the United States to the Euro area. In particular, an increase in the level of US TFP in different subsectors of the economy relative to the Euro area results in an increase in the growth rate of European TFP. Furthermore, we find additional evidence to suggest that the greater adoption of ICT technology in the Euro area increases Euro area TFP in two seperate channels (i) by increasing TFP directly and (ii) by increasing the ability of the Euro area to learn from and converge to US TFP levels. Over the sample period in question, there is strong evidence to suggest significant changes in the relative patterns of Euro area and US TFP growth. Therefore, we also address the possibility of stuctural changes in Euro area TFP rates within the modelling framework.

Achieving a greater understanding of the dynamics of Euro area growth is clearly of concern to a variety of governments and institutions. The European Central Bank's (ECB) constitution calls for it to promote economic growth within the Euro area as long as this does not undermine its primary goal of price stability. As a result the ECB has become a key participant in public debates about the need for structural reforms to boost the potential capacity for growth in the Euro area. Discussions of this issue have, for instance, regularly featured in the official statements accompanying the decisions of the ECB Governing Council and in the public statements of the ECB President.[1] The relatively poor European growth performance of the past 10 years has had an important influence on the policy focus of national governments, the European Commission, and the European Central Bank (ECB). This reform agenda has been formalised in the Lisbon Agenda set of policy proposals and discussed in high-profile publications such as the 2003 *Sapir Report*.

The contents of the rest of the paper are as follows. Section 2 reviews some of the recent literature examining the economic performance of the Euro area and the United States. Section 3 outlines the model of technology diffusion employed. Section 4 discusses the EU KLEMS database, while section 5 presents the results of the empirical application. A final section offers some concluding comments.

2. The United States and the Euro Area

"If the United States sneezes, the rest of the world catches a cold" ((IMF (2007), World Economic Outlook). The notion of the United States as the "engine" of the world economy with its business cycle leading the rest of the world, is reinforced by recent research by Dées and Saint-Guilhem

[1] For example, see Jean-Claude Trichet: Testimony before the Committee on Economic and Monetary Affairs of the European Parliament, 23rd May 2005. Available online at: www.bis.org/review/r050530b.pdf.

(2009). In emphasising the US dominance in terms of its weight within each country's trade, US (18%), Euro area (16%), Japan (11%) and UK (8%), Dées and Saint-Guilhem raise concern about the harmful spillover effects of a US recession on other economies. While they maintain that some economies have decoupled themselves from the current US recession, they find that the influence of the United States on other economies is larger than direct trade ties would suggest.

Much of the research looking at the United States and Europe has addressed the relationship between trends in both labour and total factor productivity in the different regions. Van Ark, O'Mahony and Timmer (2008) maintain that Europe experienced a slowdown in labour productivity from the mid 1990s as a result of the slower emergence of the knowledge economy compared to the United States. They claim that this represents a long-term pattern of convergence. They break up the sample into three sub-samples. Between 1950 and 1973 European labour productivity growth was characterised by strong investment and imitation of foreign technology thus suggesting a catch-up pattern. This convergence process ended in the mid 1970s when labour productivity growth in both Europe and the United States began to slow. During this time Europe's labour force participation and hours worked declined. Since 1995, US labour productivity growth increased while European labour productivity declined. They find that investment in information technology and the share of technology producing industries was lower in Europe. They emphasise the need for improved labour productivity growth in European market services to boost overall growth and narrow the gap with the United States, by creating a"single market" for the services industry through the adoption of the Services Directive in 2006. These trends in respective labour productivity rates are also examined in McQuinn and Whelan (2008). Figure 1, which is reproduced from McQuinn and Whelan (2008)[2], shows Euro Area and US labour productivity growth from 1973 until 2006. It is clear from the graph that until the mid 1990s the growth of labour productivity in the Euro area always exceeded that in the United States.[3]

In Figure 2 we present comparisons of capital stock and TFP growth rates for the US and Euro area.[4] The first graph in Figure 2 shows that capital input has generally grown faster in the US than in the Euro area. In particular, the figure highlights the strong growth in the capital stock during the mid to late-1990s when the US went through a period of very strong growth in investment. In a growth accounting framework, one of the implications of the stronger US capital growth is that the TFP growth record of the Euro area relative to the US has been even stronger than its positive

[2]Figure 1 p.646.

[3]This is similar to the findings of O'Mahony et al (2008). Many authors, including Blanchard (2004), maintain that the Europe's superior productivity performance and subsequent slowdown is a result of the catching up process. From the middle of the 1980s hours worked per capita declined considerably in the Euro area, while US hours worked per capita increased significantly after initially being behind Europe in the 1970s.

[4]This graph is also reproduced from McQuinn and Whelan (2008) (Figure 4 p. 653).

labour productivity growth record. Indeed, the second graph in the figure shows that TFP growth[5] in the Euro area exceeded the comparable series for the US over almost every 3-year period from the early 1970s until 1992. The period since, however, has shown US TFP growth moving ahead. In particular, the period since 2000 has seen the gap between Euro area and US TFP growth widen, with the Euro area appearing to have settled down at a very low growth rate of about 0.5 percent per year.

In terms of empirically examining the relationship between the two regions, a recent study by Giannone, Lenza and Reichlin (2008) represents an important contribution. They analyse output dynamics in the Euro area and compare differences with the United States. It appears that cycles in both the Euro area and the United States are driven by a common world shock while the Euro area appears to lag the US. They examine the gap between real GDP per capita of country i with respect to the Euro area. The gaps with the US and other countries have been stable over the last thirty years and they find that the gap between the US and Euro area is stationary. It closes during recessions as Europe reacts slowly to worldwide shocks. The Euro area cycle seems to be smoother than the US one and recessions are shorter in the euro area. Euro area growth follows US growth which they test using Granger causality tests. The Euro area adjusts to US growth but the US does not respond to Euro area shocks. After a worldwide shock the US adjusts immediately while the Euro area reacts slowly taking 5 years to reach its steady state. They also find that the US economy has a higher ability to absorb technology faster than the euro area.

In the next section we outline the model of technology spillover used in the analysis.

