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Output gaps and technological progress in European Monetary Union

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Abstract

Output gaps for ten European countries and the USA are estimated based on a CES production function with input augmentation in technological progress. The substitution parameter is estimated from the coefficients of the labour and capital demand functions. Estimation is carried out using Johansen's cointegration method. For six of the eleven countries analysed, the use of the Cobb Douglas form would not be appropriate. The output gap estimates show a similar cyclical pattern for all countries. They remain mostly within ±4% except for Finland and Greece. Separating labour-augmenting and capital-augmenting technological progress gives insight into the driving forces of growth for individual countries.

Key words: output gap, potential output, CES production function, EMU

JEL classification numbers: C32, E32

Tuotantokuilut ja tekninen kehitys EMUssa

Suomen Pankin keskustelualoitteita 20/2001

Maria Antoinette Dimitz
Tutkimusosasto

Tiivistelmä

Selvityksessä estimoidaan potentiaalisen ja aktuaalisen kokonaistuotannon välinen ns. tuotantokuilu kymmenessä Euroopan maassa ja Yhdysvalloissa. Estimointi perustuu CES-tuotantofunktioon, jossa tekninen kehitys lisää efektiivisiä panosmääriä. Panosten välinen substituutiojousto mitataan työn ja pääoman kysyntäfunktioista Johansenin kointegraatiomenetelmää käyttäen. Tarkastelluista yhdestätoista maasta kuuden tapauksessa Cobbin–Douglasin tuotantofunktion muoto ei osoittautunut sopivaksi. Kaikissa maissa estimoidun tuotantokuilun suhdannevaihtelu näyttää samantyyppiseltä. Tuotantokuilut pysyvät enimmäkseen vaihteluvälillä ±4 % lukuun ottamatta Suomea ja Kreikkaa. Työtä ja pääomaa lisäävien teknisen kehityksen komponenttien erottaminen toisistaan valottaa yksittäisten maiden taloudelliseen kasvuun vaikuttaneita tekijöitä.

Asiasanat: tuotantokuilu, potentiaalinen tuotanto, CES-tuotantofunktio, EMU

JEL-luokittelu: C32, E32

Contents

1 Introduction

The output gap is the difference between an economy's actual and potential output. It can thus be understood as the deviation of output from its equilibrium level.

Output gaps play an important role for monetary policy decisions, especially in the European context. A positive output gap (that is a production level above the economy's potential) is an indicator for the tension on goods and labor markets and hence for the future evolution of prices. If actual output is below or above potential, prices will adjust so that the equilibrium situation of a closed output gap is restored. But as prices are rigid in the short run a positive or negative output gap might occur during the adjustment process.

Thus potential (or trend) output can be formalized as the production level consistent with stable inflation. The output gap is correspondingly the component of output associated with a changing inflation rate. The main goal in the monetary policy strategy of the European System of Central Banks is price stability. To have estimates of the current and future aggregate European output gap is thus of great importance for prudent monetary policy decisions. Orphanides (2000) for example shows that an overestimation of the US economy's productive capacity during the 1960s and the 1970s was the basis for an overactivist stabilization policy in these years and thus is likely to have been the primary cause of the high inflation numbers of the 1970s.

Potential output and the output gap cannot be observed directly and must therefore be estimated using information from other available economic variables. Several methods are mentioned in the literature; they can be classified into three broad categories: statistical methods, structural approaches and the production function approach. What follows is a broad description of these methods, their advantages and drawbacks.

First there are **statistical methods** that are based on some filtering technique. The simplest representative in this category is the *Split Time-trend Method,* formerly used by the OECD Secretariat (see Giorno et al. (1995)). Basically an economic cycle is defined as the period between two peaks, and within each cycle a deterministic trend growth rate of output is calculated. This method is very simple in its application, but it does not allow for structural breaks. Furthermore, it is not useful for the determination of the current output gap, as this needs ad hoc assumptions about the current position in the cycle. This, however, would already require some idea about the current output gap.

The second representative of the statistical methods is the *univariate Hodrick-Prescott filter* (HP filter; see Hodrick and Prescott (1997)). Potential output is determined as the output level that simultaneously minimizes a weighted average of the gap between actual and potential output and the rate of change of trend output. The method essentially offers a trade-off between the proximity of the trend to actual data and the smoothness of the trend. This method is widely used, mainly because of its simplicity and because it requires only output data. Its disadvantages are associated with the need to fix the weight for the two components in the minimization process, the so-called smoothness parameter, a priori and the fact that the filter smooths out possible structural breaks. However, the main drawback is the so-called end-of-sample problem. This arises because at the end and at the beginning of the sample the "penalty" for letting potential output follow the trend of the data will be small, as the filter does not take the subsequent reversion of the trend into account. It simply extends the latest trend to the future, thus making forecasts little meaningful. One way of dealing with this problem is to add projections of the actual output series, but the accuracy of the current estimates of potential output and the output gap will depend critically on the quality of these forecasts.

To account for the criticism that the univariate Hodrick-Prescott filter does not use available economic or structural information, it was extended by Laxton and Tetlow (1992) by incorporating economic variables other than output. This *multivariate HP filter* introduces one or more additional components in the minimization process, such as a goodness-of-fit condition on structural relations like the Phillips curve or Okun's law. Further extensions to this approach are given in St-Amant and van Norden (1997). But even within this more complex framework the end-of-sample problem still remains. The extended data requirements and the need to fix even more weights for the minimization process are additional drawbacks. Because of the included structural information this method is often referred to as a *semistructural* approach.

A more advanced filter method is the so-called *Structural Timeseries Models or Unobserved Components* (STM/UC) approach. Like the previous method it is semistructural as it draws information from both actual output and other observable economic variables. Apel and Jansson (1997), Rasi and Viikari (1998) and Gerlach and Smets (1999) are recent applications of this approach. The unobserved variables potential output and the NAIRU (non-accelerating inflation rate of unemployment) are estimated simultaneously within the same trivariate system of observables comprising information on unemployment, output and inflation. Identification is achieved through the use of structural relations as the Phillips curve or Okun's law. Potential output can then be derived by using a Kalman filter. The main advantage of this approach is that it is consistent with economic theory. However, as the application requires considerable econometric expertise and the results can be fairly sensitive to the econometric specification the approach is less useful in the international context in which simplicity, transparency and comparability are important factors.

The second broad category of methods to estimate potential output and the output gap are **structural methods**. Its main representative is the Structural Vector Autoregressive (S-VAR) model. This approach exploits the relation between inflation and growth to distinguish between permanent and transitory shocks. Several variants can be found in the literature; the most common is given by Blanchard and Quah (1989), who base their method on long-run restrictions imposed on output. The main advantage of this class of models is that they are based on economic theory and do not require arbitrary assumptions. Furthermore, they are not subject to end-of-sample problems and are thus better suited for forecasting. The main drawback is that the results are sometimes counterintuitive. The structural VAR can be regarded as a simultaneous equation system with instrumental variables. If these instruments are poorly correlated with their associated explanatory variables, an identification problem occurs.

