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Abstract

Output gaps for 11 EU countries, the US and Japan are constructed based on measures of potential output derived from a CES production function. This production function accommodates differences in substitution elasticities between countries. Indeed, the empirical evidence shows that real wage elasticities of labour demand differ widely across countries. The national output gaps constructed turn out to significantly explain future changes in inflation. Moreover, the analysis also reveals that an aggregate European output gap significantly precedes aggregate European inflation, as well as inflation in the individual EU countries. These findings imply that an aggregate European output gap may serve as an inflation indicator for the preparation of a single European monetary policy.

Key words: output gap, potential output, inflation, Phillips curve

JEL code: E32, E5

1 INTRODUCTION

The relation between economic activity and inflation is a well-known research topic which has particular relevance to monetary policy. Indeed, monetary authorities base their policies on a number of indicators which may provide information on the future course of inflation. The deviations of output and unemployment from their equilibrium levels, hereafter referred to as *output gap* and *unemployment gap*, respectively, are indicators of inflation which recently received a lot of attention, both in academic circles and among policy-makers. Recent studies focused, among other things, on the construction of equilibrium levels of output (potential output) and unemployment (NAIRU), as well as on the role of output and unemployment gaps in the monetary policy preparation process [1].

The study presented here focuses predominantly on the construction of output gaps and their relation to inflation for 11 EU countries (*i.e.* Austria, Belgium, Germany, Denmark, Spain, Finland, France, Italy, the Netherlands, Sweden and the United Kingdom), complemented by Japan and the United States for comparison. The output gaps have been defined in terms of gross value added in businesses and thus differ from existing output gaps constructed by institutions such as the OECD and the IMF, which are formulated in terms of gross domestic product. The reason for the construction of these alternative output gaps is that these will be employed in the multi-country model developed by the Nederlandsche Bank, EUROMON, and will thus have to be constructed and endogenized in a model-consistent way [2]. In addition, there are other differences which will be discussed later.

The output gap measures the difference between actual and potential output, and reflects tensions on goods and labour markets. Deviations from potential output are not permanent but will sooner or later evoke a price response restoring the equilibrium between actual and potential output. Hence, output gaps may play a significant role as information variables in preparing Europe's single monetary policy. In addition, output gaps may provide insight into the sensitivity of public finances to cyclical developments. This is of particular importance for a proper understanding of developments in national budget deficits in the euro area, especially given the arrangements laid down in the Stability Pact.

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[1] See *e.g.* Giorno, Richardson, Rosevaere and Van den Noord (1995), Clark, Laxton and Rose (1996), Gordon (1997), De Masi (1997), Debelle and Laxton (1997), Rasi and Viikari (1998) and Estrella and Mishkin (1998).
[2] See De Bondt, Van Els and Stokman (1997).

Potential output and thus the output gap are not observed directly and must therefore be constructed using information from other economic aggregates which can be observed. In the present study, output gaps have been constructed on the basis of the production function method, which explicitly relates potential output to the availability of factors of production and to technological change by means of a production function. In contrast to the OECD and IMF, which employ a Cobb-Douglas production function, the present study adopts the more general Constant Elasticity of Substitution (CES) production function to model the production process [3]. The CES production function allows for differences in substitution elasticities between countries. One of the advantages of the production function method over other calculation methods for potential output and output gaps is the required consistency with the model structure of EUROMON referred to above. EUROMON not only describes the demand side of the economies of EU countries, Japan and the US, but also the supply side.

The empirical results of the study show that overall the flucutuations in the national output gaps significantly precede movements in inflation in the countries concerned and can thus serve as information variables in monetary policy preparation. In addition, taking into account foreign import prices, the aggregate European output gap turns out to make a significant contribution to explaining inflation, both for the EU and euro area as a whole as for almost all individual EU countries. This is an interesting result, as the ECB's policy will focus predominantly on the monetary situation and prospects for inflation within the entire euro area. The fact that an aggregate European output gap has predictive power for inflation in individual countries may strengthen its position an a policy indicator.

The present study is organized as follows. Section 2 first briefly discusses a number of conceptual and methodological aspects. In Section 3 the used method of constructing output gaps is explained in greater detail. Section 4 goes into the empirical results, particularly the estimated parameters of the CES production functions for the various countries and the calculated output gaps which are partly based on them. Also, a comparison is made with the output gaps constructed by the OECD. Subsequently, Section 5 deals in greater detail with the relationship between output gaps and inflation, both for individual countries and for the EU and the euro area as a whole. Finally, Section 6 makes a number of comments and presents the most important conclusions.

[3] For a concise overview of the methodology adopted by various policy institutions, see EMI (1997). In particular, the Deutsche Bundesbank also employs a CES-production function approach to estimate the output gap (see Deutsche Bundesbank Monatsbericht (1995)).

2 CONCEPTUAL AND METHODOLOGICAL ASPECTS

An output gap is defined as the difference between actual output and potential output. Potential output describes the supply side of the economy and reflects the production level at *normal* utilization of the factors of production at the current state of technology. As potential output is ultimately determined by the availability of factors of production and technological progress, its trend corresponds to the economy's sustainable long-term growth. The idea underlying output gaps is that due to the presence of short-term price rigidities demand shocks provoke a supply reaction, causing actual and potential output to differ. These differences (*i.e.* an output gap which is not zero) cannot, however, last in the long term and will trigger a price adjustment process to restore equilibrium. In this light, potential output is sometimes also defined as the output level in a situation of stable inflation, and thus an output gap may also be viewed as a tension variable leading inflation. However, the difficulty in deriving an output gap is that potential output is an *unobserved* variable. Potential output must therefore be constructed. Various methods have been designed for quantifying potential output, starting with the seminal work of Okun (1962). Broadly stated, the main difference between the alternative methods lies in the way in which use is made of information contained in other economic variables.

A first class of methodology concerns filter methods, distilling information from observed economic variables which are assumed to be highly correlated with potential output. In their most simple form – the so-called univariate filter methods - potential output is derived directly from actual output by applying a filter for trend calculation, for instance the Hodrick-Prescott (HP) filter or a long-term moving average. The filtered series, then, is potential output**.** However, these simple methods are only statistical tools which do not use economic or structural information, and, in addition, do not provide any insight into the composition of potential output (see De Brouwer (1998) on the performance of the ·μ-filter in measuring the output gap for Australia). Accordingly, Laxton and Tetlow (1992) extend the univariate HP-filter by incorporating additional economic information, such as information on the Phillips-curve, NAIRU and economic indicators (capacity utilization). By conditioning on this information this multivariate HP-filter gives a more precise estimate of potential output.

Another, more advanced, filter method is the so-called unobserved components (UC) approach, which makes use of both actual output and other observed economic variables, such as inflation, to determine potential output. In UC-models the underlying economic structure is formulated in state-space form, and potential output can be derived by for instance using a Kalman filter. The advantage of this method is that it is firmly based on an underlying economic model which combines various sources of relevant information. Gerlach en Smets (1999) have used this approach to estimate an aggregate output gap for the EU and its impact on monetary policy (see also Kuttner (1994), and Rasi and Viikari (1998) for a recent application). A disadvantage is the method's complexity and its difficult operationalization within the framework of macro-economic policy models.

A second methodology used to estimate the potential output is the structural vector autoregression (S-VAR). This method exploits the statistical relationship between inflation and growth to distinguish between permanent and transitory movements in output. It is based on long run restrictions on output and does not constrain the short run dynamics of the permanent component of output. In a recent survey article Dupasquier, Guay and St-Amant (1999) compare the S-VAR with long run restrictions with the so-called Cochrane decomposition method and the multivariate Beveridge-Nelson methodology [4]. It is argued that one advantage of the S-VAR method is that it allows for estimated transitional dynamics following permanent shocks. In terms of precision however, it appears difficult to distinguish between these methodologies.

For the construction of potential output and output gaps, the present study relies on a third methodology, the production function method, which explicitly describes the production process through a production function. This approach has various advantages. The Introduction already referred to the required consistency with EUROMON's model structure. In addition, the use of a production function makes it possible to analyse the underlying components of potential output and to explain output gap fluctuations in terms of changes in factor inputs and total factor productivity. Although the production function method is a structural approach and has a strong intuitive appeal it can be criticized on several grounds. It still relies on simple detrending techniques such as the HP-filter to derive potential output, *ad hoc* assumptions must be made about potential labour and capital, and capital stock data may be of poor quality. Moreover, the choice of the production function is somewhat arbitrary, and the normal capacity utilization may change over time as a result of new production technologies and changes in management techniques. However, most of these criticisms apply to most of the other methods as well. Interestingly, De Brouwer (1998) points out that in estimating output gaps for Australia, the multivariate HP-filter and the production function method perform best in terms of predicting inflation.