3. Model

3.1. Model Assumptions

In looking at the relationship between the United States and the Euro area, we use a standard model of technology transfer. The model has been employed in a variety of different applications. For example, Nelson and Phelps (1966) look at the effect that educated people have on innovation, and how education can speed the process of technology diffusion, while Bernard and Jones's (1996) version of model is based on technology diffusion in the manufacturing sector of the USA. The version of the model used in this paper is outlined fully in McGuinness (2007) and constitutes a slightly different version of the model presented in Acemoglu (2008).

In our version of the model, we are interested in the gap in technology growth levels between

[5]McQuinn and Whelan (2008) generate their estimates of TFP using a similiar method to that employed in EU-KLEMS.

different economic areas. The underlying assumption is that there is a lead economic region - the United States and an economic region which follows - the Euro area. The United States has technology level, A_t, which grows at rate g, while the Euro area has technology level B_t, where $B_t < A_t$. The United States technology growth rate is assumed to be exogenous while the Euro area's technology growth is endogenous. In continuous time these technology levels grow at a rate of:

$$\dot{B}(t) = \lambda \left(A(t) - B(t) \right). \tag{1}$$

where $(A(t) - B(t))$ is the technology or productivity gap between the United States and the Euro area. The parameter λ measures the portion of the gap that can be closed due to the Euro area's convergence speed through absorbing knowledge and new technology from the US. The greater the gap the more the Euro area has to learn and therefore the greater the degree of convergence required.

3.2. Solution to the Steady State and Convergence

The steady-state solution of (1) is where technology in both regions grows at the same rate. Therefore, the growth rate of the Euro area $B(t)$ is given by:

$$\frac{\dot{B}(t)}{B(t)} = \lambda \left(\frac{A(t) - B(t)}{B(t)} \right). \tag{2}$$

In the steady state, the growth rate of the follower must equal the growth rate of the lead country, g.

$$\lambda \left(\frac{A(t) - B(t)}{B(t)} \right) = g. \tag{3}$$

This can easily be shown to imply the following

$$B(t) = \frac{\lambda}{g + \lambda} A(t). \tag{4}$$

consequently, the Euro area can never fully catch-up with the United States as:

$$\frac{\lambda}{g + \lambda} < 1 \tag{5}$$

In this case, the Euro area always has technology levels, which are less then the United States and can only experience increases in technology if there is a gap between the level of technology in the US and Europe. As long as the United States grows at rate g, then Europe can acquire new technologies from them. Therefore, in the steady state Europe must have lower technology levels than the United States.

McGuinness (2007) has derived the general solution for the convergence process to the steady-state path. By solving equation (1) it can be shown that the steady state equilibrium is relevant if convergence occurs. It is expressed below with all $B(t)$ terms on the left hand side

$$\dot{B}(t) + \lambda B(t) = \lambda A(t) \tag{6}$$

Given that $\frac{\dot{A}(t)}{A(t)} = g$, its particular solution is $A(t) = A(0)e^{gt}$ therefore the differential equation can be re-written in the form

$$\dot{B}(t) + \lambda B(t) = \lambda A(0)e^{gt} \tag{7}$$

One possible solution for a $B(t)$ process that will satisfy this equation is in the form $D_1 e^{gt}$ where D_1 is some unknown coefficient. It must satisfy the following equation

$$gD_1 e^{gt} + \lambda D_1 e^{gt} = \lambda A(0)e^{gt} \tag{8}$$

Canceling the e^{gt} terms, gives

$$gD_1 + \lambda D_1 = \lambda A(0) \tag{9}$$

so that

$$D_1 = \frac{\lambda}{g + \lambda} A(0) \tag{10}$$

so this is solution corresponds exactly to the steady-state path in which the follower country has income levels that are a constant fraction of the leader's level:

$$B(t) = \frac{\lambda}{g + \lambda} A(t) \tag{11}$$

We will label this solution as

$$B^1(t) = \frac{\lambda}{g + \lambda} A(t)$$

Now note that we have a solution of the form

$$B(t) = B^1(t) + B^2(t)$$

which has the property that

$$\dot{B}(t) = \dot{B}^1(t) + \dot{B}^2(t) \tag{12}$$

So, a combined solution of this form will still satisfy equation (6) as long as

$$\dot{B}^2(t) + \lambda \dot{B}^2(t) = 0 \tag{13}$$

Which solves as

$$B^2(t) = D_2 e^{-\lambda t} \tag{14}$$

The general solution is the combination of the two solutions above

$$B(t) = \frac{\lambda}{g+\lambda} A(0) e^{gt} + D_2 e^{-\lambda t} \tag{15}$$

or, alternatively:

$$B(t) = \frac{\lambda}{g+\lambda} A(t) + D_2 e^{-\lambda t} \tag{16}$$

Given that $e^{-\lambda_t}$ tends toward zero as time goes on, the solution converges to the first term, which is growing at rate g, as required in the steady state.

Therefore, this clearly demonstrates that even if there is TFP growth in the follower country and this closes some of the gap with the leader country, the follower will never actually catch-up because $\frac{\lambda}{g+\lambda}$ is less then one. The leader will always be growing at rate g, this implies that the follower will always have technology levels below that of the leader. The model also shows that it is not the countries' ability to invent new capital goods that is the key to growth but instead their ability to absorb and learn technology from advanced countries. Therefore, the higher the absorption speed of the follower countries, the faster they will converge on the leader.

4. The EU KLEMS Database

The EU KLEMS Growth and Productivity Accounts database, as described in detail in Timmer, O'Mahony and Van Ark (2007), is the principal data source for this study. The database is the product of a research project financed by the European Commission and undertaken by a group of organisations from across the EU in close cooperation with national statistical institutes as well as the European Commission and the OECD. The EU KLEMS dataset is specifically designed for the analysis of growth and productivity developments, at an industry level, across European countries. The data used in the present study is based upon the March 2007 release of the database. The variables covered in the EU KLEMS database can be broken down into three main categories, specifically, "basic" variables, growth accounting variables and an "additional" variables series.

The first of these categories relates to a basic series of variables including output and intermediate inputs, namely, energy, material and service inputs, at current and constant prices, as well as labour input (employment and hours worked). The "basic" variables dataset was largely constructed on the basis of the national accounts of individual countries. The data series was harmonised on a cross-country basis using the NACE industrial classification as well as similar price concepts for inputs and outputs. This category of variables is available for the original EU-15 countries for the thirty-five year period from 1970-2004 and from 1995 onwards in respect of the EU member states joining on 1 May 2004 i.e. EU-10.

