PRODUCTION FUNCTION APPROACH TO CALCULATING POTENTIAL GROWTH AND OUTPUT GAPS

- ESTIMATES FOR THE EU AND THE US -

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Introduction

Any meaningful analysis of cyclical developments, of medium term growth prospects or of the stance of fiscal and monetary policies are all predicated on either an implicit or explicit assumption concerning the rate of potential output growth. Such pervasive usage in the policy arena is hardly surprising since potential output constitutes the best composite indicator of the aggregate supply side capacity of an economy and of its scope for sustainable, non-inflationary, growth. Given the importance of the concept, it is hardly surprising that the measurement of potential output is the subject of contentious and sustained research interest. The European Commission has recently moved from HP filtered trend estimates to a production function approach. The main motivation for making this change was not so much dissatisfaction with properties of the HP filter. Indeed, the within sample estimates generated by both approaches are rather similar. The switch was mainly motivated by the following considerations. With an economics based method, one gains the possibility of examining the underlying economic factors which are driving any observed changes in the potential output indicator and consequently the opportunity of establishing a meaningful link between policy reform measures with actual outcomes. To have more economic information is useful for discussions of stability and convergence programs with member states. An additional advantage of using an economic estimation method is that it is capable of highlighting the close relationship between the potential output and NAIRU concepts, given that the production function (PF) approach to calculating potential output requires estimates to be provided of "normal" or equilibrium rates of unemployment. At a wider level, another advantage is the possibility of making forecasts, or at least building scenarios, of possible future growth prospects by making explicit assumptions on the future evolution of demographic, institutional and technological trends. This of course requires to look more deeply into the determinants of the input variables entering the production function.

This paper makes an attempt to use the framework to analyse potential growth and its determinants for the EU and the US. The 1990's have witnessed some important shifts in the underlying growth performances of the EU and US economies, with a significant gap opening up in terms of GDP, and more importantly, GDP per capita, growth rates. From a situation over the period 1980-1995 when EU and US living standards were growing at roughly an equivalent rate, the second half of the 1990's has seen the emergence of a significant growth gap in favour of the US. These growth divergences have been the subject of intense research efforts in recent years[1], with policy makers keen to decipher the reasons for their own respective outturns and to further refine the "magic formula" for boosting their long run growth performances[2]. Of course, the production function framework is a descriptive tool which essentially allows for growth accounting by providing informtion about the contribution of employment, capital formation and technical progress but it does not explain their more fundamental economic determinants. This paper therefore makes an attempt to go beyond the production function framework as commonly used by the Commission and address some growth issues which appear to be both quantitatively important and relevant in a European context. Potential candidates for an explanation of growth differentials are differences in the level of regulation; in the structure of financial markets; in the degree of product market integration; in the size of knowledge investment; and the ageing of the labour force.

[1] See, amongst others, Scarpetta et al (2000); Bassanini et al (2002); Colecchia and Schreyer (2002); and OECD (2003);.

[2] See, for example, Temple (1999) and Ahn and Hemmings (2000) for surveys of the literature on economic growth.

- **LEVEL OF REGULATION** : In recent studies both the OECD (2002, 2003) and the IMF (2002) have stressed that levels of regulation are potentially crucial driving forces for efficiency gains. Given the EU's relatively weak performance on a range of different measures of regulation, the IMF study concluded that deregulating the EU economy to US levels could increase output by nearly 7% and productivity by 3% in the longer term (see Bayoumi et al.(2003)). The OECD study pointed to deleterious effects in terms of physical investment rates and to a particularly negative impact from regulation in a panel of OECD service industries.

- **STRUCTURE OF FINANCIAL MARKETS** : In academic discussions a lot of attention has been given to the link between financial markets and growth (see, for example, Levine (1998)). Special emphasis is devoted to the question of the relative effectiveness of bank based or equity based financial systems. Could stockmarkets, for example, have special advantages in the commercial assessment of innovations or as vehicles for fostering international portfolio and direct investment ? The question of financial market efficiency is also a central concern for the EU authorities, with the Financial Services Action Plan (FSAP) summarising a large set of policy initiatives aimed at improving the functioning of the EU's financial architecture.

- **PRODUCT MARKET INTEGRATION** : Related to the creation of the single market and EMU, the relationship between trade integration and productivity growth becomes relevant. Here again recent studies (see, for example Frankel and Rose (2000) and Alesina et al. (2002)) suggest significant gains from further integration. In this context, the initial benefits from increased trade openness amongst Euro area Member States are already beginning to emerge in the post-EMU environment.

- **KNOWLEDGE INVESTMENT** : With the striking impact of ICT, there has been considerable interest in analysing the effects of investments in knowledge and human capital formation. With Europe lagging behind not only in terms of ICT penetration rates but also with regard to other indicators of knowledge production (such as R&D investments and the share of high tech industries) the creation of knowledge capital has emerged as a central policy concern. Both the Lisbon process and the more recent EU growth initiative are concrete examples of ongoing policy programmes aimed at boosting the pace of innovation.

- **AGEING** : An unavoidable consequence of declining birth rates is an ageing of the labour force. While so far there has been little research carried out on the possible consequences of ageing for productivity, nevertheless there is a widespread suspicion that an older labour force will be less adept in creating and adopting new technologies. Given the magnitude of the demographic transition in Europe, it seems appropriate to explore the possible consequences for productivity of this "greying" phenomenon.

In terms of content, the paper is laid out as follows. Section 1 provides an overview of the PF methodology in conceptual terms, including a description of the Kalman Filter inspired NAIRU estimation method. Section 2 goes on to present the results from applying the methodology to the EU15, the Euro Zone as well as the US. The final section of the paper goes beyond pure growth accounting and tries to assess empirically by using cross section and time series information from 21 OECD countries over the period 1975 to 2000 the impact of the more fundamental growth determinants mentioned in the introduction on investment and TFP.

1. Measurement of Potential Output

The production function approach essentially uses the concept of a neoclassical production function to determine the supply potential of an economy. Trend growth is determined by the average investment rate, trend growth of total factor productivity the trend in labour force participation and the equilibrium level of unemployment. The output gap is simply calculated as a residual between actual and trend GDP.