An important aspect of the production function method is the choice of the production function. On the one hand, the functional form must be sufficiently flexible to adequately describe the

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[4] The Cochrane decomposition method is based on the permanent income theory and uses consumption to define the permanent component of output (see Cochrane (1994). The Beveridge-Nelson decomposition amounts to saying that any I(1) process can be written as the sum of a random walk, initial conditions and a stationary process. Multivariate extensions have also been applied to identify the trend component of output (see Evans and Reichlin (1994)).

production process, while, on the other, a high degree of flexibility makes the econometric estimation of the production function more difficult. Often a simple Cobb-Douglas specification is postulated to describe the production function, although a major disadvantage is its fixed substitution elasticity. More particularly, in a Cobb-Douglas structure real wage movements have a one-to-one effect on labour productivity; formulated more precisely, a 1% increase in real wages ceteris paribus leads to a 1% decrease in employment. Empirical studies generally do not confirm this fixed pattern. In the present study technology is modelled according to a CES production function. Apart from the fact that real wage elasticity may then differ from –1, and thus vary from country to country, movements in labour productivity are influenced also by technological progress. The CES function may be seen as a generalization of the Cobb-Douglas function. This offers the opportunity to test statistically whether or not the simpler Cobb-Douglas structure could be applied. One drawback of the CES function is that, a priori, there is no guarantee that the labour income share is constant in the steady state or on a long-run balanced growth path. Therefore, using a CES structure in a larger economic model calls for a proper treatment of long-run properties, in particular with respect to price and wage formation. However, a further elaboration of this point is outside the scope of the present study.

3 A CLOSER LOOK AT THE PRODUCTION FUNCTION METHOD

A number of steps can be distinguished in the determination of potential output. The first step is the choice of the production function. The second step comprises the estimation of the production function's parameters. From this, total factor productivity (TFP) can then be derived as the difference between actual and estimated output. TFP is a measure of technological progress. The third step constructs the potential factor inputs, *i.e.* the utilization rate of labour and capital under normal conditions. Potential employment in businesses is calculated on the basis of the NAWRU (non-accelerating wage rate of unemployment) and relates to the level of employment compatible with constant wage inflation. The NAWRU is calculated on the basis of a simple equation which relates unemployment and fluctuations in wage inflation. The stock of potential capital is simply replaced by the actual stock of capital goods. The fourth step derives potential output on the basis of the estimated production function with potential factor inputs and the TFP trend component as arguments. Finally, the output gap is the difference between actual and potential output. Below, the various steps are described in further detail.

Step 1: *CES production function*

The output measure used in empirical analysis in Section 4 below is the real gross value added in businesses, for brevity's sake referred to as output in businesses. Output in businesses Y_t is thus described by the production function

$$Y_t = A_t F(K_{t-1}, L_t \mid \theta) \tag{1}$$

where K_{t-1} en L_t are the factor inputs capital and labour, respectively, and

$$A_t = A e^{\beta\, t + \varepsilon_{y_t}} \tag{2}$$

is total factor productivity. Production technology is described by a CES functional form

$$F(K_{t-1}, L_t \mid \theta) = \left(\delta\, L_t^{-\rho} + (1-\delta)\, K_{t-1}^{-\rho}\right)^{-1/\rho}, \qquad \rho > \text{-}1 \tag{3}$$

with $\theta = \{\delta, \rho\}$, δ being a distribution parameter indicating the labour intensity of output, and ρ, a substitution parameter. Note that constant returns to scale underlies (3). Rewriting (1) in logarithms (represented by lower case letters) gives

$$\begin{aligned} y_t &= a_t + f(K_{t-1}, L_t \mid \theta) = a_t - \frac{1}{\rho} ln\left(\delta\, L_t^{-\rho} + (1-\delta)\, K_{t-1}^{-\rho}\right) = \\ &\quad a + \beta\, t - \frac{1}{\rho} ln\left(\delta\, L_t^{-\rho} + (1-\delta)\, K_{t-1}^{-\rho}\right) + \varepsilon_{y_t}. \end{aligned} \tag{4}$$

If the substitution parameter ρ approaches zero, the CES function reduces to Cobb-Douglas in which the distribution parameter δ – assuming profit maximization – is given by the labour income share [5]. The log of total factor productivity is

$$tfp_t = y_t - f(K_{t-1}, L_t) = a_t = a + \beta\, t + \varepsilon_{y_t}, \tag{5}$$

[5] Formally, $\lim_{\rho \to 0} F(K_{t-1}, L_t \mid \theta) = L_t^{\delta} K_{t-1}^{1-\delta}$.

where the technology parameter β reflects the trend growth rate of total factor productivity and ε_y its stochastic component. From (5) it follows that the description of y_t can be divided into an explained part, $f(K_{t-1}, L_t)$, and an unexplained part, tfp_t. The unexplained part is also known as the Solow residual [6].

Step 2: Determination of the parameters of the CES function and derivation of total factor productivity

The non-linear nature of the CES function makes the estimation of parameters δ en ρ considerably more difficult, in contrast to a Cobb-Douglas specification which has a linear form. The restriction on δ, viz. $0 < \delta < 1$, complicates the non-linear optimization of the estimation problem even further in terms of convergence and finding a global maximum. In order to alleviate these technical problems, the parameters are estimated in two steps. The first step concerns the estimation of ρ and β on the basis of the first-order condition derived from profit maximization under the CES production structure. In logs, the first-order condition yields

$$y_t - l_t = c_0 - \sigma(w_t - p_t) + (1+\sigma)\beta\, t + \varepsilon_t \qquad (6)$$

where

$$\sigma = \frac{-1}{1+\rho} \qquad (7)$$

denotes the real wage elasticity, y_t is output, l_t labour input and $w_t - p_t$ real wages. Equation (6) describes the relation between labour productivity, real wages and technical change. For $\rho = 0$, or $\sigma = -1$, the Cobb-Douglas specification follows, where the trend term disappears from equation (6) and labour productivity is determined entirely by real wages (except for a constant and a white-noise component).

Given estimated values for β en ρ on the basis of (6), δ can now be estimated in a second step by means of estimation of (4). Although the resulting equation (4) is also non-linear, this two-step estimation provides better results than direct estimation of (4) [7]. However, equations (4) and (6) as such are still not particularly suitable for empirical analysis. Due to transaction and

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[6] Strictly speaking, ε_y is the Solow residual.

[7] In addition, in estimating the restricted parameter δ a (continuous) transformation is applied which maps the real numbers on the unit interval.

adjustment costs and the related hoarding of factor inputs, actual output and labour productivity will deviate from their 'equilibrium' levels given by (4) and (6). Hence, we add dynamics to the equilibrium relations and estimate the following *error correction* specification for labour demand

$$\Delta l_t = \alpha_0 + \alpha_1 \Delta l_{t-1} + \alpha_2 \Delta y_t + \alpha_3 \Delta y_{t-1} + \alpha_4 \Delta (w-p)_t + \alpha_5 \Delta (w-p)_{t-1} + \gamma_1 ((y-l) + \sigma (w-p) - (\sigma+1) \beta t)_{t-1} + \varepsilon_{l_t}, \tag{8}$$

and output

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_{t-1} + \alpha_2 \Delta l_t + \alpha_3 \Delta l_{t-1} + \alpha_4 \Delta k_{t-1} + \alpha_5 \Delta k_{t-2} + \gamma_2 ((y-l) + \frac{1}{\bar{\rho}} ln\left[\delta + (1\text{-}\delta)(K/L)^{-\bar{\rho}}\right] \text{-} \bar{\beta} t)_{t-1} + \varepsilon_{y_t}. \tag{9}$$

Estimation of (8) gives coefficients $\bar{\sigma}$, $\bar{\beta}$ and $\bar{\rho} = \rho(\bar{\sigma})$. Given the values for $\bar{\rho}$ and $\bar{\beta}$, equation (9) produces an estimate of the distribution parameter δ [8]. Note that in the error correction term of (9), output is formulated per unit of labour.