The second category of variables, the growth accounting series, includes data on capital services, labour services, and total factor productivity. This growth accounting series is based upon the methodology of Jorgensen and Griliches (1967) together with the more recent input-output framework of Jorgensen, Gollop and Fraumeni (1987) and Jorgensen, Ho and Stiroh (2005).

The measure of total factor productivity (TFP) in EU-KLEMS is based on a standard growth accounting approach. The growth rate of TFP is defined as the growth rate of output minus the weighted growth rates of inputs (intermediate inputs (X) , capital (K) and labour (L)), where the weights (v) denote two-period average shares of the inputs in the nominal value of output (Timmer et al., 2007). The assumption of constant returns to scale implies that the weights sum to 1. The contribution of each input to growth is defined as the product of the input's growth rate and its two-period average revenue share.

$$\Delta \log TFP_{it} = \Delta \log Y_{it} - \overline{v}_{it}^{x} \Delta \log X_{it} - \overline{v}_{it}^{k} \Delta \log K_{it} - \overline{v}_{it}^{l} \Delta \log L_{it} \qquad (17)$$

Table 1[6] shows the percentage contributions of the various NACE sectors to overall employment and output between 1980 and 2005. The striking feature about this Table is the large significant contribution that the construction sector made to both output and employment in the EU and the US, with the formers contribution being the largest. Retail and wholesale trade also had a significant effect on employment contributing 9.8 per cent and 15.9 per cent to total employment in the EU and US respectively. Financial Intermediation contributed 7.4 per cent to output in the US over this period and 5.9 per cent in the EU, the contributions to employment in these sectors were also very significant. The real estate sector made very little contribution to employment but contributed 8.1 per cent to output in the EU and 9.4 per cent in the US. Renting made a large contribution to both output and employment in both areas. The contributions of the agricultural and manufacturing sectors were positive but smaller in magnitude to both output and employment in the EU and US.

In Table 2 we present annual average sectoral TFP growth rates for both the US and the Euro area. Over the entire sample, the results highlight negative TFP growth in a number of sectors, namely mining, renting and hotels in both the EU and US, with negative TFP growth in electricity and construction in the US only. This suggests productivity deterioration in these sectors. The negative TFP growth in the construction sector is masked by its large employment contribution.

[6] The data for the NACE categories only relate to data that is available and not for the whole economy.

The electrical equipment sector shows the largest TFP growth, with the fastest growth in the US. This reflects the increased manufacturing of computers and telecommunications equipment. TFP growth in the chemicals and post and telecoms sectors are larger in the EU than the US. Overall, the results imply that employment has been the largest contributor to output growth during this time period while productivity growth has had a smaller but significant contribution. The US leads in terms of productivity growth especially in ICT production. Van Ark et al. (2003) find that the US has faster productivity growth in sectors that make intensive use of ICT.

Given the apparent change in the relative growth rates of TFP in both regions, as suggested, for instance, by Figure 2, in Table 2, we also present an average of the different TFP growth rates for the sub-period 1995 - 2005. The mid 1990s appears to be the period when US growth rates began to increase relative to those in Europe. A comparison of the averages for the entire sample compared to the sub-period highlight this point at the sectoral level. The relative improvement in the US performance can be witnessed in a number of sectors such as the machinery, electrical equipment, manufacturing, repair of motor vehicles and the retail trade.

5. Regression Specifications

In this section we outline the empirical models based on the discussion in section 3. The regression specifications are discussed in discrete time as that is the format of the data. In the initial model, we examine the pure learning effect on TFP growth in Euro area economy as described in equation (1). This is done by using the technology gap between the Euro area and the United States:

$$\Delta \log TFP_{it}^{ea} = \lambda \left(GAP_{it-1}\right) + \epsilon_{it} \tag{18}$$

where the gap is defined as the difference between TFP in the different sectors of the Euro area's economy and TFP in the equivalent sectors of the United States:

$$GAP_{it} \equiv \left(\log TFP_{it}^{us} - \log TFP_{it}^{ea}\right) \tag{19}$$

The portion of the gap that is closed each year is measured by the parameter λ. Therefore the convergence of the Euro area is due to its ability to absorb and implement new technology and knowledge from the US. The gap can be lagged because the following country can only acquire technology from the previous periods. We estimate (18) with OLS.

Given the inevitable heterogeneity across the different sectors of the economy, we modify the initial specification to include sector-specific dummies. These are included in the following panel data fixed effects specification:

$$\Delta \log TFP_{it}^{ea} = \lambda \left(GAP_{it-1} \right) + \sum_{i=1}^{26} \beta_i \left(DUMMY_i \right) + \epsilon_{it} \quad (20)$$

The dummies quantify the growth rates of TFP in each of the sectors of the Euro area economy in the absence of any convergence to US TFP levels.

Table 3 reports results from estimation of equation (18) over the period 1981 - 2005. The results conform with *a priori* expectations based on the theoretical model outlined in section 3. The OLS estimate in (18) suggests that 2.8 per cent of the gap is closed each year. The result is highly significant at the 5 per cent significance level. This suggests that the speed of convergence of the Euro Area to US TFP levels is approximately 3 per cent per annum. The inclusion of sector-specifc dummies of the economy results in convergence speeds which are approximately half those of the OLS estimates - 1.2 per cent in (20). Again these results are highly significant. The p-values for the inclusion of the sector-specific dummies implies that heterogeneity across sectors is significant. For robustness sake, we also estimate a random effects version of (18). The results are also in Table 4 and the similarity of the fixed effects and random effects estimates is reassuring. Overall, it would appear that convergence between Euro area and US TFP levels is in the region of 1.5 per cent per annum.

5.1. Role of ICT Technology in Convergence

From Figure 2, it is evident that, in aggregate terms, over the past 10 years, US TFP growth rates have increased quite consistently relative to those in Europe. One of the main reasons given for US TFP growth during this period has been greater use of Information Communications Technologies (ICT). Studies by Oliner and Sichel (2000) and (2002), Jorgenson and Stiroh (2000), Jorgenson, Ho and Stiroh (2005) all cite the greater adoption of ICT technologies as being a major contributing factor to US TFP growth over the period. Greater use of ICT contributed to greater growth in the US economy through greater levels of ICT investment, strong productivity effects from ICT using industries and a more productive use of ICT, generally, throughout the economy.