The third category of methods consists of the **production function approach**. This is the method currently used by the OECD (see Giorno et al. (1995)) and the IMF (see De Masi (1997)), and it is also the method that is used in this paper, although in a model setting different from that of these two institutions. First a specific form of production function is estimated. Then its input factors labor and capital are replaced by their potential values. According to this approach potential output is the output level consistent with the population and the trend rates of unemployment, labor market participation, the marginal product of labor and the labor share. This approach has the advantage that it allows explicit statements about the underlying reasons for a change in potential output. The main drawback is that the method still relies on simple detrending techniques such as the HP filter, as it takes a filter method (with all the problems mentioned above) to determine the potential output factors. Furthermore capital stock data may be of very poor quality. The criticism of the somewhat arbitrary choice of the specific production function could be overcome by using a flexible functional form and non-parametric estimation techniques. Specific functional forms, however, are advantageous in leading to very efficient statistical inference. Overall, the approach is still an improvement as compared to pure filtering techniques, as it allows to distinguish explicitly the underlying components of potential output.

The paper is organized as follows. Section 2 describes the model and explains the several steps of the estimation procedure of output gaps. Section 2.4 gives some comments on the data set used; more details can be found in the Annex. Section 3 shows the empirical results, starting with the estimates of the production function parameters (3.1). The graphs of the evolution of the NAWRU (non-accelerating wage-inflation rate of unemployment) and the output gap over time for each country are presented (3.2 and 3.3) followed by a comparison with results from similar studies (3.4) and an analysis of the path of technological progress (3.5). Section 4, finally, concludes and makes proposals for further research.

2 The model

The determination of potential output and, hence, the output gap entails several steps. First, a form of the production function is chosen. Second, the parameters of the specific production function are estimated and technological progress can be determined as the residuals of the production function estimation. Third, the potential factor inputs are estimated and inserted into the production function to get estimates of potential output. The output gap is then given by the difference between actual and potential output.

2.1 Choice of a production function

Most of the literature on the estimation of output gaps using the production function approach works with the Cobb Douglas form. This extremely simple form of a production function is based on the validity of the so-called Kaldor facts of the growth literature[1].

Empirical evidence, however, shows that the 1990's saw a substantial fall in the labor share in several European countries. The implication is that the use of the Cobb Douglas production function, supported by pre-1990 data, may not be appropriate.

To account for this fact this paper estimates the parameters of the Constant Elasticity of Substitution (CES) production function. This more general form does not restrict the substitution elasticity to be one, as does the Cobb Douglas form, and hence allows for differences between countries (see Kmenta (1967)). It is thus an appropriate framework for explaining the observed movements in some of the critical ratios of the Kaldor facts. The specific form of the CES production function used in this paper is one that allows for input augmentation in the technological progress. Thus it takes the form

$$Y_t = F(K_t, L_t) = \left[\delta \cdot (B_t L_t)^{-\rho} + (1-\delta) \cdot (X_t K_t)^{-\rho}\right]^{-\frac{1}{\rho}},$$

where Y_t is gross value added in businesses, L_t and K_t are the input factors labor and capital (both referring to business sector), B_t and X_t are labor- and capital-augmenting technological progress, respectively, δ is the distribution parameter indicating the labor intensity of output, and ρ is the substitution parameter. As is shown in Ripatti and Vilmunen (2001) this framework allows for a time-varying labor share, as it is fundamentally affected by the evolution of X_t and the capital output ratio.

The Cobb Douglas production function is just a special case of the CES production function and the validity of the former can thus be tested once the parameters are estimated. Specifically, the CES function is reduced to the Cobb Douglas case if the substitution parameter ρ approaches zero.

2.2 Determination of the parameters of the CES production function

The next step is to estimate the substitution and the distribution parameter of the CES function. The non-linear nature of the CES function makes this

[1] The so called Kaldor Facts represent a set of stylized facts about economic growth, which any reasonable growth model should be able to explain:

1. Per capita output grows at a rate that is roughly constant.
2. The capital-output ratio is roughly constant.
3. The real rate of return is roughly constant.
4. The shares of labor and capital in national income are roughly constant.

See e.g. Kongsamut et al. (1997).

task considerably more difficult than in the (log-linear) Cobb Douglas case.

First the parameter ρ is estimated using the profit-maximizing labor market and capital market equations of a competitive firm. The two equations satisfying the production efficiency condition are given in log-linear form as follows:

$$y_t - l_t - \frac{1}{1+\rho}(w_t - p_t) - \frac{\rho}{1+\rho}b_t + \frac{\log\delta}{1+\rho} = 0, \tag{1}$$

$$y_t - k_t - \frac{1}{1+\rho}r_t - \frac{\rho}{1+\rho}x_t + \frac{\log(1-\delta)}{1+\rho} = 0 \tag{2}$$

with lower case letters being the logs of Y_t, L_t, K_t, B_t and X_t, respectively, $(w_t - p_t)$ the log of the real compensation rate for business sector and r_t being the real rental price of capital, proxied by the real interest rate. Equation (1) gives the labor demand schedule and describes the relation between labor productivity, real wages and labor-augmenting technological progress. Equation (2) is the capital accumulation schedule and shows correspondingly the connection between capital productivity, the real interest rate and capital-augmenting technological change.

To simplify the notation equations (1) and (2) can be rewritten as

$$y_t - l_t - \sigma(w_t - p_t) - (1-\sigma)b_t + \sigma\log\delta = 0, \tag{3}$$

$$y_t - k_t - \sigma r_t - (1-\sigma)x_t + \sigma\log(1-\delta) = 0 \tag{4}$$

where $\sigma = \frac{1}{1+\rho}$ is the elasticity of substitution in the CES case.

The above equations can be interpreted as long-run relations between the variables $z_t = \begin{bmatrix} y_t & l_t & k_t & (w_t - p_t) & r_t & t \end{bmatrix}'$, reflecting the steady state. I allow for a linear trend in the data set, as the stochastic specification of b_t and x_t might contain a deterministic drift. It is assumed that y_t, l_t, k_t, $w_t \sim$ I(1) (i.e. are integrated of order one).

From the vector autoregressive equation system z_t I tried to identify at least one of the two equations (3) or (4) as cointegration relations. The coefficient of $(w_t - p_t)$ or r_t, respectively, gives then an estimate for σ and consequently for ρ[2] .

The next step is to estimate the distribution parameter δ together with the technological variables b_t and x_t. These three reduce to two, as the last one is identified once the other two have been fixed. The approach of this paper is to fix δ at the average labor share of each country $(\tilde{\delta})$, corresponding to the procedure in the Cobb Douglas case. Depending on which equation was identified, b_t or x_t is computed as an error correction term to the labor or capital market equation, respectively. The other technological variable is then determined as residual to the production function.