On the basis of the estimated values for the parameters $\bar{\theta}$ of the CES-production function, total factor productivity can now be calculated as

$$\overline{tfp}_t = y_t - f(K_{t-1}, L_t \mid \bar{\theta}). \tag{10}$$

Step 3: Determination of potential factor inputs

Before potential output can be determined, the stock of potential capital (K_t^*) and potential employment in businesses (L_t^*) must first be calculated. Generally, the potential stock of capital is replaced by the actual stock of capital goods, justified on the grounds that this series does not show much fluctuations itself, so that

$$K_t^* = K_t. \tag{11}$$

[8] On the basis of (8), under profit maximazition the Cobb-Douglas specification may be tested for statistically via a Wald test using $H_0 : \sigma = -1, \beta = 0$ as null-hypothesis.

Potential employment in businesses is calculated on the basis of the NAWRU concept. The NAWRU is unemployment rate at which nominal wage inflation is constant. In this way, potential output and potential employment are linked to inflation [9]. The NAWRU, however, is not observed directly. Assuming a *constant* NAWRU, it can in principle be calculated from a system of estimated price and wage equations [10]. Recent theoretical insights, however, have shown that equilibrium unemployment is *time-dependent* rather than constant, and follows actual unemployment due to hysteresis effects and the presence of labour market rigidities (Layard, Nickell and Jackman, 1991) [11]. Here, we adopt Elmeskov's (1993) method used at the OECD, to construct a time-varying NAWRU. This method is based on a simple, technical equation which relates unemployment and movements in wage inflation:

$$u_t - u_t^N = \lambda \Delta^2 w_t, \qquad \lambda < 0. \tag{12}$$

This equation postulates that labour market pressures, *i.e.* if the actual unemployment rate is below the NAWRU, translate into increases in wage inflation. Subsequently it is assumed that the NAWRU only changes gradually over time, so that $\Delta u_t^N \approx 0$ approximately holds. Taking left and right first differences in (12) then gives the following expression for λ,

$$\lambda = \frac{\Delta u_t}{\Delta^3 w_t}, \qquad \Delta^3 w_t \neq 0. \tag{13}$$

If we substitute (13) in (12), it then follows that

$$u_t^N = u_t - \frac{\Delta u_t}{\Delta^3 w_t} \Delta^2 w_t. \tag{14}$$

Equation (14) shows that the NAWRU follows actual unemployment and that the difference depends on fluctuations in unemployment and wage inflation. As the NAWRU calculated according to (14) may be very erratic, the HP-filter is subsequently applied to u_t^N, *i.e.* $u_t^{N*} = \mathrm{HPF}(u_t^N)$. This latter variable is used to calculate potential employment on the basis of

$$L_t^* = L_t^{S*}(1 - u_t^{N*}) - L_t^{G*}, \tag{15}$$

[9] Torres and Martin (1990) prove formally that by applying the NAWRU concept in the definition of potential output there is consistency between the labour market and the goods market equilibrium.
[10] This approach is also often adopted in determining NAIRU (non-accelerating inflation rate of unemployment), see for instance Staiger, Stock and Watson (1997) for a calculation of the US NAIRU.
[11] This seems to be validated empirically by the recent period of steadily falling unemployment figures in a situation of relatively stable inflation in, amongst other countries, the US and the Netherlands.

where L_t^{S*} is the HP-filtered labour supply and L_t^{G*} HP-filtered employment in the public sector.

Step 4: Derivation of potential output and output gap

Potential output in businesses is now given by

$$y_t^* = tfp_t^* + f(K_{t-1}^*, L_t^* \mid \bar{\theta}) . \qquad (16)$$

where L_t^* denotes potential labour consistent with the NAWRU, K_t^* the 'normal' stock of capital goods and tfp_t^* total factor productivity at its trend level. Since productivity growth changes over time a simple linear trend is inappropriate, therefore total factor productivity is HP-filtered, *i.e.* $tfp_t^* = \mathrm{HPF}(\overline{tfp}_t)$ [12]. In (16) $\bar{\theta}$ represents the estimated parameters of the CES production function. Finally, for the output gap it follows that

$$gap_t = y_t - y_t^* . \qquad (17)$$

4 EMPIRICAL RESULTS ON OUTPUT GAPS

The output gaps for the 11 EU countries considered and the US and Japan were calculated on the basis of the construction method described above. As noted before, output gaps in the present study relate to the real gross value added in businesses and not to real GDP [13]. Section 4.1 first discusses the NAWRU estimates, that constitutes an important element in deriving potential output. Subsequently, Section 4.2 deals with the estimation results for labour demand and the CES-production function. Finally, Section 4.3 presents the calculated output gaps, referred to as EUROMON output gaps, and compares these to the output gaps calculated by the OECD.

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[12] The actual total factor productivity is generally quite erratic, resulting in -if untrended- the same erratic movements in potential output, which is inconvenient and implausible as a measure of production potential.

[13] There are conceptual problems in the determination of potential production in the public sector (see Giorno *et al.* (1995)).

4.1 The NAWRU

Equation (14) forms the basis for the empirical determination of the NAWRU. It implies that the NAWRU is equal to actual unemployment minus a correction factor, which depends on the movements in wage inflation and the change in actual unemployment. This correction factor

$$c(u_t, w_t) = \frac{\Delta u_t \Delta^2 w_t}{\Delta^3 w_t} \qquad (18)$$

has extreme values if the denominator in (18) is close to zero. This is particularly the case with smoothed quarterly data. Subsequently, extreme outliers distort the HP-filtered NAWRU and thus potential employment and potential output. In such cases, these outliers are corrected by using seasonally adjusted data or by equating the NAWRU in the period(s) concerned to the actual unemployment rate. The data used for calculating the NAWRU relate to the wage rate per employee, w, and unemployment as a percentage of the working population, u [14].

Figure 1 shows the calculated HP-filtered NAWRUs for the 13 individual countries over the 1971-1996 period. The figure indicates that in most countries the NAWRU increases during this period. In the second half of the 1980s, however, a strong economic recovery and the corresponding decrease in unemployment resulted in a temporary drop in the NAWRU.
A striking pattern is the strong rise of the NAWRU in Japan from 1990 onwards, albeit at relatively low absolute levels. A quite different picture emerges for the US, the UK and the Netherlands. In line with declining actual unemployment in a period of relatively stable or falling inflation, the NAWRU in these countries has been decreasing since the mid-1980s: in the US from 8.5% in 1983 to just over 5% in 1996, in the UK from 11% in 1985 to 7% in 1996, and in the Netherlands from 10% in 1985 to just over 6% in 1996 [15]. Finland and Sweden, too, show different developments. In the early 1990s both countries were hit by a severe recession, with negative growth figures in 1991-1993.