In more formal terms, with a production function, GDP (Y) is represented by a combination of factor inputs - labour (L) and the capital stock (K) -, corrected for the degree of excess capacity (U_L, U_K) and adjusted for the level of efficiency of labour (TFP). In many empirical applications, a Cobb Douglas specification is chosen for the functional form. This greatly simplifies estimation and exposition. Thus potential GDP is given by:

$$Y = (U_L L \; TFP)^{\alpha} (U_K K)^{1-\alpha} \quad (1)$$

Various assumptions enter this specification of the production function, the most important ones are the assumption of constant returns to scale and a factor price elasticity which is equal to one. The main advantage of this assumption is simplicity. However these assumptions seem broadly consistent with empirical evidence at the macro level. The unit elasticity assumption is consistent with the relative constancy of nominal factor shares. Also, there is little empirical evidence of substantial increasing/decreasing returns to scale (see, e.g. Burnside et al. (1995) for econometric evidence).

The output elasticities of labour and capital are represented by α and $(1-\alpha)$ respectively. Under the assumption of constant returns to scale and perfect competition, these elasticities can be estimated from the wage share. The same Cobb-Douglas specification is assumed for all countries, with the mean wage share for the EU15 over the period 1960-2000 being used as the estimate for the output elasticity of labour. While the output elasticity for labour may deviate somewhat from the imposed mean coefficient in the case of individual Member States, such differences should not seriously bias the potential output results.

To summarise therefore, in moving from actual to potential output it is necessary to define clearly what one means by potential factor use and by the trend (i.e. normal) level of efficiency of factor inputs.

- **CAPITAL** : With respect to capital this task of defining potential factor use is straightforward since the maximum potential output contribution of capital is given by the full utilisation of the existing capital stock in an economy. Since the capital stock is an indicator of overall capacity there is no justification to smooth this series. In addition, the unsmoothed series is relatively stable for the EU and the US since although investment is very volatile the contribution of capital to growth is quite stable since net investment in any given year is only a tiny fraction of the capital stock figures. In terms of the measurement of the capital stock, the perpetual inventory method is used which makes an initial assumption regarding the size of the capital / output ratio.
- **LABOUR** : The definition of the maximum potential output contribution of employment is more involved since it is more difficult to assess the "normal" degree of utilisation of this factor of production. Since there is no strict physical limit, the definition that we therefore apply is the level of employment consistent with stable, non accelerating, (wage) inflation (NAWRU). Potential employment is generated from a smoothed labour force series which

is generated by applying a HP filtered participation rate to the working age population figures. With the smoothed participation rate leading to a less volatile labour force series, potential employment is then set equal to the labour force minus the NAIRU estimates for the respective countries. One of the big advantages of this approach is that it generates a potential employment series which is relatively stable whilst at the same time also providing for year-to-year changes to the series to be closely linked to long run demographic and labour market developments in areas such as the working age population, trend participation rates and structural unemployment.

- **TREND EFFICIENCY** : Within the production function framework, potential output refers to the level of output which can be produced with a "normal" level of efficiency of factor inputs, with this trend efficiency level being measured as the HP filtered Solow Residual.

Normalising the full utilisation of factor inputs to one, potential output can be represented as follows :

$$Y_t^P = (L_t^P TFP_t^T)^\alpha K_t^{1-\alpha}. \quad (2)$$

Five factors influence potential output in the production function approach these are

- *POPW - (Population of Working Age)*
- *parts - (Smoothed Participation Rate)*
- *nairu - (Structural Unemployment)*
- *iy - (Investment to Potential GDP Ratio)*
- *TFP - (Trend Solow Residual)*

Population of working age, trend participation and the NAIRU determine potential employment

$$L_t^P = POPW_t * parts_t * (1 - nairu_t) \quad (3)$$

The investment to output ratio determines capital accumulation

$$I_t = iy_t Y_t^P \quad (4)$$

$$K_t = I_t + (1 - dep)K_{t-1} \quad (5)$$

In standard use of the production function methodology no structural equations are formulated for the investment rate, the particpation rate and TFP. They are simply modelled as time series processes. Finally the population of working age is taken from EUROSTAT population projections.

Some economic theory is used for modelling the NAIRU. The actual unemployment rate is decomposed into a structural and a cyclical component

$$u_t = nairu_t + u_t^C. \quad (6)$$

and the Kalman Filter is used to estimate these two components subject to the following assumptions. Concerning the cyclical component of unemployment it is assumed that it, is systematically related to the change in wage inflation ($\Delta^2 w_t$), changes in the growth rate of labour productivity ($\Delta^2(y_t - l_t)$), the wage share ($\Delta^2 ws_t$)and the terms of trade ($\Delta^2 tot_t$) as formuilated by the following Phillips curve relationship

$$\Delta^2 w_t = \beta^y \Delta^2 (y_t - l_t) + \beta^{ws} \Delta^2 ws_t + \beta^{tot} \Delta^2 tot_t - \beta^u u_t^C + v_t^w \qquad (7)$$

Since no further information on the NAIRU is available, a flexible enough stochastic process is chosen to model this series. We consider a second order random walk (see Harvey, 1989, chapter 2) that is specified according to:

$$(1 - L) nairu_t = \lambda_{t-1} + a_t^N \qquad (8)$$

where L is the lag operator and the slope λ_t is itself a random walk such that:

$$(1 - \mathrm{L})\lambda_t = \mathrm{a}_t^\lambda \qquad (9)$$

The random variables a_t^N and a_t^λ are orthogonal Gaussian white noises with variances $\mathrm{V_N}$ and V_λ respectively. Notice that $\mathrm{V}_\lambda = 0$ yields a random walk plus drift process while $\mathrm{V_N} = 0$ implies an I(2) model. The short-term movements are described as a stationary autoregressive process of order 2:

$$(1 - \phi_1 \mathrm{L} - \phi_2 \mathrm{L}^2)\mathrm{u}_t^\mathrm{C} = \mathrm{a}_t^\mathrm{C} \qquad (10)$$

where a_t^C is a Gaussian white noise with variance $\mathrm{V_C}$ orthogonal to a_t^N and a_t^λ.