[2] In some cases the equation system was reduced to a partial labor or capital market system, i.e. to $z_t = \begin{bmatrix} y_t & l_t & (w_t - p_t) & t \end{bmatrix}'$ or $z_t = \begin{bmatrix} y_t & k_t & r_t & t \end{bmatrix}'$, respectively.

In some cases the Cobb Douglas production function was taken instead of the CES. First, in cases where the estimated elasticity of substitution is very close to 1 (and hence the substitution parameter almost zero) and leads to implausible results. This is justified, as in these cases the Cobb Douglas production function cannot be rejected anyhow (see section 3.1 for more details). Second, in cases where no reasonable results could be found from cointegration analysis[3]. And third, in cases where the identified cointegration relation indicates a substitution elasticity greater than 1. This would imply that the input factors are gross substitutes. I do, however, think that the case of highly substitutable inputs is implausible and hence decided to go on with the Cobb Douglas form as a border solution instead.

The specific form of the Cobb Douglas production function is

$$Y_t = F(K_t, L_t) = A_t \cdot L_t^{\alpha} \cdot K_t^{1-\alpha},$$

with α being fixed at the average labor share. In the Cobb Douglas case it is not possible to identify a separate labor- and capital-augmenting technological progress. Hence an overall technological progress A_t, usually denoted as Solow residual or total factor productivity, is estimated as the residual of the production function.

2.3 From the production function to output gap estimates

The final step is to insert the potential production factor inputs into the production function to get estimates for potential output and the output gap. First the $\hat{B}_t$ and $\hat{X}_t$ series are smoothed using an HP filter to get rid of measurement errors ($\hat{B}_t^*$ and $\hat{X}_t^*$, the star denoting the HP-filtered series). Potential capital stock is simply replaced by the actual capital stock based on the observation that this series is not subject to heavy fluctuations. That is:

$$K_t^{pot} = K_t. \tag{5}$$

Potential employment on the other hand is estimated based on the NAWRU (non-accelerating wage-inflation rate of unemployment) concept used by the OECD. The NAWRU is defined as the unemployment rate for which nominal wage inflation is constant. Following the paper of Bolt and van Els (2000) I adopt Elmeskov's (1993) method, which is also used by the OECD. According to this approach the change in the wage inflation is negatively correlated with the difference between actual unemployment and the NAWRU:

$$u_t - u_t^{NAWRU} = \lambda \Delta^2 w_t^{econ}, \quad \lambda < 0, \tag{6}$$

with u_t being the economy-wide actual unemployment rate, u_t^{NAWRU} being the unemployment rate associated with steady wage inflation and w_t^{econ} being the economy-wide nominal compensation rate for employees (business and public

[3] In principle the rejection of the CES production function also implies the rejection of the Cobb Douglas form as this is only a special case. Nevertheless the estimates based on the Cobb Douglas form are shown as a benchmark case.

sector). Assuming that the NAWRU changes only gradually over time, so that $\Delta u_t^{NAWRU} \approx 0$, and taking the first differences on both sides of equation (6) gives

$$\lambda = \frac{\Delta u_t}{\Delta^3 w_t^{econ}},$$

which, after substituting it back into equation (6) gives a formula for the computation of the NAWRU:

$$u_t^{NAWRU} = u_t - \frac{\Delta u_t}{\Delta^3 w_t^{econ}} \Delta^2 w_t^{econ}. \tag{7}$$

Hence, the NAWRU equals the actual unemployment rate minus a correction factor reflecting changes in the unemployment rate and the wage inflation. The resulting NAWRU estimates are then smoothed using again the HP filter (u_t^{NAWRU*}).

Given the smoothed NAWRU estimates, potential dependent employment in business sector can then be derived according to the following equation:

$$L_t^{pot} = L_t^{econ*}(1 - u_t^{NAWRU*}) - L_t^{gov*} - L_t^{self*}, \tag{8}$$

with L_t^{econ*}being the HP-filtered labor force and $L_t^{gov*}$and L_t^{self*} being the HP-filtered employment in the public sector and self-employment, respectively.

The final step is to insert these potential production factors into the estimated CES production function to get estimates of potential output in the business sector:

$$y_t^{pot} = -\frac{1}{\hat{\rho}} \cdot \log \left[\tilde{\delta} \cdot \left(\hat{B}_t^* L_t^{pot} \right)^{-\hat{\rho}} + (1 - \tilde{\delta}) \cdot \left(\hat{X}_t^* K_t^{pot} \right)^{-\hat{\rho}} \right].$$

The output gap is then the difference between actual and potential output:

$$gap_t = y_t - y_t^{pot}.$$

This completes the estimation process.[4]

2.4 Some comments on the data set

This paper is concentrated on the business sector of the economy. The justification lies in the difficulties to measure public sector variables, especially the capital stock. Hence the relevant data series are drawn from the OECD

[4]For those countries where the Cobb Douglas production function was used a parallel procedure is adopted. Potential output is then given by

$$y_t^{pot} = \hat{a}_t^* + \alpha l_t^{pot} + (1 - \alpha) k_t^{pot},$$

with $\hat{a}_t^*$ being the log of the HP-filtered technological progress series A_t and l_t^{pot} and k_t^{pot} being the logs of potential dependent employment and the potential capital stock, respectively (from equations (5) and (8)).

Business Sector Data Base that contains quarterly data for the business sector, only. Because not all necessary data are available for Luxembourg and Portugal these countries had to be left out. Thus the examined countries are the EMU countries Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands and Spain, as well as Greece, which became a part of the European Monetary Union in January 2001. The United States are also examined as a benchmark.

The main problem concerning the OECD Business Sector Data Base is that the data are only available until 1997 or 1998 for most of the countries. Because of the well-known end-of-sample properties of the HP filter this would not allow firm conclusions even for the year 1998. For economic policy decisions it is, however, of great interest to have information about the current output gap. To account for this demand the available yearly OECD Economic Outlook forecasts until 2001 were disaggregated to quarterly data. For literature concerning the disaggregation of annual time series data to quarterly figures see e.g. Chan (1993); in this paper an AR(4) process was fitted through the yearly data and adjusted for the difference between the estimated yearly average and the OECD estimates.

Clearly the quality of these chained quarterly data does not only depend on the chosen disaggregation method but also on the quality of the forecasts. Therefore it should be emphasized that this procedure is not meant to provide forecasts of the output gap until 2001. Rather it should ameliorate the significance of the HP-filtered data so that at least for the available quarterly data the uncertainty concerning the current output gap is reduced. The following graphs of the estimated output gaps show the results for the whole (extended) data set. But in order to avoid misinterpretations a vertical line is drawn where the interpolated data start for the GDP series. It should be emphasized that results beyond that point are highly uncertain.

The starting point of the data set varies from country to country, in some cases data are available from 1960 onward. For the estimation of the parameters of the CES production function in general all available data were used. In some cases, however, it was necessary to reduce the data set in order to get stable and reasonable results. The output gap, however, is then shown for the whole data range by assuming that the production function does not change over time. For more detailed information about the data set used for each country consider the Annex.