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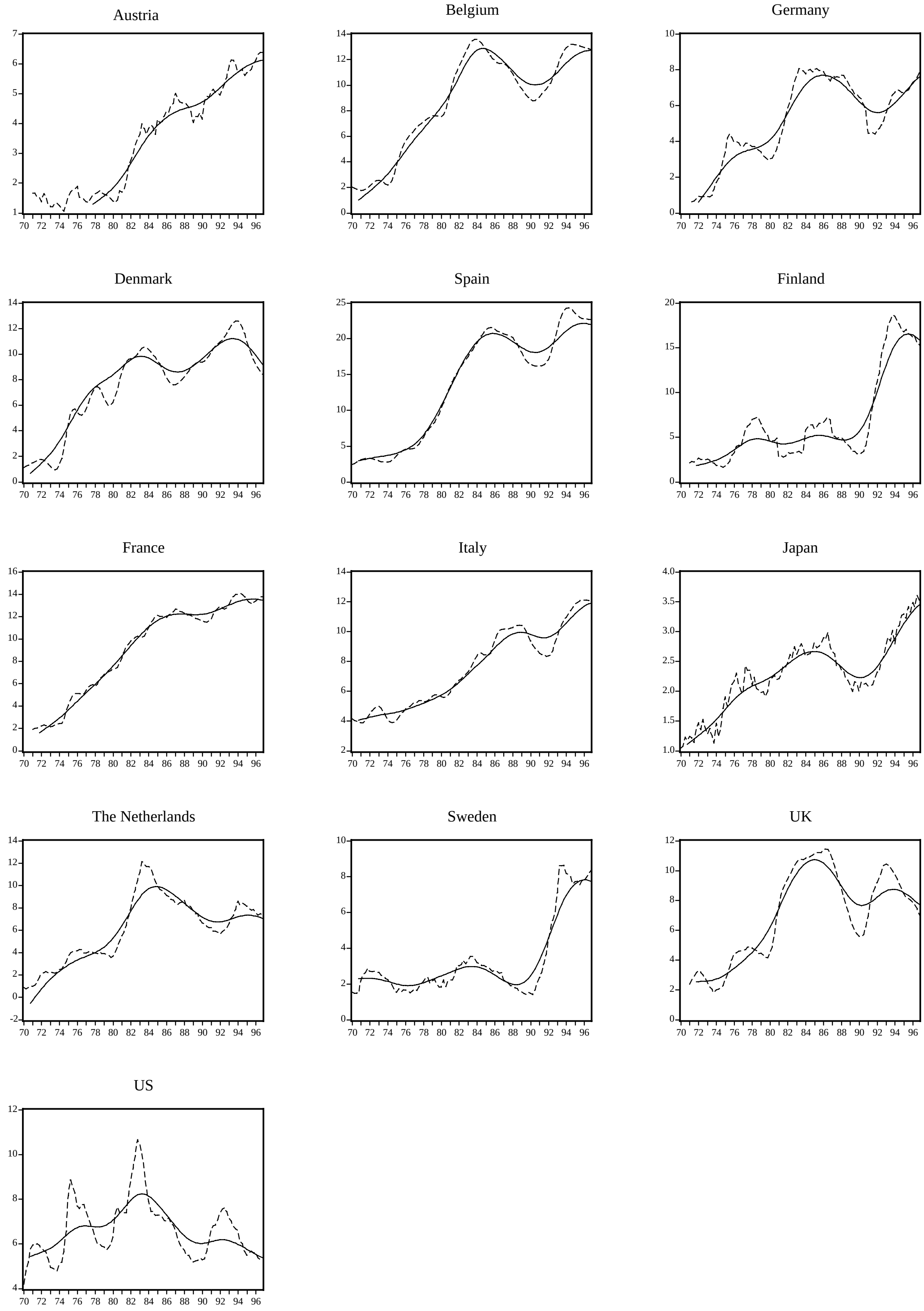
[14] Data have been derived from the EUROMON model database. These relate to figures published by the OECD. Because of the HP filter's endpoint problem, wage and unemployment figures have been supplemented with recent OECD forecasts for 1997-2000 (Economic Outlook, June 1998). As a result, the HP-filtered NAWRUs in 1995 and 1996 are not subject to any distortion. See section 4.3 for a more detailed explanation of the HP filter's endpoint problem.
[15] These estimates for the Netherlands roughly correspond to the estimates for NAIRU reported by Wanningen (1998).

Figure 1: NAWRU (solid) and Unemployment Rate (dashed) (in %)



In Finland the NAWRU rose from 6% in 1990 to 16% in 1994. In Sweden, the NAWRU rose by about 5 percentage points in the same period to a level just below 8%. Remarkably, in most countries the rising trend levelled off or reversed in 1995-1996. This pattern is confirmed by provisional calculations for the NAWRU for recent years (not shown here).

4.2 Estimation results for the labour demand equation and CES-production function

As discussed in Section 3, the parameters of the production function are estimated in two steps. The first step comprises the estimation of labour demand equation (8) [16]. Rewriting first-order condition (6) yields the long-term equation for unemployment

$$l_t = c_0 + y_t + \sigma(w_t - p_t) - (1+\sigma)\beta\, t. \tag{19}$$

This long-term equation implies a long-term 1.0 elasticity of employment vis-à-vis output. In addition, it follows from (19) that a 1% increase in real wages leads to a σ % decrease in employment, and that the trend-based rate of technological change is attended by a decrease in employment of $(1+\sigma)\beta$ % per quarter. The estimates for the parameters concerned were obtained by using dynamic error correction specification (8). Since this dynamic specification generally leads to different short and long-term effects of shocks in output and real wages, one implicitly accounts for the existence of labour hoarding and costs of adjustment. The present study's analysis focuses primarily on the long-term parameters found, which are of main importance for the calculation of potential output.

Annex 1 lists the estimation results. Except for Austria and Denmark, employment l was measured as the number of hours worked in businesses and the wage variable w relates to the wage rate per hour worked in businesses. For Austria and Denmark employment was measured in persons and the wage variable as the wage rate per employee in businesses. Output y is the volume of the gross value added in businesses at factor costs; p is the deflator of gross value added in businesses. The data were taken from the EUROMON model's database and were derived from OECD figures (National Accounts; Employment Outlook). For most countries, figures are available for the sample period 1975:1-1996:4; for earlier years, data are not available for the number of hours worked. For Belgium and Japan, the data period is 1975:1-1995:4; for Austria 1977:1-1995:4; for Denmark 1971:1-1996:4; and for Italy, 1976:1-1996:4.

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[16] Although not specified in (8), seasonal and random dummies have been included in the estimation equation; see Annex 1.

Table 1 shows both the estimated long-term coefficients and, for comparison, the relevant parameters from the NiGEM model (NIESR, 1998). Apart from Spain, for which a Cobb-Douglas production structure was adopted, the estimated long-term wage elasticities σ vary from –0.24 for Austria to –0.82 for the US. In addition, all estimated values for the technology parameter β significantly differ from zero, except those for the US. This tentatively implies that the CES functional form provides a better description of the production structure than Cobb-Douglas. This is confirmed by a formal statistical analysis. The null hypothesis of a Cobb-Douglas specification is rejected in 11 out of 13 cases. Only in Spain and the US a Cobb-Douglas specification is not rejected at the 5% level [17]. For Spain, Cobb-Douglas was actually imposed (with the corresponding –1 wage elasticity) because unrestricted estimation gave the implausible value of $\sigma < -1$. As shown by (19), in the Cobb-Douglas specification the trend term disappears from the labour demand equation because of $\sigma = -1$.

Table 1 Estimated results long-run parameters

Countries	EUROMON			NiGEM	
	δ	σ	β	σ	β
AU	0,56 (c)	-0,24	2,3%*	-0,59	2,2%
BE	0,31*	-0,78*	3,2%*	0,69	1,2%
DE	0,59 (c)	-0,53*	2,7%*	-0,52	3,1%
DK	0,63	-0,61	2,2%*	-0,59	2,2%
ES	-	-1	-	-1	-
FI	0,19	-0,34*	3,4%*	-0,27	2,8%
FR	0,47*	-0,73*	3,5%*	-0,65	2,7%
IT	0,80	-0,52*	3,2%*	5,60	2,6%
NL	0,43	-0,27	2,3%*	-0,59	2,2%
SW	0,14*	-0,68*	2,7%*	-0,59	2,2%
UK	0,17*	-0,60*	1,8%*	-0,67	3,0%
JP	0,12*	-0,30*	2,6%*	-0,41	2,0%
US	0,87*	-0,82*	0,6%	-0,44	1,1%

Explanation: * significant at 5%-level; (c) calibrated value; for Germany, the unification in 1991 is taken into account.

A comparison with NiGEM provides a mixed picture. For Germany, Denmark, Spain, Finland, France, Sweden, the UK and Japan, the estimated substitution elasticities match remarkably well. This also holds for the estimates of the technology parameter β, except for the UK where

[17] For the US, a Cobb-Douglas production structure is rejected at the 10% level.

it is considerably larger on an annual basis. For Austria and the Netherlands, the EUROMON results show a smaller substitution elasticity (in absolute values) of approximately 0.25 against 0.6 according to NiGEM. A possible cause is that the NiGEM results for Austria, Denmark, the Netherlands and Sweden relate to pooled estimations, in which the substitution elasticity and the technology parameter were assumed to be identical across countries. For the US the substitution elasticity in EUROMON (in absolute values) is considerably larger than in NiGEM. This may be due to the much longer sample period of 1965:4-1996:3 on the basis of which the NiGEM equation was estimated. As for Euromon, NiGem also estimates a fairly low level of technological progress for the US. For Belgium and Italy, NiGEM reports a positive σ , or $\rho < -1$, a result which is difficult to interpret in terms of a CES production structure.