Disparities in the rate of ICT adoption are increasingly cited as one of the main reasons for the differences in productivity growth between the Euro area and the US. Jorgenson, Ho and Stiroh (2008) suggest that more flexible labour markets and advanced innovation in the United States resulted in higher productivity growth in the US compared to the Euro area. Inklaar, Timmer and van Ark (2006) find that ICT had a significant impact on growth in the US economy through an increase in ICT investment, strong productivity contributions from ICT-producing industries and more productive use of ICT in the rest of the economy. van Ark and Inklaar (2005) find that the EU is not realising the same productivity gains from ICT as the US. This result may be related to more productive use of ICT in the US, particularly in the market services sector.

Given our modelling framework, we address the role played by ICT in a European context by examining, explicitly, whether the greater use of ICT technologies in the Euro area can, indeed, increase European growth rates of TFP.

In Table 4 we summarise the contribution of ICT capital services to output growth between 1980 and 2005 for the Euro area. The sectors making the largest contributions to growth include those sectors specifically associated with ICT adoption. These include Pulp (15.3 per cent), Electrical equipment (16.2 per cent), Chemicals (7.3 per cent), Post and telecommunications (66.9 per cent) and Financial Intermediation (59 per cent). Transport and Renting also had a very significant effect on growth.

To assess the impact of ICT technology on TFP growth we use the variable $GOConKIT$ from the KLEMS database. We label the variable "ICT". The variable measures the contribution of ICT capital services to output growth[7]. We allow the ICT variable to operate through two different channels - a direct and indirect channel. In the direct case, greater use of ICT simply increases the growth rate of TFP, whereas in the second, indirect, channel, increased use of ICT, operates through the gap by increasing the convergence towards US TFP levels, thereby, also increasing Euro area TFP levels. Starting with the direct effect, we amend (20) accordingly

$$\Delta \log TFP_{it}^{ea} = \lambda \left(GAP_{it-1} \right) + \beta_1 \left(ICT_{it} \right) + \sum_{i=2}^{27} \beta_i \left(DUMMY_i \right) + \epsilon_{it} \tag{21}$$

The second regression now incorporates the indirect effect of ICT through the gap along with the direct effect. The effect on the gap is measured by interacting the gap with the ICT variable in the case of each industry sector.

$$\Delta \log TFP_{it}^{ea} = \alpha \left(GAP_{it-1} \right) + \beta_1 \left(ICT_{it} \right) + \beta_2 \left(ICT_{it} * GAP_{i,t-1} \right) + \sum_{i=3}^{29} \beta_i \left(DUMMY_i \right) + \epsilon_{it} \tag{22}$$

In this case, the rate of convergence is now given by $(\alpha + \beta_2 * ICT_{it})$. So sector-specific λ_is can be estimated, which are a function of the gap and the rate of ICT adoption in each sector.

[7] In percentage terms.

In Table 5 we present the results from incorporating the impact of ICT adoption. The inclusion of the ICT variable is very significant and positive, indicating that the direct effect of greater adoption of ICT has a positive influence on Euro area TFP growth. In the presence of solely the direct effect, the rate of convergence remains positive and significant at 1.5 per cent. The results of equation (22) can be found in the second column of Table 5. In this case both the direct and indirect effect are estimated. As can be seen from the Table, the coefficient on the ICT variable remains positive and significant. There are now separate rates of convergence for each sector of the economy - the rate of convergence in each sector ranges from a high of approximately 2.6 per cent per annum in the agricultural sector to a low of 1.2 per cent per annum in the case of manufacturing.

It is interesting to contrast this positive and significant role observed for ICT adoption and European TFP growth rates with similiar type studies by van Ark and Inklaar (2005) and Stiroh (2002). Both report negative[8] estimates of ICT on TFP growth. The main difference, of course, between our model and these earlier approaches, is the explicit assumption of the United States as a growth leader in relation to the Euro area.

5.2. Structural Change

The whole-economy trends in TFP growth rates evident in Figure 2 suggest that, over the sample period 1980 - 2005, a change took place in the respective performances of the Euro area and US economies. It would appear that Euro area TFP rates were significantly larger than US rates throughout the 1980s and into the early 1990s. However, from the late 1990s onwards, the United States has experienced consistently higher growth rates. We investigate the implications of these changes in the context of our modelling framework by examining for structural changes in the model over the sample period. To do this we follow Baltagi and Griffin (2006) and Bai and Perron (1998) and re-specify (20) to include the additional dummy variables D_{t-T}, which allow for the possibility of multiple structural breaks

$$\Delta \log TFP_{it}^{ea} = \lambda\left(GAP_{i,t-1}\right) + \sum_{i=1}^{26} \beta_i \left(DUMMY_i\right) + \sum_{j=1}^{14} \theta_j \sum_{t=1990}^{2004} D_{t-T} + \epsilon_{it} \qquad (23)$$

These dummies span the period t when the break is first hypothesised to occur until T, the end of the sample. Fourteen structural breaks from 1990 - T until 2004 - T are allowed for. This results in 14 additional variables. We test down and include only structural breaks, which are

[8] but insignificant

significant, in our final estimation. This results in just one significant dummy for the period 2001 - 2005. The results are in Table 6.[9] From the table, it can be seen that the θ coefficient is negative, thereby, suggesting a significant decline in the growth rate of Euro area TFP over the period 2001 - 2005.

What implications does this have for our convergence λ estimate? One simple way to address this is to conduct a series of recursive estimates - we start by estimating the original model (20) over the period 1980 - 1992 and continue to add a year until the end of the sample. This gives an indication of how the λ estimate varies through time. The plot of the coefficients is in Figure 3. The rate of convergence appears to have reached a maximum in the mid 1990s and, thereafter, declined to its present rate of approximately 1.5 per cent. This suggests that one reason for such strong growth in Euro area TFP over the period 1980 - 1995 was the ability of the Euro area economy to absorb and adapt new technologies from the United States. However, since this period, this learning capacity has declined somewhat with obvious implications for Euro area growth.