Table 1: Estimation results (1970-2002)*

Unemployment equation

$$u_t = u_t^* + u_t^C$$

$$(1-\phi_1 L - \phi_2 L^2) u_t^C = a_t^C \qquad (1-L)^2 u_t^* = a_t^\lambda$$

	EU12	US
ϕ_1	1.76 (.11)	1.04 (.21)
ϕ_2	-.86 (.11)	-.45 (.18)
Q(4)	2.15 [.71]	3.94 [.41]

Phillips curve

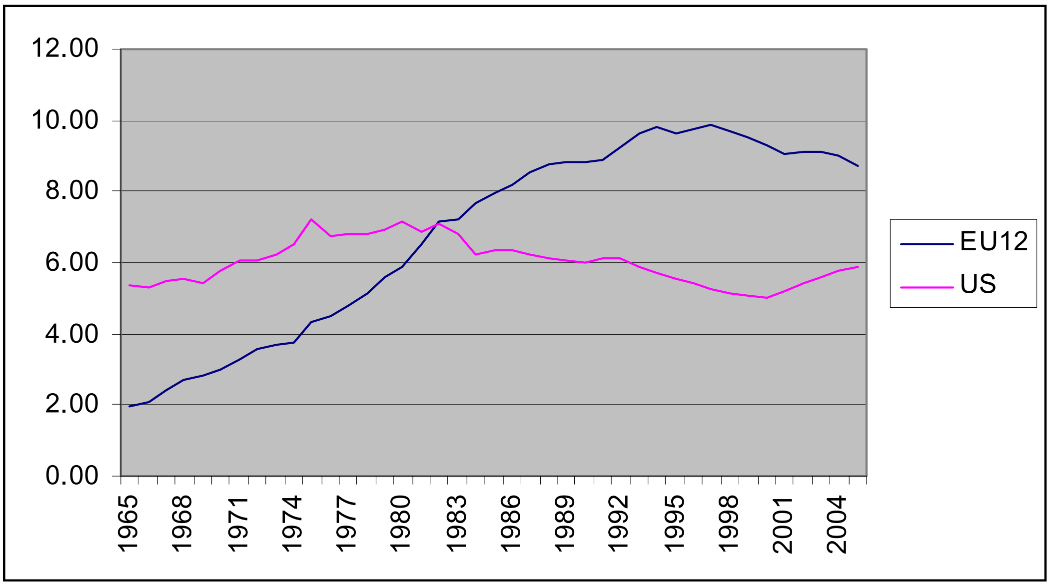
$$\Delta^2 w_t = c_w + \beta^y \Delta^2 (y_t - l_t) + \beta^{tot} \Delta^2 tot_t + \beta^{ws} \Delta^2 ws_t - \beta^u (u_t - u_t^*) + a_t^w$$

	EU12	US
β^y	.85 (.25)	.69 (.13)
β^{ws}	1.13 (.24)	.76 (.15)
β^{tot}	.31 (.22)	.97 (.24)
β^u	.53 (.24)	.58 (.19)
R^2	.49	.58
Q(4)	1.19 [.88]	2.41 [.66]
-2×Log-likelihood	-187.45	-151.79

Notes: (*) standard errors are displayed between parentheses and p-values in brackets.Q(4) represents the Ljung-Box statistics computed on the first four autocorrelations. (**) the parameter value is imposed.

The estimation results show some surprising similarities between the Euro Zone and the US labour market. The elasticity of wages w. r. t. the unemployment rate is similar between Europe and the US, the same is true for the response of wages to productivity. Nevertheless this should not be interpreted as if the EU and US labour market operate in a similar fashion. As shown by the following graphs the structural unemployment rates behave very differently. The US rate is fairly stable while the European rate shows large permanent fluctuations. This suggests that either permanent shocks (e. g. skill biased technical progress) have an effect on unemployment or temporary shocks generate permanent unemployment effects (hysteresis effects).

Graph 1: EU12 and US NAIRU



2. Potential Output and Output Gap Estimates – EU and US

This sub-section presents estimates on the growth rate of potential output in the EU15, Euro Zone and the US based on the variant of the production function approach presented in Section 1. In addition to the potential growth estimates, the tables and graphs presented also include actual growth rates and the associated output gaps[3], as well as the decomposition of potential growth into its respective labour, capital and TFP components, for each year of the period 1981-2005. In addition, in order to provide an insight into the key driving forces behind the figures, the series for the important determining variables which lie behind these estimates are also provided, namely trend total factor productivity, Kalman Filter derived NAIRU's, the population of working age, participation rate changes and finally the investment to GDP ratio. All the estimates have been calculated on the basis of clear assumptions regarding the latter exogenous variables and using the following data sources and inputs : for the historical period the series have been taken from ECFIN's AMECO databank, with the Commission services final Autumn 2003 forecasts for the years 2003-2005 being used. These latter forecasts have been produced by ECFIN's country desk officers.

When comparing the growth contributions of labour, capital and TFP in EU15 over the last two decades compared with the experience of the US over the same period, there are striking differences. As shown in the accompanying tables, the US boom in the 1990's is clearly driven by capital formation and an acceleration of TFP, with the annual average growth rate increasing from 2 ¾% over the period 1991-1995 to 3 ½% for the period 1996-2000 and staying at around 3% in the medium term. The figures for Europe are clearly less impressive in terms of the overall growth rate acceleration and the compositional changes are also different to that of the US. Potential growth was roughly constant in EU15 at a rate of 2.2% which is virtually

[3] It should be noted that the ECFIN production function approach is estimated to ensure that the output gaps produced are symmetric i.e. the mean of the output gap over the sample period is zero. In addition, the data for EU15 and the Euro Zone shown in this paper differ slightly from those of ECFIN's AMECO database since for illustrative purposes the production function methodology is applied directly to the aggregated AMECO series.

identical to the outturn achieved for 1991-1995. In terms of the composition of potential growth, EU15 witnessed an improvement in the contribution of labour from .3 to .6% which was compensated by a decline in the contribution from TFP. This process is projected to continue until 2005. This happens despite a decline in the growth rate of working age population and is due to both an increase in the participation rate as well as a decline in the NAIRU which peaked in 1996 at 8.4% and is now at 7.2%