From the literature it is known that the distribution parameter δ of the CES production function is difficult to estimate. Given the estimates for σ and β retrieved from the labour demand equation, δ is estimated via equation (9) in a second step. The results are also included in Table 1. In 6 of the 13 cases the distribution parameter is significantly different from zero. It is further remarked that the distribution parameter δ does not represent the labour income share, only in the limit as the substitution elasticity approaches -1. For $\sigma \neq -1$, δ depends, among others, on initial conditions, real wages and a time trend. Therefore, this parameter may vary substantially across countries. As for Austria and Germany, no plausible estimation could be made, and the value was calibrated to match the share of labour in the business sector's value added [18].

4.3 Output gaps

After estimating the parameters of the production function, and constructing the potential output factors as well as the total factor productivity trend, potential output and the output gap can be calculated from (14) and (15). Allowance must be made for the so-called endpoint problem of the HP-filter, which is used several times in the construction of potential output. This problem implies that the HP-trend value of a variable has the tendency to deflect towards the actual values at the end of the observation period. In the present study the endpoint problem was solved by extendng the sample period by using OECD forecasts for the series concerned [19].

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[18] The complete estimation results are not specified here but are available from the authors on request. For the stock of capital goods excluding dwellings in (9), OECD data were used.

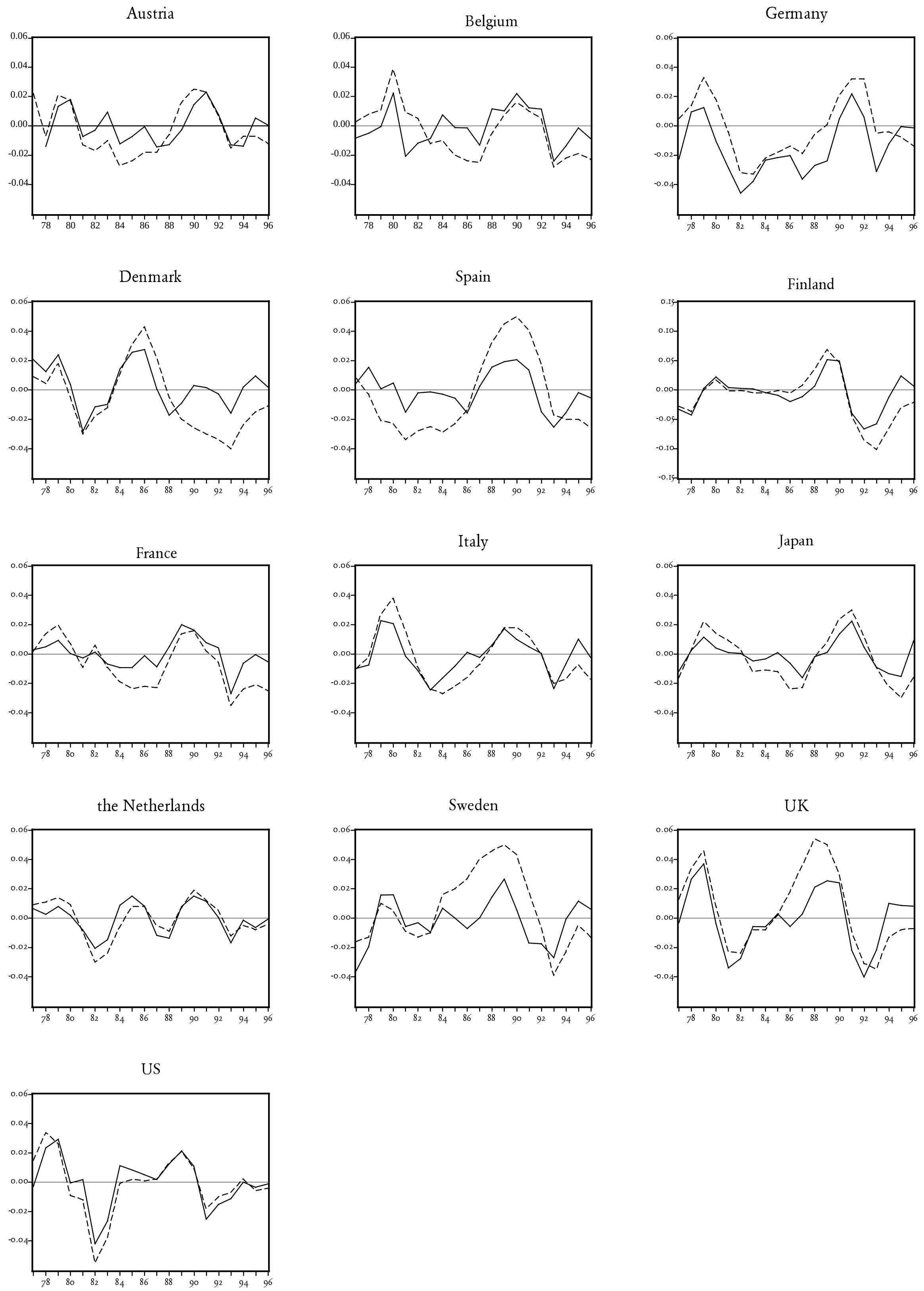
[19] This research report has made use of forecasts for the 1998-2000 period regarding supply of labour, employment, remuneration per employee and output; source: OECD Economic Outlook, June 1998. Of course, the HP filter also has a comparable starting-point problem, which was alleviated in the present study by omitting the first 8 observations from the filtered series.

Figure 2 presents the EUROMON output gaps for the individual countries on an annual basis for the period 1977-1996. For comparison, Figure 2 also includes the OECD output gaps. For 10 out of 13 countries considered, the maximum positive output gap is between 2% and 3%, while the maximum negative gap in 7 out of 13 countries is between –2% and –3%. Finland shows large extremes of +5.2% and –6.7%, which reflect the severe recession that hit the country in the early 1990s. In the early 1980s many countries experienced negative output gaps, which gradually turned into positive gaps in the late 1980s. In the early 1990s output gaps turned negative again, followed by a gradual recovery near the end of the period under review. As Figure 2 shows, the EUROMON output gaps largely correspond with the OECD gaps. Table 2 shows that the correlations for 1977-1996 between the EUROMON and OECD output gaps vary from 0.58 for Sweden to 0.93 for Japan (last column). For 10 of the 13 countries the correlations exceed 0.75. Closer inspection of Table 2 makes clear that the OECD gaps show greater volatility. For 11 out of 13 countries, the extreme values of the OECD output gaps are larger in absolute terms than those of the EUROMON output gaps. The exceptions are Germany and the UK, with larger maximum negative EUROMON output gaps. The differences can be partly explained from differences in approach. The OECD predominantly uses a Cobb-Douglas production function in constructing output gaps.

Table 2 Comparison of EUROMON and OESO output gaps (in %)

Countries	EUROMON			OESO			Correlation
	Minimum	Maximum	Standard Deviation	Minimum	Maximum	Standaard Deviation	
AU	-1,4	2,3	1,2	-2,7	2,5	1,7	0,76
BE	-2,4	2,2	1,3	-2,8	3,9	1,8	0,58
DE	-4,6	2,2	1,9	-3,3	3,3	2,0	0,82
DK	-2,8	2,7	1,5	-4,0	4,3	2,3	0,75
ES	-2,6	2,1	1,3	-3,4	5,0	2,7	0,67
FI	-6,7	5,5	3,1	-10,2	6,9	4,2	0,84
FR	-2,7	2,0	1,1	-3,5	2,0	1,7	0,84
IT	-2,5	2,3	1,3	-2,7	3,8	1,8	0,84
NL	-2,1	1,5	1,1	-3,0	1,9	1,3	0,87
SW	-2,7	2,7	1,4	-3,9	5,0	2,5	0,58
UK	-4,0	3,7	1,4	-3,5	5,4	2,8	0,82
JP	-1,6	2,3	1,0	-3,0	3,0	1,8	0,93
US	-4,2	2,9	1,8	-5,5	3,4	2,0	0,92

Figure 2: Output Gaps: Euromon (solid) and OECD (dashed)



The previous subsection, however, showed that the Cobb-Douglas specification is restrictive and may thus distort the calculation of the output gaps. In addition, there is a difference in aggregation. The EUROMON gap only refers to the business sector while the OECD gap also includes the public sector. Also, the OECD uses other forecasting techniques in order to alleviate the HP-filter's endpoint problem. Finally, in contrast to the OECD, the EUROMON output gap was constructed using employment figures expressed in hours.