6. Conclusion

The relationship between key economic indicators of the United States and the Euro area is an area of continuing interest. Many studies have examined the relative performance of these key economic regions, however, few studies have modelled an explicit long-run relationship between both areas.

In our modelling framework, we assume that the United States acts as a growth leader for the Euro area. We examine this through a TFP channel and assume that the greater the difference in levels between TFP in the United States and Europe, the greater the growth rate of European TFP. We also incorporate the impact of greater ICT adoption in this process. Our model estimates yield plausible and significant results suggesting, indeed, the transmission of total factor productivity spillovers from the United States to the Euro area and, also, the importance of this channel in influencing European growth. We also examine for, and detect, the presence of structural breaks in European TFP rates during the sample period.

Recent studies, such as McQuinn and Whelan (2008), have outlined a relative gloomy outlook for future European economic performance, suggesting, in particular, the potential for a further worsening of the Euro area's productivity performance. This is because recent growth has relied heavily on increases in capital and labour inputs, with very little improvement in Total Factor Productivity. Therefore, the results of this study highlight the need for Euro area policy-makers to

[9] Full regression results are available, upon request, from the authors.

focus their energies on policies likely to improve the ability of the Euro area to absorb and learn from technologies advanced in the United States. Policies, which improve the flexibility of the European economy and enable it to adapt in this fashion will be a crucial elemant in re-stimulating future European growth.

References

[1] Acemoglu, Daron, (forthcoming 2008). "Introduction to modern economic growth,"

[2] Bai J. and Pierre Perron (1998). "Estimating and testing linear models with multiple structural changes," *Econometrica*, Econometric Society, vol. 66(1), pp. 47-78, January.

[3] Baltagi, B. and J.M. Griffin (2006). "Swedish liquor consumption: New evidence on taste change," Chapter 7 in *Panel Data Econometrics: Theoretical Contributions and Empirical Applications*, Badi H. Baltagi, editor, Elsevier Science, Amsterdam, (2006), pp. 167-192.

[4] Bernard, B. Andrew and Charles I. Jones (1996). "Technology and convergence" *The Economic Journal*, Vol. 106, pp 1037-1044

[5] Blanchard, Olivier (2004). "The economic future of Europe," *Journal of Economic Perspectives*, 18, Issue 4, 3-26.

[6] Dées Stéphane di Mauro Filippo Pesaran and Arthur Saint-Guilhem (2009). "The role of the United States in the global economy and its evolution over time" ECB Working Paper Series No 1034, March.

[7] Dew-Becker, Ian and Robert J. Gordon (2006). "The slowdown in European productivity growth: A Tale of Tigers, Tortoises and textbook labor economics" working paper, NBER and Northwestern University.

[8] Giannone, Domenico Lenza, Michele and Lucrezia Reichlin (2008). "Business cycles in the Euro area" In Alberto Alesinar and Francesco Giavazzi, editors, *Europe and the Euro*, forthcoming.

[9] Inklaar, Robert, Timmer, Marcel, and van Ark, Bart, (2006). Mind the gap! International comparisons of productivity in services and goods production," GGDC Research Memorandum GD-89, Groningen Growth and Development Centre, University of Groningen.

[10] International Monetary Fund (2007)."Decoupling the train? Spillovers and cycles in the global economy", World Economic Outlook, Chapter 4, 121-160.

[11] Jorgenson, D.W. and Z. Griliches (1967). "The explanation of productivity change". *Review of Economics and Statistics* Vol. 34, pp 249-283.

[12] Jorgenson, D.W., F.M. Gollop and B.M. Fraumeni (1987), Productivity and U.S. economic growth, Harvard Economic Studies: Cambridge, MA.

[13] Jorgenson, Dale W., Mun S. Ho, and Kevin J. Stiroh. (2005) Information technology and the American growth resurgence, MIT: Cambridge.

[14] Jorgenson, Dale W., Mun S. Ho, and Kevin J. Stiroh (2008). “A retrospective look at the U.S. productivity growth resurgence.” Journal of Economic Perspectives, 22(1): 324.

[15] Jorgenson, Dale W. and Kevin J. Stiroh. (2000) Raising the speed limit: U.S. economic growth in the information age. Brookings Papers on Economic Activity, 125-211.

[16] McGuinness, Anne (2007). “Institutions and total factor productivity convergence”, Central Bank and Financial Services Authority of Ireland Research Technical Paper 9/RT/07.

[17] McQuinn, Kieran and Karl Whelan (2008). “Prospects for growth in the Euro area”, *CESifo Economic Studies*, Vol 54(4), pp.642-680.

[18] McQuinn, Kieran and Karl Whelan (2007a). “Solow (1956) as a Model of Cross-Country Growth Dynamics” *Oxford Review of Economic Policy*, Vol. 23, pp 45-62

[19] McQuinn, Kieran and Karl Whelan (2007b). “Conditional convergence and the dynamics of capital-output ratio” *Journal of Economic Growth*, Vol. 12, pp 159-184

[20] Nelson, Richard R. and Edmund S. Phelps (1966). “Investment in human capital, technological diffusion, and economic growth” *American Economic Review*, Vol. 56, pp 69-75

[21] Oliner, Steven D. and Daniel E. Sichel (2000). “The resurgence of growth in the l1990s: Is information technology the story”, *Journal of Economic Perspectives*, vol. 14, no.4, p. 3-22, Fall.

[22] Oliner, Steven D. and Daniel E. Sichel (2002). “Information technology and productivity: Where are we now and where are we going?” Federal Reserve Bank of Atlanta Economic Review, vol. 87 (Summer 2002), pp. 15-44.

[23] Sapir, Andre et al (2004). *An Agenda for a Growing Europe: The Sapir Report*, Oxford University Press.

[24] Timmer Marcel P., O’Mahony Mary and Bart van Ark (2007). “EU KLEMS growth and productivity accounts: An overview”, *International Productivity Monitor*, Vol. 14, pp 71 - 85.

[25] Solow, M. Robert (1956) “A contribution to the theory of economic growth,” *The Quarterly Journal Of Economics*, Vol. 70, pp 65-94

[26] van Ark Bart, and Robert Inklaar (2005). Catching up or getting stuck? Europe's trouble to exploit ICT's productivity potential, GGDC Research Memorandum GD-79, Groningen Growth and Development Centre, University of Groningnen.