3 Empirical results

3.1 Estimates of the parameters of the production function: Is the Cobb Douglas case appropriate?

Table 1 summarizes the results from the cointegration analysis[5]. The first column shows the average labor share, i.e. the value at which δ was fixed. The remaining columns report the estimates for the substitution elasticity and the substitution parameter and indicate whether they come from capital or labor market equation, or both.

Country	$\hat{\boldsymbol{\delta}}$	$\hat{\boldsymbol{\sigma}}$	**stand. error**	$\hat{\boldsymbol{\rho}}$	**cap./labor equ.**
Austria	0.54	0.43	0.11	1.33	cap.+labor equation
Belgium	0.53	1	-	0	no result from eqs.
Finland	0.54	0.54	0.08	0.85	labor equation
France	0.55	1.61/1	0.21/-	-0.38/0	labor equation
Germany	0.57	0.47	0.12	1.13	labor equation
Greece	0.25	0.46	0.06	1.17	cap.+labor equation
Ireland	0.52	0.92/1	0.24	0.09/0	labor equation
Italy	0.42	1	-	0	no result from eqs.
Netherlands	0.56	0.31	0.11	2.23	labor equation
Spain	0.46	0.94/1	0.14/-	0.06/0	capital equation
USA	0.59	0.84	0.09	0.19	labor equation

Table 1: Results from cointegration analysis; δ: average labor share
σ : elasticity of substitution, ρ : substitution parameter, $\sigma = \frac{1}{1+\rho}$

In six out of eleven cases the substitution parameter is derived from the labor market equation; for Germany and the United States the partial labor market model was used. For Spain the (partial) capital market equation was identified, and for Austria and Greece the capital and the labor market give a joint value for the substitution parameter. For Belgium and Italy none of the equations could be identified and thus I proceeded with the Cobb Douglas production function as a benchmark case.

As can be seen from the parameter estimates the assumption of a zero substitution parameter is rejected for at least six of the eleven countries, indicating that the use of the Cobb Douglas production function without testing the underlying assumptions would be inappropriate. For Ireland and Spain the Cobb Douglas case cannot be rejected. In these cases ρ is so close to zero that I decided to take the Cobb Douglas production function instead of the CES. The reason is that in these cases the two technological progress series are like mirror images and hence without any additional information as compared to the case with the Solow residual only. The output gap estimates for the CES form would then be mainly determined by the filtering of the $\hat{B}_t$ and $\hat{X}_t$ series giving implausible results. For France

[5] The cointegrating vectors are indentified using Johansens Maximum-Likelihood method (Johansen (1988)). Software used: PcFiml (e.g., Doornik and Hendry (2000)).

the estimated substitution elasticity is above 1, indicating that the input factors are gross substitutes. As this is implausible the Cobb Douglas case is taken once more. For all remaining cases the substitution elasticity significantly smaller than 1 suggests that labor and capital are gross complements.[6]

3.2 Determination of the NAWRU

Figure (1) shows the calculated HP-filtered NAWRU estimates for the eleven countries together with the unemployment rate.

It should be noted that the unfiltered NAWRU estimates had to be corrected for outliers before starting the filtering process. The reason is that the NAWRU gets extreme values if the denominator in equation (7) is close to zero. These extreme values are corrected in order not to distort the HP-filtered NAWRU series. In some cases it was necessary to seasonally adjust the wage series before calculating the NAWRU; the remaining outliers were corrected by hand[7].

From the graphs it can be seen that for most of the countries the NAWRU showed an upward trend until the mid 1980s. This was followed by a short period of temporary decreasing or stable NAWRU due to a strong economic recovery and decreasing unemployment rates in the second half of the 1980s. The only exception is Austria where the upward trend continues. This can be explained by the Austrian employment policy that prevented the unemployment rate from increasing until 1980. From 1990 onward most countries show another upswing of the NAWRU that is especially pronounced in the Finnish case, reflecting the severe recession in the early 1990s. It is only in the second half of the 1990s that almost all countries show a trend shift toward a decreasing non-accelerating wage-inflation rate of unemployment.

[6] There is a wide range of literature examining the value of the substitution elasticity between labor and capital. Generally the conclusion is that the assumption of a unity substitution elasticity underlying the Cobb Douglas form is rejected in most cases, although there seems to be a considerable amount of uncertainty as to whether it exceeds or falls short of one. Here I only want to quote some few very recent examples.

Rowthorn (1996) reports the results of 33 econometric studies which have estimated the substitution elasticity. He concludes that out of the 33 studies the estimates exceed 0.8 in only 7 cases and the overall median is equal to 0.58 providing counterevidence to the assumptions underlying the Cobb Douglas form.

Rowthorn (1999) reports cross-country estimates of the substitution parameter based on different estimates of the elasticity of labor demand and different sets of countries and gets a substitution elasticity above or close to unity only in 6 of 52 cases.

Duffy and Papageorgiou (2000) present further cross-country evidence using a panel of 82 countries over a 28-year period. For the entire sample they estimate, based on different methods, a substitition parameter ρ between -0.2 and -0.7 (i.e. a substitution elasticity significantly above 1).

Bolt and van Els (2000) follow a similar approach as in the present paper but concentrate on the labor market side and on total factor productivity only. Their estimates of the substitution elasticity for 11 European countries, Japan and the United States suggest that it falls short of unity for all countries except Spain.

[7] The correction was done taking the mean of the two neighboring values.