Table 3 focuses on the correlation between the calculated EUROMON output gaps for the countries considered. The correlation coefficients in this Table were calculated for the seasonally adjusted quarterly figures of the EUROMON output gaps for the period 1977:1-1996:4. In addition to the national output gaps, the aggregate output gaps for the EU and the euro area were also calculated and correlated with that of the individual countries (see column and row 12) [20]. The aggregate output gaps are based on the aggregation of actual and potential output for the EU and euro area; actual and potential output in businesses were first aggregated individually and then confronted with one another. The aggregates were calculated using constant exchange rates vis-à-vis the Deutsche mark (base year: 1990) [21]. The data of the aggregate output gaps thus calculated cover the period 1978:1-1996:4.

Table 3 Correlation coefficients EUROMON output gaps, 1979:1-1996:4

	AU	BE	DE	DK	ES	FI	FR	IT	NL	SW	UK	EU	JP	US
AU	1,00	0,53	0,66	0,14	0,37	0,12	0,51	0,47	0,43	0,15	0,01	0,58	0,50	-0,16
BE		1,00	0,41	0,24	0,61	0,31	0,58	0,56	0,46	0,31	0,25	0,67	0,47	0,22
DE			1,00	0,30	0,29	-0,07	0,47	0,48	0,59	0,12	0,31	0,67	0,52	0,28
DK				1,00	0,07	-0,08	0,08	0,23	0,51	0,16	0,30	0,34	0,09	0,36
ES					1,00	0,48	0,67	0,43	0,25	0,35	0,55	0,70	0,39	0,26
FI						1,00	0,46	0,42	0,13	0,62	0,49	0,54	0,04	0,25
FR							1,00	0,70	0,45	0,45	0,38	0,81	0,38	0,28
IT								1,00	0,48	0,51	0,40	0,83	0,29	0,45
NL									1,00	0,33	0,38	0,69	0,42	0,53
SW										1,00	0,48	0,64	-0,06	0,44
UK											1,00	0,67	0,05	0,70
EU												1,00	0,43	0,56
JP													1,00	0,00
US														1,00

[20] In our study, the EU includes 11 countries, that is, Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden and the UK. The euro area excludes Denmark, Sweden and the UK from this group.

Looking at the correlation coefficients in Table 3, note that France and Italy are correlated most strongly with the EU gap (approximately 0.82), followed by a large group consisting of Belgium, Germany, the Netherlands, Spain, Sweden and the UK (around 0.65-0.70). Denmark has the lowest correlation with the EU output gap (around 0.35). Remarkably, the correlation coefficient of the output gaps of the US and the UK with that of Japan is virtually zero. The EU output gap's correlation coefficient with the US is 0.56, and with Japan 0.43. The Dutch output gap is most strongly correlated with that of the EU as a whole (0.69), Germany (0.59) and the US (0.53). Splitting the sample period reveals some interesting patterns. Table 3a shows that for a number of countries, in particular Belgium, Spain, Finland and France, the correlation between the EU and euro area on the one hand, with the national gaps on the other, has increased. This indicates economic convergence over the years. However, for Germany and the UK the correlation decreased. In the case of Germany this is likely to be due to the German unification. The US also show a decreasing correlation over time, which for a large part may be attributed to the diverging growth rates between Germany and the US over the last decade.

Table 3a Correlation coefficients EUROMON output gaps, 1979:1-1986:4 and 1987:1-1996:4

	AU	BE	DE	DK	ES	FI	FR	IT	NL	SW	UK	JP	US
79:1-86:4													
euro area	0,67	0,44	0,92	0,34	0,32	0,21	0,72	0,88	0,67	0,67	0,67	0,51	0,64
EU	0,68	0,48	0,92	0,44	0,36	0,15	0,66	0,82	0,74	0,70	0,79	0,53	0,68
87:1-96:4													
euro area	0,72	0,88	0,65	0,29	0,82	0,52	0,92	0,84	0,78	0,42	0,29	0,57	0,18
EU	0,55	0,81	0,49	0,28	0,88	0,72	0,92	0,87	0,70	0,61	0,56	0,44	0,43

5 OUTPUT GAPS AND INFLATION

5.1 The triangle model of inflation

This section deals with the relationship between output gaps and inflation in the countries considered. To what extent do fluctuations in the output gaps constructed precede changes in the

[21] See Winder (1997) for an overview and evaluation of possible aggregation methods in constructing aggregated EU data.

inflation rate? If so, the output gap could serve as an indicator for monetary policy. The framework used here for studying the relationship between output gap and inflation is the modern version of the well-known Phillips curve model, the so-called triangle model of inflation (see Gordon, 1997; Lown and Rich, 1997). This model assumes a direct link between the output gap and inflation. In a full structural model of inflation, however, behaviour in product and labour markets would play an explicit role [22]. In macro-economic policy models, for instance, price rises are explained from cost increases, such as unit labour costs and import costs, as well as changes in profit margins. Clearly, output gap changes not only have an effect on inflation directly, but also via labour costs. Whereas a more structural model of inflation is perhaps to be preferred for the purpose of a detailed policy analysis, our focus here, however, is on the question whether or not the output gap is a suitable indicator for future movements in inflation. No attempt is made to examine the various channels through which the output gap influences inflation.

The triangle model can be described as follows: [23]

$$\pi_t = a(L)\pi_{t-1} + b(L)\, d_t + c(L)\, s_t + \varepsilon_t \qquad (20)$$

The three elements which make up this model are: 1) inertia of the inflation process, captured by including lags of the inflation variable π_t; 2) demand factors or indicators of excess demand, indicated by d_t; and 3) supply factors represented by the symbol s_t. $a(L)$, $b(L)$ and $c(L)$ are polynomials of the lag operator L, with $Lx_t = x_{t-1}$, and ε_t a white noise error term.

Inflation inertia have different causes, including backward-looking elements in expectation formation, institutional factors such as wage and price contracts of a particular duration, and the presence of adjustment and transaction costs. The consumer price index (CPI) was used as a measure of inflation, where $\pi_t = \Delta_4 \ln p_t$, p being the CPI. The exception is Belgium, for which inflation was measured on the basis of the movements in the deflator of private consumption as no sufficiently long CPI series was available. The empirical analysis includes eight lags of inflation (see also Clark, Laxton and Rose, 1996).

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[22] Witness the modelling of inflation in structural macro-economic policy models. For the Dutch case see for instance Fase, Kramer and Boeschoten (1992) and De Bondt, Van Els and Stokman (1997). Gali and Gertler (1998) propose another approach, based on recent advances in the theoretical modelling of inflation dynamics.

[23] Actually, the triangle model may be seen as being derived from a more structural approach in which the labour market and wage determination play an explicit role; see Clarke and Laxton (1997).

The empirical analysis uses the output gap $gap_t = y_t - y_t^*$ as an indicator of excess demand. A positive (negative) output gap means that output in businesses exceeds (falls below) the level of potential output, causing upward (downward) pressures on inflation. Only *lagged* values of the gap have been included as an explanatory factor, and possible cross country differences in the timing of the effects of changes in the output gap on inflation were taken into account. For some countries moving averages of lagged output gaps were used as an explanatory factor. If the contemporaneous output gap were to be used as an explanatory factor, simultaneity problems arise (see also Lown and Rich, 1997). In that case, the estimated coefficient would reflect not only the influence of output gap changes on inflation, but also the consequences of a change in inflation for the output gap [24].

In order to allow for the impact of supply shocks, the equation includes changes in real import prices of goods and services. These changes are determined largely by fluctuations in the prices of energy and other raw materials, but also by the producer prices in the countries to and from which goods and services are exported and imported. This, it should be noted, means that the real import price rise cannot be exclusively considered a supply factor, but also takes into account international spillovers of inflation due to demand shocks. Ceteris paribus, higher (lower) import price rises are attended by higher (lower) domestic inflation. The real import price rise is defined as $\Delta_4 \ln(pm/p)_t$, pm being the price index of imports of goods and services.