EU15

	Output Gaps (% of Potential Output)		Potential Growth (annual % change)		Contributions to Potential Growth*			Determinants of Labour Potential and Capital Accumulation			
	HP Filter	PF method	HP Trend Growth	PF Potential Growth	Labour Contribution	Capital Accumulation Contribution	TFP Contribution	Growth of Working Age Population (annual % change)	Trend Participation Rate (% of Working Age Population)	NAIRU (% of Labour Force)	Investment Ratio (% of Potential Output)
1981	-0.7	-1.3	2.1	2.2	0.3	0.8	1.1	1.1	66.2	6.3	19.8
1982	-1.8	-2.5	2.0	2.2	0.4	0.7	1.1	1.1	66.2	6.7	19.2
1983	-2.1	-3.0	2.1	2.3	0.5	0.7	1.1	1.0	66.2	7.0	18.8
1984	-1.8	-2.8	2.2	2.2	0.4	0.7	1.1	0.9	66.2	7.3	18.6
1985	-1.6	-2.5	2.3	2.2	0.3	0.7	1.2	0.5	66.3	7.4	18.7
1986	-1.2	-2.0	2.4	2.2	0.3	0.7	1.2	0.4	66.4	7.5	19.1
1987	-0.8	-1.4	2.4	2.3	0.3	0.7	1.2	0.4	66.5	7.6	19.7
1988	1.0	0.3	2.5	2.5	0.4	0.9	1.2	0.4	66.6	7.7	20.9
1989	2.1	1.2	2.5	2.6	0.4	0.9	1.2	0.5	66.8	7.7	21.8
1990	2.7	1.4	2.4	2.8	0.6	1.0	1.2	0.6	67.0	7.7	21.9
1991	2.1	0.8	2.3	2.4	0.3	0.9	1.2	0.5	67.1	7.9	21.3
1992	1.0	-0.3	2.3	2.3	0.3	0.8	1.1	0.4	67.3	8.0	20.8
1993	-1.5	-2.5	2.2	1.9	0.2	0.6	1.1	0.3	67.4	8.3	19.2
1994	-0.9	-1.8	2.2	2.1	0.3	0.7	1.1	0.3	67.6	8.3	19.3
1995	-0.6	-1.4	2.2	2.1	0.4	0.7	1.0	0.2	67.8	8.3	19.5
1996	-1.1	-1.8	2.2	2.0	0.4	0.7	1.0	0.2	68.1	8.4	19.6
1997	-0.7	-1.4	2.2	2.2	0.5	0.7	0.9	0.2	68.4	8.3	19.8
1998	0.0	-0.6	2.2	2.2	0.5	0.8	0.9	0.2	68.7	8.1	20.7
1999	0.7	0.0	2.2	2.2	0.6	0.8	0.8	0.2	69.1	8.0	21.3
2000	2.2	1.2	2.1	2.4	0.8	0.8	0.8	0.3	69.5	7.7	21.9
2001	1.8	0.6	2.1	2.3	0.8	0.8	0.7	0.3	69.9	7.4	21.5
2002	0.9	-0.4	2.0	2.1	0.7	0.7	0.7	0.4	70.3	7.3	20.7
2003	-0.3	-1.6	2.0	2.0	0.6	0.6	0.7	0.3	70.6	7.2	20.2
2004	-0.3	-1.7	2.0	2.0	0.6	0.6	0.8	0.3	71.0	7.0	20.4
2005	0.1	-1.4	2.0	2.1	0.6	0.7	0.8	0.3	71.4	6.8	20.6
2006				2.0	0.5	0.7	0.8	0.1	71.8	6.8	20.7
2007				2.0	0.5	0.7	0.9	0.1	72.2	6.7	20.7
2008				2.0	0.4	0.7	0.9	0.0	72.6	6.7	20.7
Periods	Period Averages										
1981-1990	-0.4	-1.2	2.3	2.3	0.4	0.8	1.2	0.7	66.4	7.3	19.9
1991-2000	0.1	-0.8	2.2	2.2	0.4	0.7	1.0	0.3	68.1	8.1	20.3
1991-1995	0.0	-1.0	2.2	2.2	0.3	0.7	1.1	0.3	67.4	8.2	20.0
1996-2000	0.2	-0.5	2.2	2.2	0.6	0.7	0.9	0.2	68.7	8.1	20.7
2001-2005	0.4	-0.9	2.0	2.1	0.7	0.7	0.8	0.3	70.6	7.1	20.7
2005-2007				2.0	0.5	0.7	0.9	0.1	72.2	6.7	20.7

US	Output Gaps (% of Potential Output)		Potential Growth (annual % change)		Contributions to Potential Growth*			Determinants of Labour Potential and Capital Accumulation			
	HP Filter	PF method	HP Trend Growth	PF Potential Growth	Labour Contribution	Capital Accumulation Contribution	TFP Contribution	Growth of Working Age Population (annual % change)	Trend Participation Rate (% of Working Age Population)	NAIRU (% of Labour Force)	Investment Ratio (% of Potential Output)
1981		-1.2		3.0	1.5	0.9	0.7	1.2	70.3	6.9	16.5
1982		-5.5		2.4	1.0	0.7	0.8	1.0	70.8	7.1	14.9
1983		-4.2		2.9	1.3	0.7	0.9	0.9	71.3	6.8	15.4
1984		-0.7		3.5	1.5	1.0	1.0	1.0	71.8	6.2	17.3
1985		0.0		3.1	1.0	1.0	1.1	1.0	72.4	6.3	17.7
1986		0.2		3.2	1.1	1.0	1.1	1.0	72.9	6.3	17.4
1987		0.5		3.0	1.0	0.9	1.1	0.8	73.4	6.3	16.8
1988		1.6		3.0	1.0	0.9	1.1	0.7	73.8	6.1	16.9
1989		2.3		2.8	0.8	0.9	1.1	0.6	74.3	6.1	17.0
1990		1.3		2.8	0.9	0.8	1.1	0.7	74.7	6.0	16.5
1991		-1.6		2.4	0.7	0.6	1.1	0.7	75.0	6.1	15.2
1992		-1.2		2.6	0.8	0.6	1.2	0.9	75.4	6.1	15.7
1993		-1.4		2.9	1.0	0.7	1.2	0.9	75.6	5.9	16.3
1994		-0.4		3.0	0.9	0.8	1.2	0.9	75.9	5.7	17.1
1995		-0.8		3.2	1.0	0.9	1.3	1.0	76.1	5.5	17.5
1996		-0.5		3.3	1.0	1.0	1.3	1.1	76.4	5.4	18.4
1997		0.4		3.5	1.1	1.1	1.3	1.2	76.6	5.2	19.5
1998		1.1		3.6	1.0	1.2	1.3	1.2	76.8	5.1	20.8
1999		1.7		3.6	1.0	1.3	1.3	1.1	77.1	5.1	21.6
2000		1.9		3.5	1.0	1.3	1.2	1.1	77.3	5.0	22.1
2001		-0.7		2.9	0.7	1.0	1.2	0.9	77.6	5.2	20.8
2002		-1.0		2.7	0.6	0.8	1.2	1.0	77.8	5.4	19.8
2003		-0.9		2.8	0.7	0.9	1.2	0.9	78.0	5.6	19.8
2004		0.0		2.9	0.7	0.9	1.2	1.0	78.2	5.7	20.4
2005		0.2		3.1	0.8	1.0	1.2	1.1	78.4	5.9	21.0
2006		0.1		3.0	0.7	1.1	1.2	0.9	78.7	5.9	21.3
2007		0.1		3.0	0.7	1.1	1.1	0.9	78.9	6.0	21.3
2008		0.0		3.0	0.7	1.1	1.1	0.9	79.2	6.0	21.2
Periods	**Period Averages**										
1981-1990		-0.6		3.0	1.1	0.9	1.0	0.9	72.6	6.4	16.6
1991-2000		-0.1		3.2	1.0	1.0	1.2	1.0	76.2	5.5	18.4
1991-1995		-1.1		2.8	0.9	0.7	1.2	0.9	75.6	5.9	16.3
1996-2000		0.9		3.5	1.0	1.2	1.3	1.1	76.8	5.2	20.5
2001-2005		-0.5		2.9	0.7	0.9	1.2	1.0	78.0	5.6	20.4
2005-2007									78.9	6.0	21.2