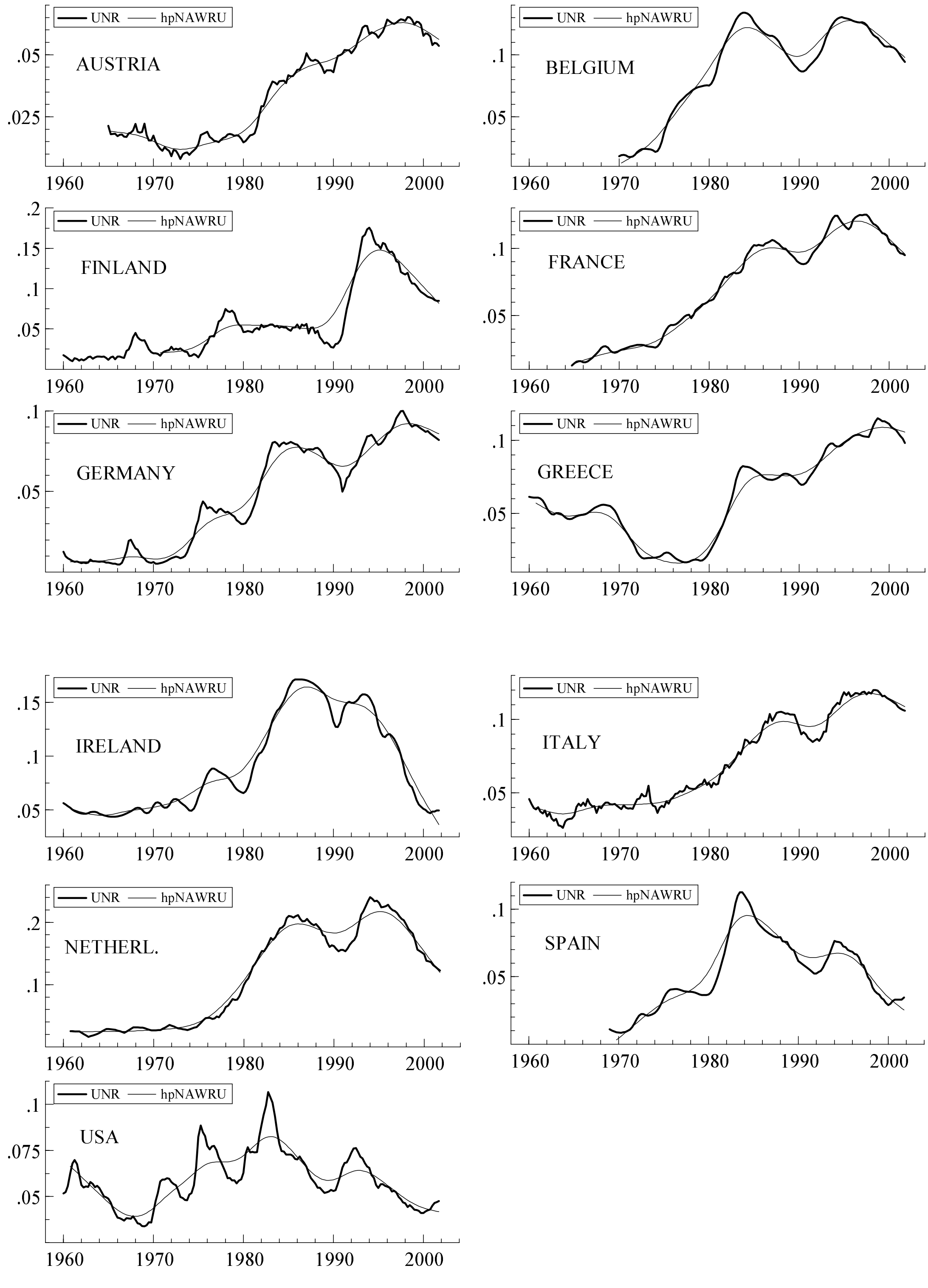

Figure 1: Unemployment rate and HP-filtered NAWRU for eleven countries.

For the countries with very high recent GDP growth rates – Spain, Ireland and the United States – the picture is somehow different. The NAWRU has been decreasing almost steadily since the mid 1980s and the graphs indicate that the lower turning point might be reached in the near future, although it must be mentioned that these movements lie already in the range of the interpolated data and thus depend heavily on the OECD forecasts[8].

3.3 Estimates of the output gap

Figure (2) finally shows the estimated output gaps for the eleven examined countries. All graphs show very clear cyclical patterns. From the figures it seems that the output gap has closed in recent time or will be closing in the near future. But allowance must be made for the end-of-sample problem associated with the use of the HP filter in several steps of the calculation process. The HP-filtered values of the variables tend to deflect toward the actual data at the end of the data set. As was mentioned before, it was tried to ameliorate the end-of-sample properties of the filter by using the OECD forecasts but still it is quite unlikely that the chosen procedure will produce huge positive or negative output gaps for the recent time.

For Austria, Belgium, France, Spain and the Netherlands the estimated output gaps remain within a range of $\pm 3\%$ for most of the time. For Germany, Ireland, Italy and the United States the output gaps fluctuate mostly within a band of $\pm 6\%$. Finland and Greece show outliers that go beyond that range. For Finland the extreme values of more than 8% in 1989 and -7% in 1993 reflect the severe recession in the early 1990s.

A very raw pattern can be seen in all the graphs: Almost all countries with a data range going back to the 1960s show a negative output gap in the end of this decade. In the first half of the 1970s the output gap gets positive. After a period of output below its potential in the second half of the 1970s almost all countries (except Ireland) show a boom around 1980 that turns into a period of closed or negative output gaps during the 1990s with only short outliers in the positive range. Around 1990 another boom phase can be seen in all the graphs with particularly high positive output gaps (relative to the previous ones) in about half of the cases. The following years show again (for most of the countries quite pronounced) negative output gaps that close around the end of the millennium. As mentioned before, the forecast data are subject to serious uncertainties and show furthermore no clear pattern, so that no reasonable interpretation can be drawn.

[8] The NAWRU estimates for these recently fast growing countries are subject to additional uncertainties. The decrease in the unemployment rate during the last five to ten years was so pronounced in these countries that the HP-filter-based NAWRU estimates follow the unemployment data rather closely. Thus the small "unemployment gap" contrasts the often stated concerns about labor market tensions in countries like Ireland or the United States. One way out could be to adjust the smoothness parameter of the HP filter in these specific cases. I think, however, that such an arbitrary procedure is hardly justifiable as it would be based on a priori assumptions about the true NAWRU.