Following Lown and Rich (1997), we also included the first differences of the output gaps and the change in real import prices. This allows for the fact that inflation pressures not only depend on the level of the output gap and the magnitude of the import price rise, but also on the degree to which these variables change over time. Apart from a constant, the equation to be estimated, therefore, has the following form:

$$\pi_t = \sum_{j=1}^{8} a_j \pi_{t-j} + b_1 \sum_{j=n}^{N} (gap_{t-j} / (N-n+1)) + c_1 \Delta_4 \ln(pm/p)_{t-1} + d_1 \Delta gap_{t-1} + e_1 \Delta\Delta_4 \ln(pm/p)_t \qquad (21)$$

Here, (n,N) are the gap's first and last lag, respectively, included in the equation. The real import price rise affects inflation with a lag of 1 quarter at the most. Longer lags provided no further

[24] For the US, OLS estimations show a very strong and significant influence of the contemporaneous gap. This significance disappeared, however, if instrumental variables estimation was used. The influence of the unlagged output gap reported by Clarke *et al.* (1996) for the US, may therefore be biased by simultaneity problems.

explanatory information. Only lags of inflation were included in (21), no leads. This seems to be at odds with, for instance, the findings by Clark *et al.* (1996) for the US, who documented that in the dynamics of the inflation process forward-looking expectational forces play an important role. Clark *et al.* used survey results regarding inflation expectations, not leads of the inflation measure itself. However, including leads of inflation reduces the significance of the output gap as an explanatory variable of inflation. This finding may be considered a confirmation of the assumption that output gaps are indicators for future movements in inflation. It would then be obvious that the inclusion of inflation leads obscures the underlying relationship between output gap and inflation.

Another aspect of (21) which has been given a great deal of attention in the literature relates to the sum of the coefficients of the lagged inflation rates. If $\Sigma a_j = 1$, the inflation process has a unit root. This means that supply and demand shocks have a permanent effect on the level of inflation. In the Phillips curve literature the unit root restriction is often imposed because of its consistency with the natural rate hypothesis put forward by Friedman (1968) and Phelps (1968), which states that in the long term no trade-off is possible between output (or unemployment) and inflation.[25] The present study has not automatically imposed the restriction but has tested whether to do so was statistically justified. If $\Sigma a_j < 1$, supply and demand shocks have, in principle, a temporary effect on the inflation level. Nonetheless, this effect will be very persistent if the sum of the coefficients of the lagged inflation terms is close to 1.[26] If the sum of the coefficient is smaller than 1, however, there is a long-term trade-off between inflation and output.

5.2 Empirical results for individual EU countries, Japan and the US

The triangle model (21) was estimated for the 13 countries considered using quarterly data. The exception is Belgium, for which due to a lack of quarterly figures annual data were used. With the exception of Austria and Japan, 1977:1-1996:4 is the sample period for which reliable output gap data are available; for Japan this period is 1979:1-1996:4, and for Austria 1980:1-1996:4. The estimation results are summarized in Table 4. The first row shows the sum of the coefficients of the lagged inflation terms.

[25] Sargent (1974) argues that applying the adding-up restriction is not a *sine qua non* for the natural rate hypothesis.
[26] For many countries the adding-up restriction is rejected statistically, although the sum of the coefficient values is often close to 1 and ADF unit root tests often indicate that inflation is a I(1) variable.

Table 4 Estimation results of the 'triangle' model for individual countries

	AU	BE	DE	DK	ES	FI	FR	IT	NL	SW	UK	JP	US
$\Sigma_{j=1}^{8} a_j$	0,861	0,589	0,886	0,944	0,925	0,956	0,973	0,985	0,901	0,947	0,971	0,817	0,934
b_1	0,173 (2,35)	0,463 (1,34)	0,091 (2,51)	0,140 (2,44)	0,092 (1,82)	0,046 (1,69)	0,073 (2,01)	0,235 (3,35)	0,090 (1,83)	0,328 (3,46)	0,262 (3,36)	0,109 (1,88)	0,130 (2,10)
c_1	0,049 (1,15)	0,261 (2,87)	0,041 (2,66)	0,049 (1,64)	0,022 (2,42)	0,044 (2,19)	0,031 (1,92)	0,035 (3,09)	0,051 (4,21)	0,053 (2,14)	0,051 (2,73)	0,032 (4,67)	0,058 (2,26)
d_1	-	-	-	-	-	0,103 (3,19)	-	-	0,080 (1,94)	-	0,289 (1,80)	-	-
e_1	0,042 (1,43)	0,229 (3,04)	0,084 (2,44)	0,082 (1,86)	-	-	0,048 (1,73)	0,063 (3,78)	0,023 (1,07)	-	-	0,022 (1,91)	0,104 (2,91)
$\overline{R}^2$	0,865	0,643	0,932	0,948	0,981	0,974	0,986	0,987	0,952	0,929	0,953	0,934	0,968
SE	0,543	1,308	0,459	0,805	0,599	0,537	0,466	0,581	0,425	0,896	0,859	0,497	0,529
$\chi^2_{LM(4)}$	5,29 (0,26)	4,23 (0,38)	7,97 (0,09)	19,55 (0,00)	5,15 (0,27)	12,42 (0,01)	9,29 (0,05)	13,24 (0,01)	3,75 (0,44)	5,63 (0,23)	9,03 (0,06)	5,80 (0,21)	13,50 (0,01)
$F_{\Sigma a_j = 1}$	6,81 (0,01)	5,61 (0,04)	9,97 (0,00)	3,60 (0,06)	21,95 (0,00)	4,29 (0,04)	1,94 (0,17)	0,84 (0,36)	13,93 (0,00)	1,47 (0,23)	0,49 (0,49)	17,94 (0,00)	6,28 (0,01)
(n, N)	(1,4)	(1,1)	(1,4)	(1,1)	(1,4)	(2,2)	(1,1)	(1,1)	(2,5)	(2,5)	(1,4)	(2,2)	(1,1)

Explanation: t-values in parentheses calculated on the basis of White heteroskedasticity-consistent standard errors (EU-15). If residual autocorrelation was significant (DK, FI, IT and US), the t-values were calculated on the basis of Newey-West heteroskedasticity and autocorrelation-consistent standard errors. The numbers in parentheses for the autocorrelation and Wald tests indicate their significance.

Using a Wald test it was assessed whether this sum may be equated to 1, in which case supply and demand shocks have a permanent effect on the inflation level. This test's outcomes ($F_{\Sigma a_j = 1}$) are reported in the last row but one. Rows 2-5 list the estimation results for the main parameters of (21), with t-values based on White heteroskedasticity-consistent standard errors reported in parentheses. *SE* is the standard error of the equation's residuals, expressed in percentages of the dependent variable. In addition, tests were conducted for residual autocorrelation up to and including the fourth order by means of the Breusch-Godfrey Lagrange Multiplier test ($\chi^2_{LM(4)}$). If residual autocorrelation could not be rejected (Denmark, Finland, Italy and the US) the t-values of the estimated coefficients were calculated on the basis of Newey-West heteroskedasticity and autocorrelation-consistent standard errors. The last row of the Table provides information on the included lags of the output gap. For Austria, Germany, Spain and the UK, and for the Netherlands and Sweden, a 4-quarter moving average with a 1 quarter and 2 quarter lag, respectively, offers the best results (*i.e.* the strongest significance for the output gap and the best goodness of fit); for Denmark, France, Italy and the US, and for Finland and Japan, it suffices to include 1 quarter and 2 quarter lag of the gap, respectively. For Belgium (annual data), a 1-year lag was found to provide the best results.

With the exception of Belgium, the output gap significantly contributes to the explanation of inflation for all countries. For Spain, Japan and the Netherlands, the output gap is significant at the 10% level; for the other countries at the 5% level or less. For Finland, particularly the short-term effect of the output gap is significant (parameter d_1). On the whole, real import prices contribute considerably to explaining inflation (parameters c_1 and e_1). The only exception is Austria, for which real import prices are not significant. For France, Italy, Sweden and the UK the restriction that the coefficients of the lagged inflation terms add up to 1 could not be rejected at the 10% level. But for other countries, too, except for Belgium and possibly Japan, this sum is close to 1, which means that supply and demand shocks generate no permanent but certainly very persistent inflation effects. It should be noted that the inflation effects of output gap shocks differ considerably by country, as shown in Table 5.

Table 5 Inflation effects of a 1-percentage point increase in the output gap during 8 quarters

Countries	Maximum effect achieved in quarter	Size maximum effect in percentage points
AU	10	0,78
BE	3 (year)	0,64
DE	11	0,53
DK	9	0,93
ES	10	0,39
FI	9	0,45
FR	11	0,61
IT	9	1,67
NL	9	0,43
SW	11	1,78
UK	9	1,91
JP	10	0,51
US	9	0,74

In interpreting the above simulation results, it is important to note that these are the consequence of a 1 percentage point rise of the output gap which lasts for *eight* quarters. Because of the strong persistence of inflation and the duration of the shock, the inflation effects continue to increase for some time, reaching their maximum around the tenth quarter. These maximums are the highest for Italy, Sweden and the UK (plus 1.5 to 2 percentage points), the lowest for Spain, the Netherlands, Finland, Japan and Germany (plus 0.4 to 0.5 percentage point). The inflation effects of shocks that only last one quarter are considerably smaller, albeit that the maximum effect is reached sooner.