3. Analysis of Growth Trends

The descriptive analysis between Europe and the US has revealed that major divergences between Europe and the US have emerged with regard to investment and TFP trends, this is worrying since these two factors are crucial for determining labour productivity and therefore the standard of living. This section therefore looks into determinants of both investment rates and TFP growth using some economic theory. From the neoclassical growth model, which underlies the PF approach it is well known that the long run level of productivity is given by the following relationship (see, for example Mankiw et al. (1992))

$$\ln\left(\frac{Y}{L}\right)^{*} = \ln(TFP^{T}(..)) + \frac{\alpha}{1-\alpha}\left(\ln(iy(..)) - \ln(n+\delta+\pi)\right). \qquad (11)$$

Therefore in order to understand productivity we have to understand the determinants generating TFP and the investment rate. This section especially looks how these two factors are influenced by levels of regulation, structure of financial markets, product market integration, knowledge investment and ageing. For the empirical analysis we follow the recent endogenous growth literature and model technical progress as the accumulation of knowledge investment via a so called knowledge production function (see, for example Jones 2003)

$$T\dot{F}P = B\left(\frac{RD}{Y}\right)^{\gamma}\left(EDU^{\kappa} Ydeprat^{\psi}\right)TFP^{\phi}. \qquad (12)$$

Knowledge is increased by the investment activities of households and firms. It is a positive function of the research intensity of firms as expressed by the R&D to GDP ratio (*RD/Y*) and the level of educational attainment (*EDU*) of the labour force. Population ageing has a potential effect if one corrects the average level of education for the time elapsed since the knowledge was created. A simple index appears to be the youth dependency ratio (*Ydeprat*). Under the assumption that human capital depreciates over time one would expect a younger labour force to have a higher capacity to create and absorb new ideas and technical developments.

The variable *B* captures other factors that could potentially affect efficiency. With an eye towards the variables of interest in this study, one can argue that all of them have a potential effect on efficiency. For example, more deregulated markets which are open to foreign competition improve average efficiency by forcing low productivity firms to exit. It is however unclear whether reducing monopoly rents will also increase a firm's incentive to innovate simply because potential rents from the innovation will be lower. Increased competition via more openness may be more successful since increased market size could compensate for higher competition. Market size (i.e. scale effects) can have additional efficiency effects if there are increasing returns to production.

Likewise the structure of financial markets can affect efficiency. It has been argued recently in the literature (e.g. Levine (1991,1997)) that equity based systems may be more efficient in terms of risk sharing, information acquisition and in terms of providing management incentives. However, theoretically a clear dominance of equity based financing cannot be established. For example, Shleifer and Vishny (1986) regard stock markets as having detrimental effects on corporate governance.

For empirical testing we formulate the following simple specification for the efficiency term in the knowledge production function

$$B = REG^{\chi} OPEN^{\phi} POP^{\varphi} FIN^{\kappa} \qquad (13)$$

where efficiency becomes a function of measures of regulation (*REG*), market size proxied by openness (*OPEN*) and population size (*POP*) and a set of financial market indicators (*FIN*). A more precise definition of these variables will be given in the following section.

Finally, the question arises of whether an increase in the level of investment in human capital will permanently increase the growth rate of knowledge ($\phi = 1$) or whether the marginal product of knowledge capital is declining ($\phi < 1$). Jones (1996) argues forcefully that the stylised facts of declining TFP growth rates and rising human capital investments over the last decades is clearly more consistent with the second view.

An important knowledge creating activity are R&D expenditures of firms. Here the interesting question arises how R&D activities are determined vis a vis physical investment. We postulate the following regression equation in order to test for the relevance of the factors of interest

$$I = iy(REG, OPEN, POP, FIN, EDU)Y \qquad (14)$$

and

$$RD = rdy(REG, OPEN, POP, FIN, EDU)Y \qquad (15)$$

Economic theory provides various justifications for these variables as possible predictors of investment rates.

Regulation **:** The level of regulation affects investment in various ways. First, to the extent to which regulation prevents entry, it lowers competition and investment. Regulation can also affect the investment costs of existing firms. Rising capital costs require higher minimum returns and thus lead to lower investment rates. Blanchard and Givazzi (2002) provide a theoretical framework for a discussion of these effects.