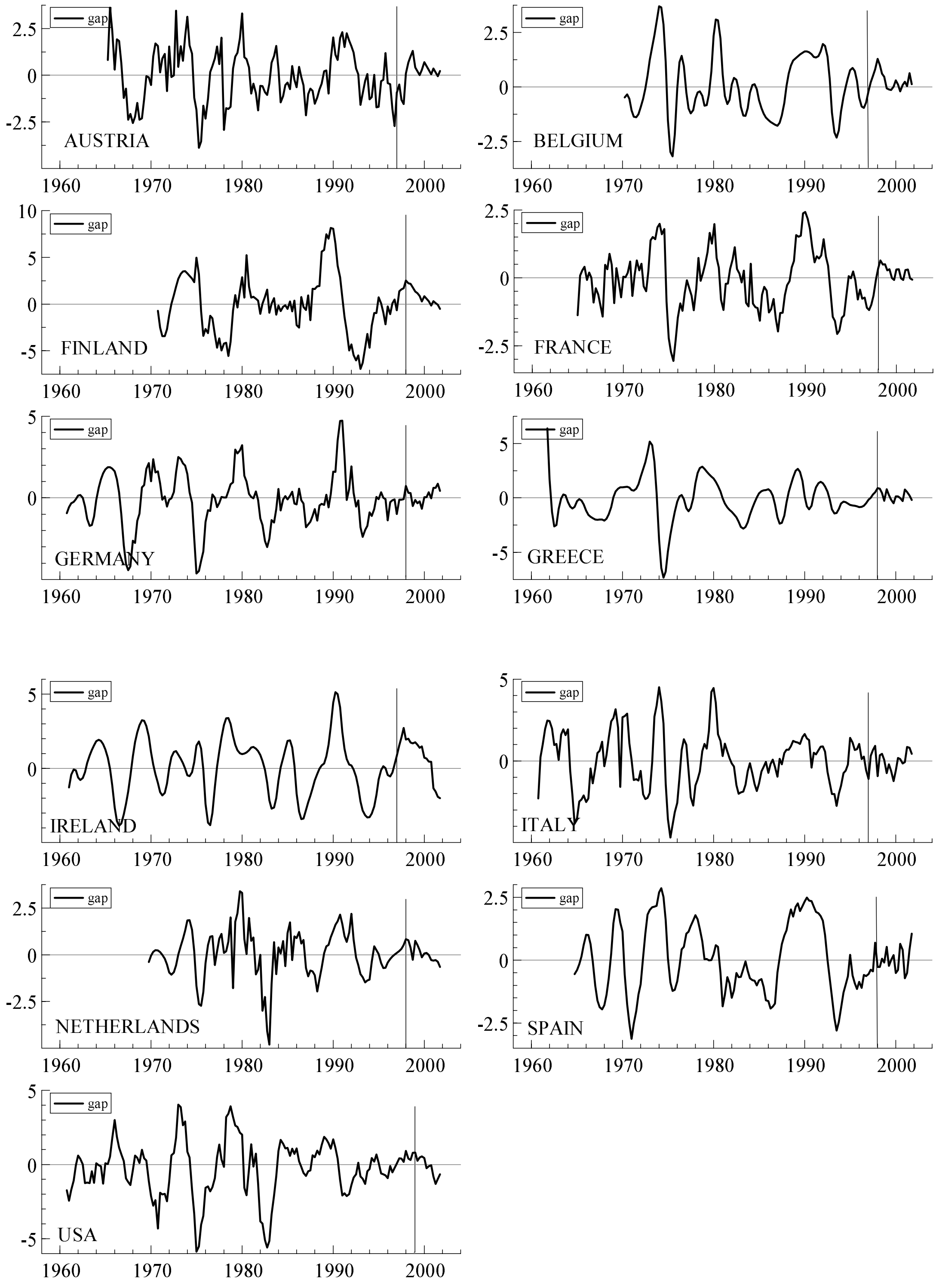

Figure 2: Estimates of the output gap for eleven countries.

One note should be added concerning recently fast growing countries like Ireland or Finland. It may be surprising to see a negative, closed or only slightly positive output gap for these countries in the recent past. However, it should again be emphasized that this may at least partly be due to the properties of the HP filter. As mentioned above the "unemployment gap", i.e. the gap between the NAWRU and the unemployment series, is small in cases where the end of the sample shows a clear trend. Thus the fact that the NAWRU estimates follow closely the unemployment rate translates into an (almost) closed output gap despite high economic growth.

3.4 Comparison with results from similar studies

Figure (3) presents a comparison of my own results with output gap estimates from two international institutions for the ten European countries in my sample. The OECD estimates are based on the production function approach using the less general Cobb Douglas form. The European Commission on the other hand uses the univariate HP filter to split the GDP series into a trend and a cyclical component.

As the concepts underlying the three series are rather distinct it is difficult to qualify the results. The three series show similar business cycles although in detail the estimates can deviate from each other rather substantially. In general the variation is smallest for my own output gap estimates, which might be due to deviating smoothness parameters or a different intensity of the use of the HP filter. The most pronounced difference in the curves, however, is the wide deviation of my estimates from OECD and EC estimates at the end of the sample. This is attributed to the end-of-sample feature of the HP filter. As it can only be overcome by using longer-term forecasts for the relevant series it seems obvious that the two institutions took advantage of available internal long-term forecasts. The variation of the estimates is especially pronounced for recently fast growing countries (Ireland, the Netherlands) or countries that are lagging behind in the business cycle (Italy, Germany). It emphazises again the uncertainty surrounding any output gap estimates based on a mechanic filter at the beginning and the end of the sample.

3.5 What can we learn from the path of the technological progress estimates?

One special feature of the approach chosen in this paper is that the specific form of the production function with input augmentation in the technological progress allows to gain insight into the driving forces of economic growth. Figure (4) depicts the logs of these technological progress series for the six countries for which the Cobb Douglas form was rejected.

To give a broad-brush picture, the labor-augmenting technological progress shows an upward trend in most cases while the capital-augmenting technological series is downward sloping. In detail, however, the single countries show