[27] van Ark Bart, O'Mahony Mary and Marcel P. Timmer (2008). "The productivity gap between Europe and the United States: Trends and causes", *Journal of Economic Perspectives*, Vol. 22, No. 1 pp 25 - 44.

Table 1: Percentage Contribution of Euro Area and US NACE Sectors to Overall Employment and Gross Output: Sample Averages 1980 - 2005

NACE		Euro Area		US	
Category	Code	Output	Employment	Output	Employment
Agriculture	A	2.9	3.6	3.2	2.5
Mining	B	1.1	0.7	2.5	0.9
Food and Beverages	C	5.2	3.8	4.6	2.2
Textiles	D	3.0	3.6	1.6	2.2
Wood	E	0.7	1.0	1.0	0.9
Pulp	F	2.6	2.6	3.2	2.7
Petroleum	G	1.3	0.2	2.2	0.2
Chemicals	H	4.1	2.1	3.4	1.3
Rubber	I	1.7	1.4	1.2	1.1
Non-Metallic material	J	1.5	1.6	0.8	0.7
Basic Metals	K	5.5	5.0	3.6	2.7
Machinery	L	3.8	4.0	2.5	2.2
Electrical equipment	M	3.7	3.9	4.8	3.7
Transport equipment	N	4.4	3.3	4.5	2.3
Manufacturing	O	1.5	1.8	1.0	1.1
Electricity	P	3.4	1.4	3.3	1.1
Construction	Q	9.2	10.7	7.6	7.0
Repair of Motor Vehicles	R	2.0	2.9	1.6	2.6
Wholesale trade	S	4.3	6.2	6.0	7.9
Retail trade	T	4.3	9.8	4.8	15.9
Hotels	U	2.6	4.6	3.1	10.5
Transport	V	6.5	6.4	4.3	4.6
Post and Telecoms	W	2.3	2.7	2.8	1.8
Financial Intermediation	X	5.9	4.7	7.4	6.9
Real Estate	Y	8.1	1.0	9.4	1.7
Renting	Z	8.6	11.0	9.5	13.1

Table 2: Summary of Average Annual Sectoral TFP Growth Rates

NACE		1980 - 2005		1995 - 2005	
Category	Code	Euro Area	US	Euro Area	US
Agriculture	A	2.0	2.0	1.1	1.0
Mining	B	-0.2	-0.6	-0.4	-1.2
Food and Beverages	C	0.0	0.4	-0.1	0.6
Textiles	D	0.4	0.9	-0.1	1.6
Wood	E	0.7	0.4	0.6	0.3
Pulp	F	0.2	0.2	0.1	0.7
Petroleum	G	0.3	0.2	0.5	-2.1
Chemicals	H	1.0	0.4	0.6	0.2
Rubber	I	0.9	1.4	0.8	1.2
Non-Metallic material	J	0.6	1.0	0.3	1.1
Basic Metals	K	0.4	0.7	0.2	0.9
Machinery	L	0.5	0.4	0.5	1.5
Electrical equipment	M	1.3	4.5	1.2	6.0
Transport equipment	N	0.5	0.6	0.5	1.3
Manufacturing	O	0.0	0.9	0.3	1.7
Electricity	P	0.7	-0.4	1.3	0.8
Construction	Q	0.1	-0.7	-0.4	-1.0
Repair of Motor Vehicles	R	0.3	1.3	-0.3	2.2
Wholesale trade	S	0.5	1.0	0.7	0.2
Retail trade	T	0.8	1.2	0.2	2.3
Hotels	U	-0.6	-0.4	-0.6	0.1
Transport	V	0.7	0.5	0.3	0.3
Post and Telecoms	W	2.1	0.6	2.9	1.4
Financial Intermediation	X	0.2	0.7	0.2	1.0
Real Estate	Y	0.6	0.3	0.5	0.6
Renting	Z	-1.0	-0.6	-1.2	-0.5

Table 3: General Model Convergence Estimates

Estimator	λ
OLS	0.028
	(0.006)
Fixed Effects	0.012
	(0.006)
P-Value of Fixed Effects	(0.000)
Random Effects	0.015
	(0.006)

Note: N = 650, the sample covers 26 sectors of the Euro area and US economies over the 25 year period 1981-2005. Standard errors are in parenthesis.

Table 4: Summary of Euro Area ICT Capital Services to Output Growth Annual Average 1980 - 2005

NACE Category	Code	Mean	Standard Deviation
Agriculture	A	0.6	0.7
Mining	B	6.6	4.4
Food and Beverages	C	4.3	1.5
Textiles	D	4.5	3.4
Wood	E	3.5	2.9
Pulp	F	15.3	8.3
Petroleum	G	2.5	4.4
Chemicals	H	7.3	4.3
Rubber	I	7.1	3.6
Non-Metallic material	J	6.3	2.8
Basic Metals	K	4.8	2.9
Machinery	L	7.5	4.5
Electrical equipment	M	16.2	12.2
Transport equipment	N	6.3	3.0
Manufacturing	O	5.6	3.4
Electricity	P	10.8	6.6
Construction	Q	4.5	1.7
Repair of Motor Vehicles	R	13.0	5.2
Wholesale trade	S	25.8	10.6
Retail trade	T	5.3	5.2
Hotels	U	2.4	2.5
Transport	V	16.7	7.4
Post and Telecoms	W	66.9	29.2
Financial Intermediation	X	59.0	18.0
Real Estate	Y	5.0	2.4
Renting	Z	54.9	22.6

Table 5: ICT Model Convergence Estimates (λ)

Coefficient	Direct	Both Effects			
λ	0.015				
	(0.006)				
α			0.018		
			(0.004)		
β_1	0.003		0.002		
	(0.001)		(0.001)		
β_2			0.036		
			(0.001)		
		λ_i			
		λ_a	0.026	λ_n	0.015
		λ_b	0.016	λ_o	0.017
		λ_c	0.018	λ_p	0.018
		λ_d	0.012	λ_q	0.017
		λ_e	0.020	λ_r	0.018
		λ_f	0.018	λ_s	0.018
		λ_g	0.017	λ_t	0.023
		λ_h	0.016	λ_u	0.021
		λ_i	0.017	λ_v	0.018
		λ_j	0.018	λ_w	0.015
		λ_k	0.018	λ_x	0.016
		λ_l	0.016	λ_y	0.016
		λ_m	0.014	λ_z	0.017

Note: N = 650, the sample covers 26 sectors of the Euro area and US economies over the 25 year period 1981-2005. Standard errors are in parenthesis.