Financial Markets **:** Another potentially important aspect affecting investment rates is access to finance. Allen and Gale (2000) see a special advantage of stock markets in the assessment of innovations. This suggests that stock markets should be favourable to new forms of investment (or investment undertaken by new firms) as well as R&D investment. Wachtel (2001) regards stock markets as a vehicle for fostering international portfolio and direct investment. Other authors have a more critical attitude towards stock markets, for example, Levine and Zervos (1998) see improved liquidity as having negative effects on savings rates and therefore on investment.

Market size (Population, Openness) **:** With knowledge capital, scale effects become more important. This should not have direct effects on the aggregate investment to GDP ratio but it is likely to have effects on the allocation of investment to different types. The endogenous growth literature (see Romer (1990)) especially stresses the sunk costs associated with R&D. Therefore bigger markets associated with larger national economies and more open borders should be positively correlated with R&D activities. Size effects have played a prominent role in the recent growth literature.

The market size/growth link is stressed in the first generation of endogenous growth models (see Jones (2001)). There is of course a large empirical literature which deals with the effect of openness on productivity growth, but only recently Alesina et al. (2001) have tried to look systematically into the effects of openness and country size on productivity.

Education: Since education affects the efficiency of labour it affects output and investment in the same direction and with the same intensity. Therefore it does not affect the investment rate as such. However, the composition of investment may be affected in the sense that more knowledge intensive forms of investment (ICT, software, R&D) may be complementary to the human capital endowment in the respective economy. Education may also play a role in attracting foreign direct investment.

Empirical Analysis and Results

The empirical analysis is based on a panel of 21 OECD countries over the period 1975 to 2000[4]. As proxies for the fundamental growth determinants in this paper we use the following variables. As a measure of regulation we use the Fraser index which has the advantage of being available over the whole sample period[5]. In addition we use the share of government consumption and the degree of openness as possible indicators for government involvement and regulation. Unlike with a direct regulation index the results which are obtained with the two latter indicators are more difficult to interpret. Government consumption could also be negative for other reasons. For example, it could represent crowding out effects, but there could also be a bias due to the way in which a government's contribution to GDP is measured. Similarly a positive effect of openness could indicate both higher competition but also market size effects.

The structure of financing is captured in the regressions below by two indicators, the "volume of bank credit as a share of GDP" and an index of stock market capitalisation. In order to reduce possible problems of endogeneity with these two indicators we use beginning of period values instead of period averages.

For modelling the effects of market size we follow Alesina et al (2001) and use three variables, namely openness, population size and the product between the two. The last variables capture possible non-linearities, for example that the degree of openness may be less important for large as opposed to small economies.

As a human capital indicator of the household sector we use the average years of schooling of the adult population. The data are from De la Fuente and Domenech (2001). In order to allow depreciation of human capital we use the youth dependency ratio as an additional regressor.

[4] Data series for the different variables used in the analysis were available, starting in the mid-1970's, for all of the EU countries, with the exception of Greece and Luxembourg. Outside the EU, comparable series were assembled for the US, Australia, Canada, Iceland, Japan, New Zealand, Norway and Switzerland. Since we are interested in medium term trends the analysis removes business cycle effects by using 5 year averages.

[5] The OECD regulation indices are usually only available for the 1990s.

Investment and R&D

When analysing investment one has to take into account the fact that its structure is changing in at least two important dimensions :

Firstly, investment is not a homogeneous aggregate but it reflects very diverse activities of firms. Especially in the 90s we observe significant structural changes. For example, the share of ICT investment in total investment has grown steadily over the 1990's, with the ICT share of non-residential gross fixed capital formation in the US presently approaching 1/3. ICT investment itself has not only a larger knowledge share in terms of software and R&D spending but is also complementary to skilled labour. In addition, overall R&D spending (whilst still comparatively small in terms of overall GDP) is playing a more prominent role in many of the more advanced economies.

Secondly, technology, allied to globalisation and capital market liberalisation, has generated a huge increase in the volume of capital movements in general and FDI flows in particular. The growing importance of multinationals in determining worldwide investment trends is reflected in the fact that the stock of FDI assets have grown from around 5% of world GDP in the mid 1980's to over 15% at the end of the 1990's. In order to capture these structural shifts, it is important not only to look at aggregate investment but also at specific investment categories such as ICT, FDI and R&D. The following table presents regression results for investment rates and various sub totals.

Amongst all the various growth determinants assessed in the regression analysis, regulation appears to be the most important driver of investment rates. The degree of regulation plays an especially important role for foreign direct investment but it is also a crucial driver for new forms of investment such as ICT. These results are consistent with a recent empirical study by Alesina et al (2003) which uses OECD regulatory indices for service industries. There is also some evidence that equity based financial systems are more favourable to physical investment. Especially, FDI flows are positively correlated with a more equity based structure for financial markets. Finally, education appears to be an important factor for foreign direct investment. These results suggest that in an environment characterised by increasing international capital mobility, levels of regulation, financial market conditions and human capital endowments are important determinants for the attractiveness of a country as an investment location.

INVESTMENT REGRESSIONS

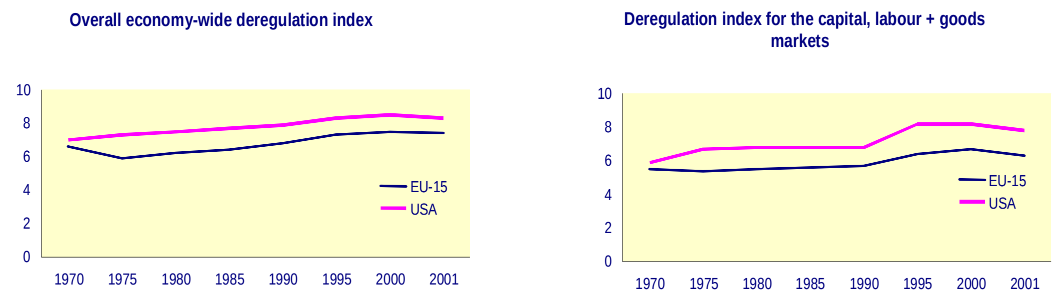
	GROSS FIXED CAPITAL FORMATION	FOREIGN DIRECT INVESTMENT	ICT INVESTMENT	R&D EXPENDITURE	
	(1)	(2)	(3)	(4)	(5)
1. GOVERNMENT CONSUMPTION	- 1)	- 1)	- 1)	1.18**	0.95**
2. DEGREE OF DEREGULATION	0.29**	3.32**	0.86**	-0.20	-0.04
3. BANK CREDIT	-0.01	-0.68**	0.16	-0.07	-
4. STOCK MARKET CAPITALISATION	0.03*	0.48**	0.13**	0.15**	-
5. OPENNESS	-3.35**	1.93	1.09	3.21*	6.87**
6. OPEN×SIZE	0.79**	0.16	-.44	-0.71	-1.86**
7. POPULATION SIZE	0.97*	0.49	1.99**	1.78**	1.72**
8. EDUCATION	-0.05**	0.53**	0.002	0.02	0.13**
9. GROWTH OF WORKING AGE POPULATION	-0.04	0.13	-.001	0.06	-0.02
COUNTRIES / OBSERVATIONS	21/89	21/85	21/61	21/89	21/100
R**2	0.77	0.79	0.81	0.93	0.92