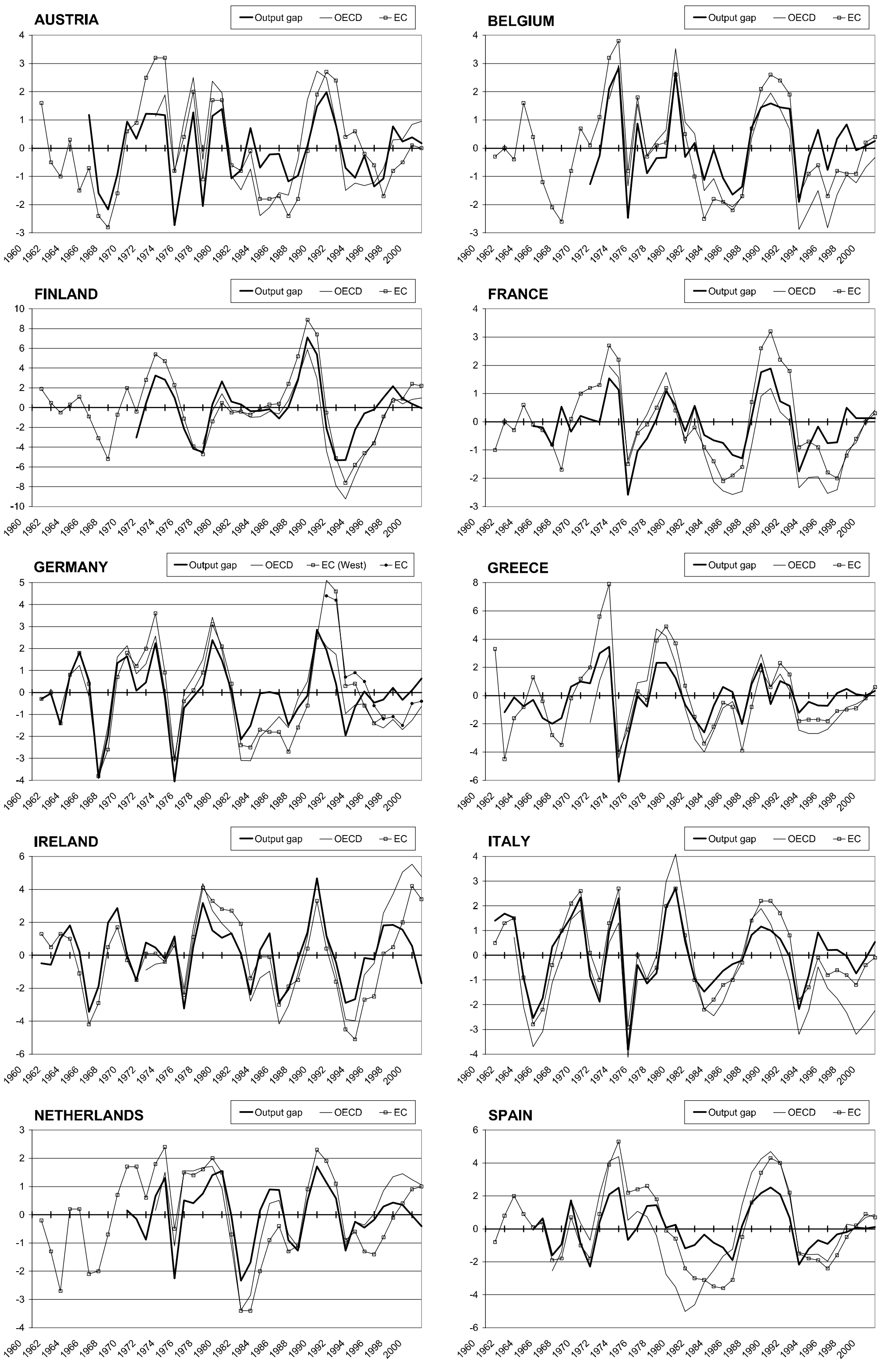

Figure 3: Comparison of own results with output gap estimates of the OECD (based on the production function approach) and the European Commission (based on the HP filter) for ten European countries (yearly data).

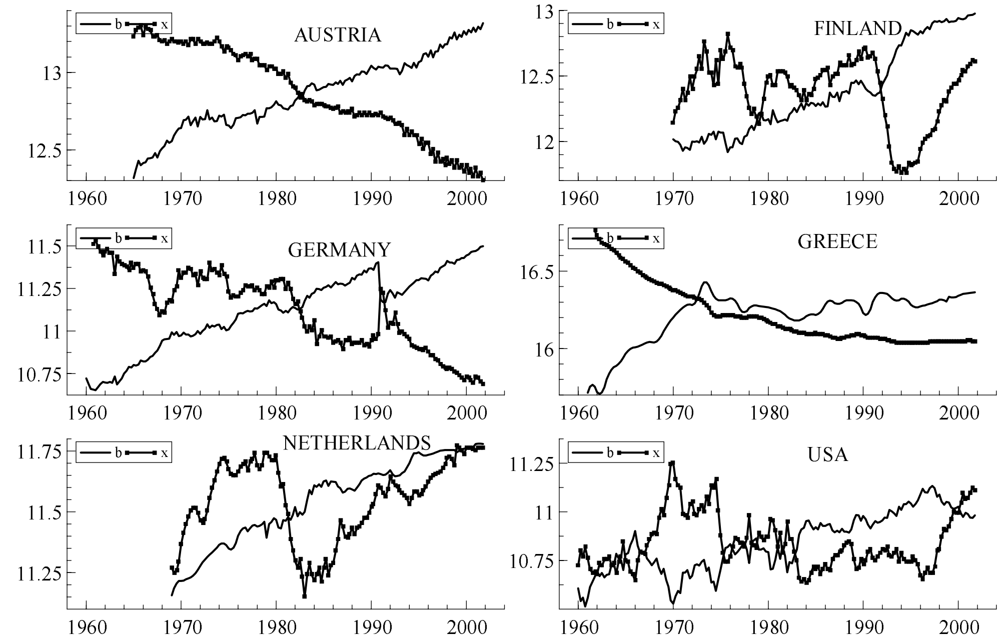

Figure 4: Labor- and capital-augmenting technological progress for Austria, Finland, Germany, Greece, the Netherlands and the United States (scale adjusted)

rather different patterns. While for Austria the path of the two series does not show any structural breaks the severe recession that hit the Finnish economy at the beginning of the 1990s is clearly visible. This recession was not a typical business cycle slowdown but due to the structural shock of the sharp fall in trade with the former Soviet Union. In this case the additional information from splitting up the technological progress gives deeper insight into the underlying factors of the economic breakdown. While graphs of the total factor productivity show a marked slowdown during the recession we can now see that contrastingly labor-augmenting technological progress only decreased slightly between 1990 and 1992. This was followed by a marked upswing 1993-95 due to restructuring in the business sector as low productivity jobs were abolished. The capital-augmenting technological progress, however, was seriously hit by the recession as the capital utilization rate decreased heavily. It only recovered in 1994 showing since then a steep upward trend in the curve. This can be explained by the fact that after the recession profound measures were taken in the business sector to increase capital productivity and fits to the observation that since 1993 the aggregate capital stock was almost stable. The growth rate of the labor-augmenting technological progress, however, has leveled out since the mid 1990s. The recent rapid growth of the Solow residual is thus attributable to the exploding capital-augmenting technological progress in the second half of the 1990s.

The third graph shows clearly the structural break of the German unification. After that the two series evolve at almost unchanged paths, with the capital-augmenting technological progress however decreasing faster in the aftermath of unification. In the Greek case the almost stable labor-augmenting technological progress since the mid 1970s can be explained by the importance of tourism for the Greek economy. The most noticeable feature in the next graph is the evolution of the capital-augmenting technological progress in the Netherlands. In deviation from the pattern for the other countries it is increasing most of the time except for a serious drop in the beginning of the 1980s. This slump was the result of a rapid rise in gas revenues in the second half of the 1970s that was followed by an undermination of the competitive position of the non-gas sector. The economy was characterized by high unit labor costs and low profitability in the non-gas sector and rising unemployment rates. The following upward swing in the path of capital-augmenting technological progress can be considered as a catching-up process.

The US case finally shows two series that are almost mirror images due to the fact that the elasticity of substitution is close to 1 (see section 3.1). However, they still contain interesting information as toward the end of the sample labor-augmenting technological progress decreases slightly while capital-augmenting technological progress on the other hand is growing remarkably fast. This pattern suggests that the main driving force behind the high economic growth during the second half of the 1990s was due to developments on the capital side.

Figure (5) shows the logs of the total factor productivity for the five countries for which I proceeded with the Cobb Douglas case. As expected the series are upward sloping in most of the cases, only the Spanish Solow residual shows a downward trend. This seems counterintuitive and may be explained by the special structure of the Spanish business sector. The particularly high self-employment rate makes the measurement of the capital stock especially difficult. Mismeasurement in times of restructuring in the business sector can lead to an underestimation of the capital stock growth rates which in turn influences the path of total factor productivity estimates.

4 Conclusion and topics for further research

Output gaps were calculated using the production function approach. Instead of choosing the Cobb Douglas form this paper estimated the parameters of the Constant Elasticity of Substitution (CES) production function, separating labor- and capital-augmenting technological progress. The estimates for the substitution parameter suggest that for more than half of the countries the use of the Cobb Douglas production function would not be appropriate.

The calculated output gaps show clear and quite similar cyclical patterns for the countries in the past. Almost all countries show a negative output gap at the end of the 1960s that turns into a positive gap in the first half of the 1970s. After a period of output below its potential in the second half of the 1970s almost all countries show a boom around 1980 that turns into a period of closed or negative output gaps during the 1990s. After another boom phase around 1990 the following years show again negative output gaps that close around the end of the millennium.