Table 6: Structural Change Estimates - Fixed Effects Model

Parameter	Variable	Estimate
λ	$GAP_{i,t-1}$	0.015
		(0.006)
θ	$D_{2001-2005}$	-0.004
		(0.001)

Note: N = 650, the sample covers 26 sectors of the Euro area and US economies over the 25 year period 1981-2005. Standard errors are in parenthesis.

Figure 1: Euro Area and US Labour Productivity Growth

Three-Year Averages, Annual Rate

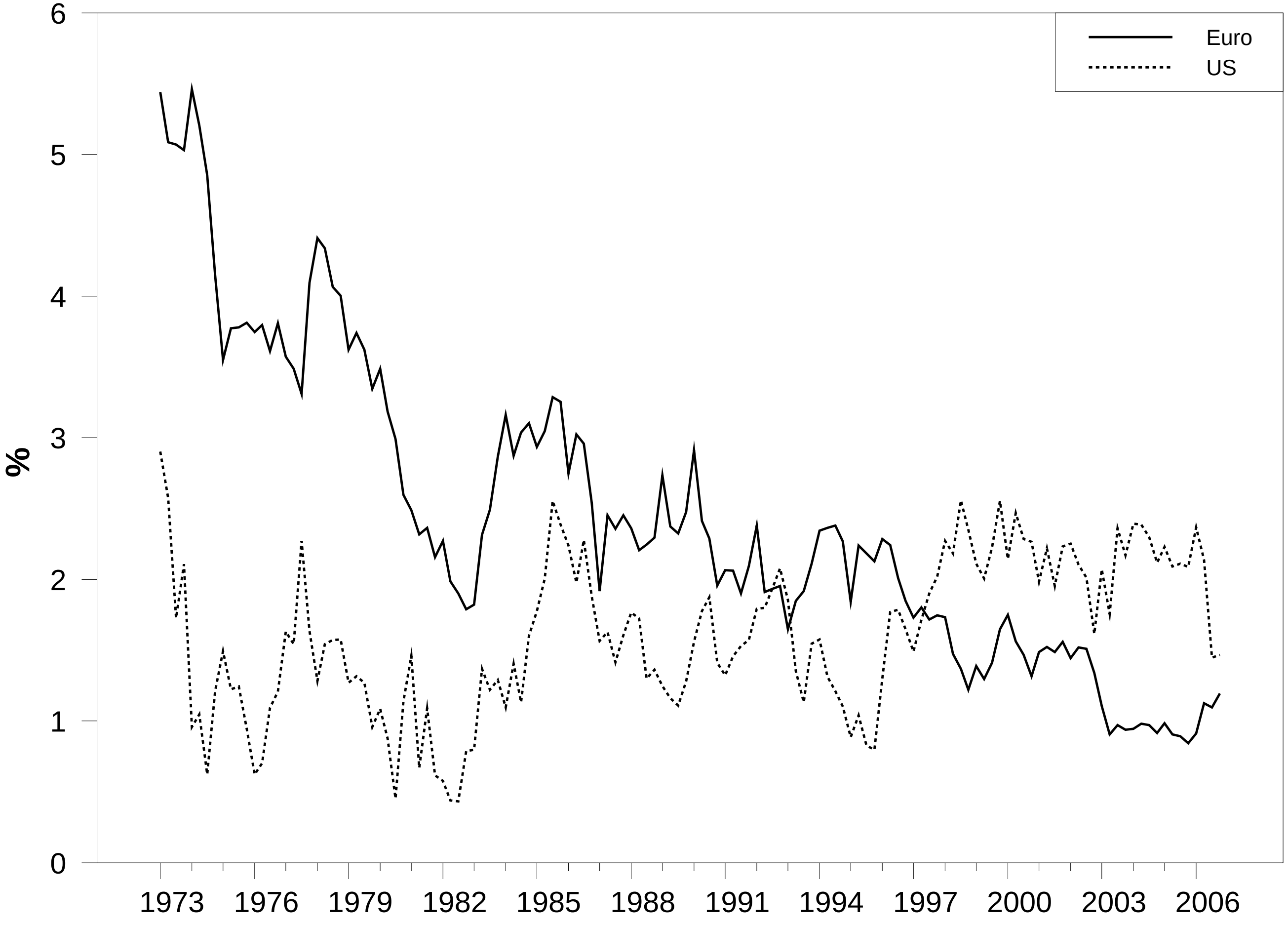
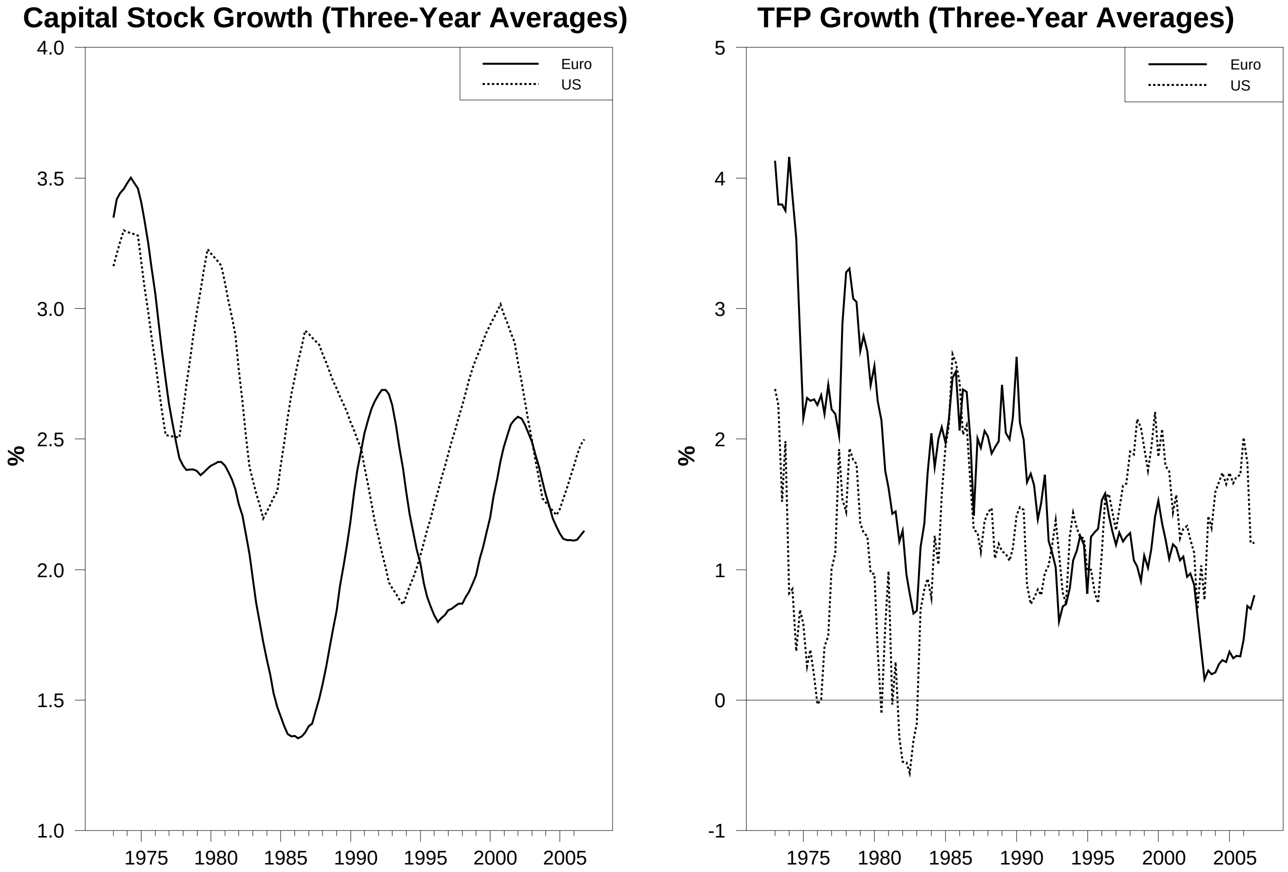