Panel regression with country fixed effects.
***/**/* indicates significance at the 1/5/10% level.
1) Government consumption is excluded from regressions (1) to (3). Collinearity between government consumption and deregulation tends to make both regressors insignificant when used simultaneously. Only results with deregulation are reported here since this indicator slightly outperforms government consumption in the regressions.

The determinants of knowledge investment are different to those of physical investment. Firstly, R&D is less affected by the regulatory environment. What seems to be more important for R&D is market size as measured by openness and population size. The lack of importance of regulation for R&D could be due to the fact that entry barriers are less important for R&D activities which are typically concentrated amongst incumbent firms. Also, theoretically the link between regulation and research intensity is less clearcut. Given the sunk cost nature of R&D activities, the prospects of more secure rents provided by product market regulations (for example in the form of higher protection against violation of property rights from new inventions) may act as an incentive for R&D. The sunk cost nature of R&D also makes it plausible that market size matters in that firms located in more open and/or larger economies will typically engage more strongly in R&D activities. Investments in R&D are usually more risky than in physical investments and therefore the attitude of all financial institutions towards the financing of such investments is important. More market based financing mechanisms, including equity markets and venture capital funds, tend to favour riskier investments. This is borne out in the empirical analysis where it is found that stock market turnover indices move more closely with R&D investment compared with bank credit measures. Whether this can be unambiguously interpreted in a causal sense is an open question. An alternative interpretation could be that stock markets simply value the returns from R&D investments more highly. This argument would be supported by the fact that R&D expenditures can equally well be explained by only concentrating on fundamentals such as market size, education and government involvement. In this case the role of education as a fundamental determining factor of R&D becomes more evident.

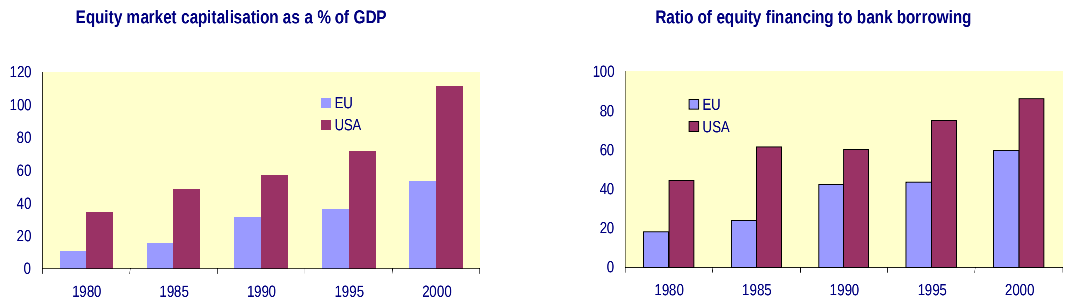
When we apply these results to analyse investment rate differential between the EU and the US we can see that both in terms of regulation and in terms of the structure of financial markets the US outperforms Europe. If we take the estimates on regulation and apply them to the EU-US differential and further take into account the impact of investment on long run levels of productivity as implied by the neoclassical growth model then the effect of regulation on the long run level of labour productivity amounts to about 5%. Given that EU levels of labour productivity are about 90% of US levels, differences in product market regulation could account for about 50% of the productivity gap. It is also interesting to observe that these estimates are close to the estimates obtained by the IMF in the last World Economic Outlook using a different methodology.

Graph 1 : Fraser institute deregulation indices



Source: Fraser institute.

Graph 2 : Financial market indicators



Source: World Bank, World Development Indicators (2002).

Total Factor Productivity

The results on TFP are consistent with theoretical priors. There is a significant effect of R&D and education on TFP. Another interesting is the negative impact of an ageing labour force on TFP. Since the mid 1970's the youth dependency ratio has declined in all OECD countries. This has led to a reduction in the inflow of young workers into the labour force and has increased their mean age. Little is known so far on the impact this might have on the creation and adoption of new ideas and technologies. The results reported here suggest however that this process could have been one of the contributors to the slowdown in productivity growth.

Like in the case of R&D, only a limited role is found for deregulation in boosting the growth of knowledge. These results broadly occupy a mid-point between a 2003 joint CEPR and IFS study which reports a negative association between deregulation and TFP and an OECD (Nicoletti and Scarpetta (2003)) study which finds a more positive effect of deregulation on TFP.

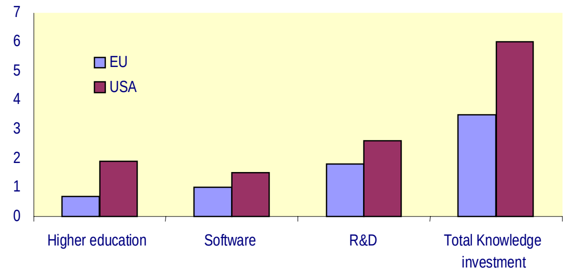
TFP / Knowledge Production Function

	TFP	**TFP**	**TFP**	**TFP**
	(1)	**(2)**	**(3)**	**(4)**
1. Youth Dependency Ratio	0.076**	0.073**	.048*	0.062
2. R&D Expenditure	0.025**	0.022**	.033**	0.009
3. Education	0.005	0.007	.009*	0.01
4. Regulation		0.04	.03	0.03
5. Government Consumption			-.06**	
6. openess		0.40**	0.25*	0.24
7. open×Size		-.13**	-.09*	-0.07
8. Population		0.05	.05	0.03
9. Bank credit				-.004
10. stock market capitalisation				0.003
11. TFP(-1)	-0.01	-.04*	-.07**	-.0.056*
Countries/Observations	21/97	21/97	21/97	21/88
R2**	.31	.40	.45	.34

(1): panel regression with country and time fixed effects

These results suggest that knowledge investment is important for TFP growth. If one looks at standard indicators of knowledge investment then one can clearly see that the US is putting more emphasis on knowledge capital than the EU. The US is leading in higher education as well as in R&D and ICT investment. From our analysis it should therefore be not surprising that TFP growth rates between the EU and the US are starting to diverge.