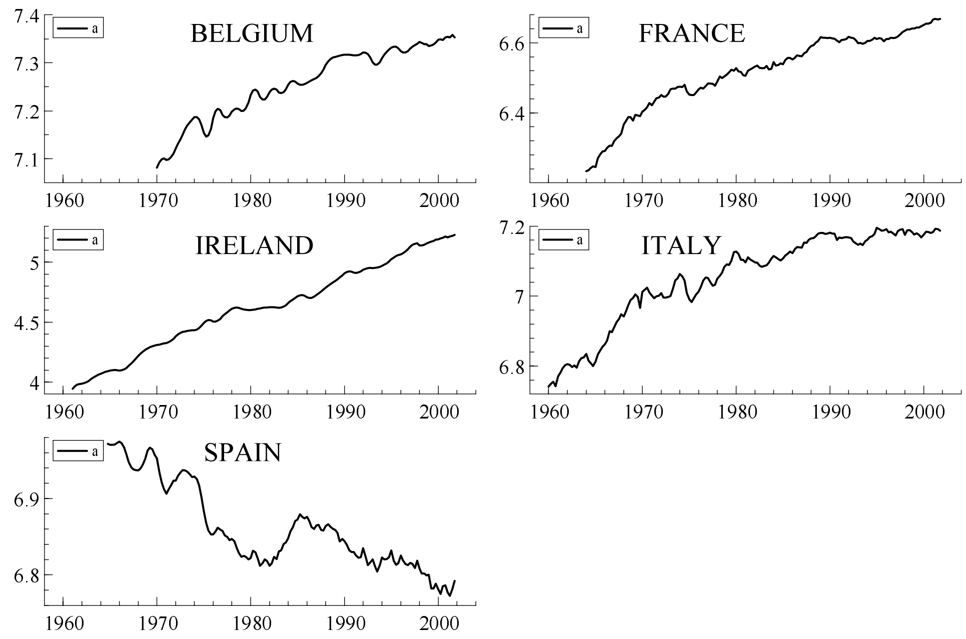

Figure 5: Total factor productivity for Belgium, France, Ireland, Italy and Spain.

The figures indicate that the output gaps have closed in recent time or would seem to be closing in the near future although this may be due to the end-of-sample problem associated with the use of the HP filter in several steps of the calculation process. Even though forecasts were used to reduce the end-point problem in smoothing, the very recent and current output gap estimates should still be interpreted with great caution. This is especially visible when comparing the results with estimates from international institutions (OECD, European Commission) who obviously work with long-term forecast series.

For Austria, Belgium, France, Spain and the Netherlands the estimated output gaps remain within a range of $\pm 3\%$ for most of the time. For Germany, Ireland, Italy and the United States the output gaps fluctuate mostly within a band of $\pm 6\%$. Finland and Greece show outliers that go beyond that range.

The analysis of the path of the two separate technological variables shows that this approach gives interesting new insights into the factors underlying economic growth. Especially in times of structural breaks like the severe recession that hit the Finnish economy in the beginning of the 1990s or the German unification, it is interesting to see whether the labor- or capital-augmenting technological progress was hit more seriously.

There are several ways in which this study can be extended.

First, the new literature on panel data and cointegration could be adopted to estimate a common production function for the whole European Monetary Union. This approach has the advantage that the bigger data set gives more significant results. Furthermore, it would allow to reduce the data set to the very recent time or to test for different subsamples whether the parameters change with respect to time. It could be tested whether an EMU-wide production function is valid for all the countries or whether subgroups can be found with a common production function.

Second, the parameters of the production function should be tested for structural breaks.

Third, own forecasts could be made for the main variables to increase the forecast horizon to get better estimates for the current output gap. However as Rünstler (2001) shows simple ARIMA-based forecasts help to reduce the end-of-sample problem to a certain extent, but they appear to under-estimate the size of the cyclical variation, thus bringing in another bias. Own macroeconomic forecasts on the other hand are more likely to be of use. However, this goes beyond the scope of this paper.

5 Annex

In the following are some details on the estimation of the substitution parameter and the NAWRU for the single countries:

- **Austria**: Data range for the calculation of ρ (labor and capital market equation): 75(1)–95(3), 4 lags in the VAR.
- **Belgium**: No stable and reasonable estimates for the substitution parameter could be found from cointegration analysis, thus the Cobb Douglas form was taken as a benchmark. The wage rate had to be seasonally adjusted in order to get reasonable NAWRU estimates.
- **Finland**: Data range for the calculation of ρ (labor market equation): 71(1)–92(1), 4 lags in the VAR. Because no stable and reasonable estimates for ρ could be found using the whole data set, it was reduced so that the deep recession in 1992 was excluded. However, Ripatti and Vilmunen (2001) use the whole data set and an extended approach and get a substitution elasticity σ of 0.59, which is rather close to my result (0.54). The wage rate had to be seasonally adjusted in order to get reasonable NAWRU estimates.
- **France**: Data range for the calculation of ρ (labor market equation): 75(1)–98(2), 2 lags in the VAR. The wage rate had to be seasonally adjusted in order to get reasonable NAWRU estimates.
- **Germany**: Data range for the calculation of ρ (labor market equation): 62(1)–90(4), 4 lags in the VAR. For the estimation process of the parameters of the CES production function only the data up to the German unification were used, as even the inclusion of dummies and step dummies was not sufficient to get robust results. It was assumed that the parameters of the CES remained stable after unification and were thus used for the whole data set. This was necessary as the time span since unification is too short to derive significant estimates. For the HP-filtering process the after-unification data for all the series were shifted down to get a smooth curve, later the filtered data were shifted up again for the same amount.
- **Greece**: Data range for the calculation of ρ (labor and capital market equation): 63(1)–96(4), 4 lags in the VAR. The wage rate had to be seasonally adjusted in order to get reasonable NAWRU estimates.
- **Ireland**: Data range for the calculation of ρ (labor market equation): 78(1)–96(4), 4 lags in the VAR. The wage rate had to be seasonally adjusted in order to get reasonable NAWRU estimates.
- **Italy**: No stable and reasonable estimates for the substitution parameter could be found from cointegration analysis, thus the Cobb Douglas form was taken as a benchmark. The wage rate had to be seasonally adjusted in order to get reasonable NAWRU estimates.

- **The Netherlands**: Data range for the calculation of ρ (labor market equation): 75(1)–97(4), 4 lags in the VAR. The wage rate had to be seasonally adjusted in order to get reasonable NAWRU estimates.

- **Spain**: Data range for the calculation of ρ (capital market equation): 80(1)–96(4), 4 lags in the VAR. The wage rate had to be seasonally adjusted in order to get reasonable NAWRU estimates.

- **United States**: Data range for the calculation of ρ (labor market equation): 68(1)–97(4), 2 lags in the VAR.

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