Figure 2: Aggregate Euro Area and US TFP and Capital Growth



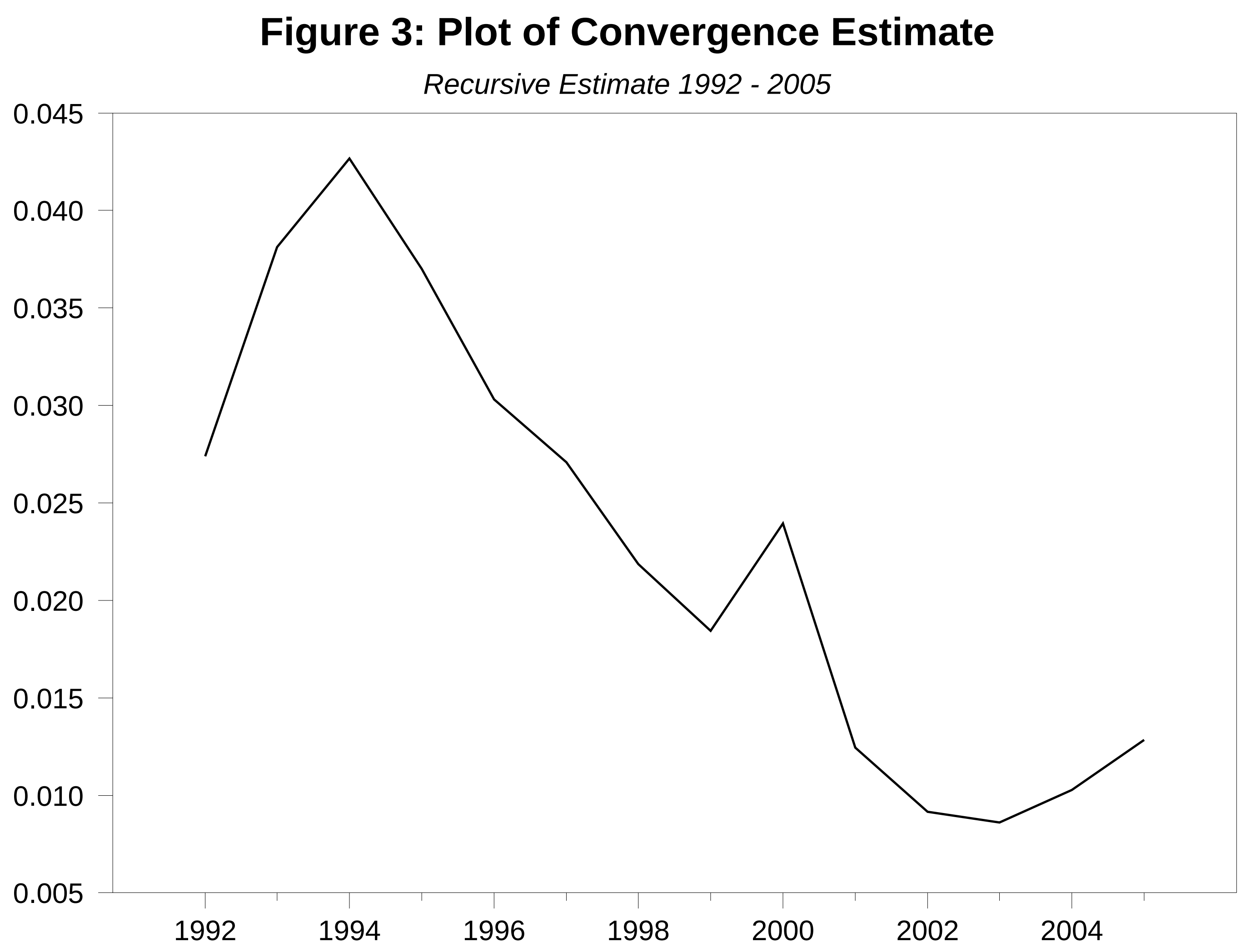


Figure 3: Plot of Convergence Estimate
Recursive Estimate 1992 - 2005
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
1992
1994
1996
1998
2000
2002
2004