Graph 3 : Investing in the knowledge economy : EU versus USA : 1998 (% of GDP)



Source : OECD.

So far our analysis of TFP has not taken into account important "new economy" developments which took place in the 90s and which have been regarded as major drivers of technical progress in this period. It is therefore important to link the results obtained with a macroeconomic knowledge production function to ICT. When thinking about possible links 4 distinct hypotheses may come to our mind.

Hypothesis 1 : The knowledge generating factors as identified by the knowledge production function, namely R&D and human capital investment can explain the international TFP growth patterns since the mid 1990s.

Hypothesis 2 : There is a large industry specific element which plays a role. Countries with high ICT industry shares have benefited from the positive productivity shocks taking place in these industries. Alternatively those countries which are high ICT users have benefited from technological spillovers. This means that the knowledge production estimates should under/overpredictpredict TFP growth in the 90 for countries with a high/low ICT production and/or investment shares.

Hypothesis 3 : It is true that the ICT revolution was industry specific, but it was not confined to a specific country. With high capital mobility, those countries which offered attractive investment locations in terms of flexible labour and goods markets and/or young labour forces which were open to the adoption of new technologies, benefited most from the ICT boom. If this hypotheis were to be correct we would expect those countries with low/high levels of regulation doing better/worse in terms of TFP growth in the 90s

Hypothesis 4 : Both industry specialisation (hypothesis 2) as well as flexibility in the adoption of new technologies (hypothesis 3) have interacted positively.

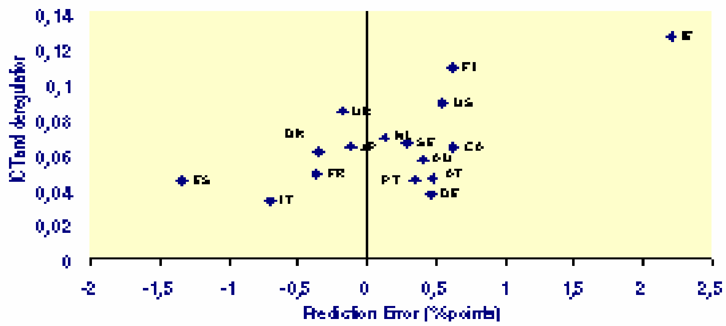
Explaining Residual of the Knowledge Production Function (96-00)

	coeff	R**2	coeff	R**2	coeff	R**2
ICT-Production	0.26***	0.40	0.13	0.11	0.09	0.09
ICT-Investment	-0.10	0.00	0.18	0.02	0.12	0.02
De-Regulation	0.40*	0.15	0.25	0.01	0.15	0.07
Age of Labour Force	0.08**	0.27	0.04	0.07	0.02	0.03
ICT & Regulation	3.02***	0.44	1.67	0.16	1.09	0.12
ICT & Age of Labour Force	0.46***	0.53	0.29*	0.18	0.19	0.15

***/**/* significant at the 1%/5% and 10% level

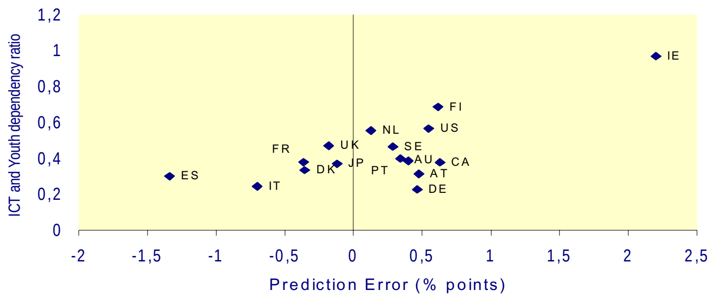
It turns out that hypothesis 4 offers the best explanation for the cross country variation of prediction errors. As can be seen clearly from the Graphs**,** there is a strong relationship between the ICT production share of a country (which is the best measure of its degree of industry specialisation), when interacted with either the regulatory burden or the age of the labour force, and the size of the deviation of actual TFP growth from the predicted growth rate[6]. This supports the interpretation whereby countries, some of which are in the EU, which have low regulatory burdens and a comparatively young labour force (creating favourable conditions in terms of technology adoption), have been better able to exploit the technological developments occurring in the mid-1990’s compared with other countries and have consequently gained in terms of higher TFP growth. In relative terms, with a strong correlation between the ICT production share and TFP growth, the analysis also indicates that industry specialisation (hypothesis 2) is probably more important than the degree of regulation and the age of the labour force (hypothesis (3) in explaining the TFP prediction errors. Finally, the clear patterns emerging for these prediction errors also leads one to reject hypothesis 1.

Graph 14 : TFP prediction error correlated with ICT production share and deregulation



Source: Commission services.

Graph 15 : TFP prediction error correlated with ICT production share and youth dependency ratio



Source: Commission services.

6 The predicted growth rate of TFP would be the rate expected on the basis of the R&D and educational inputs in the corresponding country.

Concluding Remarks

This paper has used the PF methodology to assess growth differences between the EU and the US in the 90s. Both rising investment rates and accelerating TFP growth rates can be identified as crucial factors. By looking at determinants of investment and TFP growth rates, the level of regulation appears to be a crucial factor for determining the international location of investment. Concerning TFP, the factors regarded as important in the empirical growth literature such a R&D and education are important, however they cannot entirely explain TFP growth in the 90s across OECD economies. ICT plays an important role in the 90s. the most successful hypothesis from our analysis appears to be an explanation whci acknowledges the role of ICT production, possibly related to levels of regulation.

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