5.3 The aggregate European output gap as an inflation indicator for the EU and euro area

In formulating the single European monetary policy, the European Central Bank will focus predominantly on the monetary situation and the prospects for inflation in the euro area as a whole. In policy preparation various indicator variables will play a certain role. An aggregate European output gap is an interesting candidate indicator variable, as it may provide insight into the future development of inflation in the euro area. This section examines to what extent fluctuations in an aggregate European output gap precede inflation, both in the EU and euro area as a whole and in the individual EU countries.

First, we focus on the relationship between the aggregate European output gap and aggregate European inflation. The construction of the aggregate European output gap was already discussed in Section 4.3. The aggregate European inflation relates to a weighted average of the national consumer price indices. As a supply factor we now include the real change in raw materials prices rather than import prices. The raw material price index used is a weighted average of the HWWA raw material price indices in national currencies [27]. The aggregate output gap and consumer price index were calculated for both the EU and the euro area [28]. Table 6 comprises the relevant estimation results, which again are based on equation (21). The first column shows the estimation results for EU inflation, the second for inflation within the euro area. For both levels of aggregation the European output gap significantly contributes to explaining European inflation. In contrast to the euro area, for the EU as a whole the change in the output gap too is a significant explanatory factor for inflation. Also for both levels of aggregation, the real change in raw materials prices significantly influences European inflation. Note that only four rather than eight lags of inflation were included. Including further lags reduces the significance of the other explanatory variables without improving goodness of fit.

[27] The weights employed in constructing the aggregate European CPI and raw materials price index are the shares of the countries considered in real aggregate European output. The latter is defined as the sum of the national real output expressed in Deutsche marks of 1990; see again Winder (1997).
[28] These are approximations. The EU measure actually excludes Ireland, Portugal, Greece and Luxembourg, *i.e.* countries, which have not yet been modelled in EUROMON. The euro area aggregate includes Germany, France, Italy, Spain, the Netherlands, Belgium, Austria and Finland.

Table 6 Estimation results of the ‘triangle’ model for EU inflation

	EU	Euro area
$\Sigma_{j=1}^{4}\alpha_j$	0,968	0,962
b_1	0,126 (3,19)	0,112 (2,64)
c_1	0,010 (3,01)	0,010 (2,47)
d_1	0,121 (2,40)	-
e_1	0,013 (3,73)	0,013 (4,68)
$\overline{R}^2$	0,988	0,985
SE	0,293	0,312
$\chi^2_{LM(4)}$	6,78 (0,15)	10,67 (0,03)
$F_{\Sigma a_j=1}$	5,72 (0,02)	6,36 (0,01)
(n, N)	(2,5)	(2,5)

Explanation: t-values in parentheses calculated on the basis of White heteroskedasticity-consistent standard errors (EU), or Newey-West heteroskedasticity and autocorrelation-consistent standard errors (Euro area). The numbers in parentheses for the autocorrelation and Wald tests indicate their significance.

In the same way as for the individual countries in Section 5.2, we also examined the influence of a temporary increase in the European output gap on inflation in Europe. In order to ensure comparability with the results of Table 5 as much as possible, we again opted for an increase in the output gap by 1 percentage point lasting for eight quarters. Table 7 shows the results. Both for the EU as a whole and the euro area, the maximum inflation effect is reached in quarter 13, *i.e.* 5 quarters after the output gap has returned to its base value. The size of the maximum impact on inflation in Europe is quite similar for both levels of aggregation and is in the order of 0.9 percentage point. These outcomes suggest that output gap movements may indeed have a considerable influence on the movements in inflation in Europe, the more so because in the period 1978-1996 the aggregate output gap fluctuated between plus and minus 3%, with a standard deviation of 1.3%.

Table 7 The effects on European inflation of an increase in the output gap by 1-percentage point for a period of eight quarters

Area	Maximum effect achieved in quarter	Size of maximum effect in percentage points
EU	13	0,94
Euro area	13	0,84

The above results suggest that an aggregate European output gap could very well serve as an indicator variable for the single European monetary policy. Its role as a potential indicator variable may be strengthened even further if the aggregate European output gap would precede inflation in each of the individual countries. Therefore, we again estimated equation (21) for the individual European countries but now replaced the national output gap by the aggregate European output gap. Table 8 shows the estimation results where the European output gap relates to the EU as a whole (that is including the UK, Sweden, and Denmark). The estimation period is 1978:1-1996:4.

From Table 8 it can be concluded that the EU output gap indeed has predictive power for inflation in almost all individual EU countries as well. The only exception is Spain, for which the output gap is far from significant. For Germany, Denmark (see the coefficient on the gap's first difference) and Finland there is significance at the 10% level; for the other countries at the 5% level or less. Again, the increase in real import prices contributes significantly to the explanation of inflation, Denmark being the only clear exception. It is further remarked that the change in the output gap is only significant in Denmark (on the 10% level) and the UK. This corresponds to the findings reported earlier for the EU as a whole. Note that we do not intend to suggest that the aggregate European output gap is a better indicator of inflationary pressures in individual European countries than the national output gaps. However, the fact that the aggregate output gap does precede inflation in individual countries is likely to raise its acceptance as a policy indicator.

Table 8 Estimation results of the 'triangle' model for individual EU countries with EU output gap

	AU	BE	DE	DK	ES	FI	FR	IT	NL	SW	UK
$\Sigma_{j=1}^{8} a_j$	0,926	0,678	0,920	0,954	0,946	0,956	0,966	0,991	0,891	0,940	0,974
b_1	0,173 (2,31)	0,565 (2,83)	0,127 (1,98)	0,120 (1,08)	0,056 (1,13)	0,105 (1,87)	0,121 (2,11)	0,222 (4,19)	0,159 (2,54)	0,253 (2,45)	0,367 (2,71)
c_1	0,059 (1,95)	0,284 (4,54)	0,030 (1,74)	0,035 (1,13)	0,018 (1,85)	0,037 (2,27)	0,033 (2,08)	0,036 (3,47)	0,049 (3,86)	0,044 (1,78)	0,075 (3,11)
d_1	-	-	-	0,326 (1,86)	-	-	-	-	-	-	0,522 (2,81)
e_1	0,047 (1,78)	0,212 (2,89)	0,091 (2,50)	0,052 (0,89)	-	-	0,056 (2,32)	0,058 (3,57)	-	-	-
$\bar{R}^2$	0,880	0,782	0,927	0,951	0,974	0,973	0,989	0,987	0,961	0,924	0,956
SE	0,551	1,083	0,489	0,741	0,614	0,533	0,421	0,566	0,395	0,936	0,839
$\chi^2_{LM(4)}$	4,74 (0,32)	11,14 (0,02)	14,53 (0,01)	11,63 (0,02)	11,12 (0,03)	11,36 (0,02)	2,82 (0,59)	18,28 (0,00)	1,17 (0,88)	4,77 (0,31)	3,98 (0,41)
$F_{\Sigma a_j=1}$	0,02 (0,89)	10,33 (0,01)	4,53 (0,04)	2,87 (0,10)	0,04 (0,85)	0,63 (0,43)	3,59 (0,06)	0,31 (0,58)	18,04 (0,00)	1,76 (0,19)	0,50 (0,48)
(n, N)	(1,8)	(2,2)	(2,5)	(1,4)	(1,4)	(1,1)	(1,3)	(1,1)	(1,8)	(1,4)	(1,1)

Explanation: t-values in parentheses were calculated on the basis of White heteroskedasticity-consistent standard errors. If residual autocorrelation was significant (BE, DE, DK, ES, FI, IT), the t-values were calculated on the basis of Newey-West heteroskedasticity and autocorrelation-consistent standard errors. The numbers in parentheses for the autocorrelation and Wald tests indicate their significance.

6 CONCLUSIONS

This study describes the construction of output gaps for 11 EU countries, viz. Austria, Belgium, Germany, Denmark, Spain, Finland, France, Italy, the Netherlands, Sweden and the UK, as well as Japan and the US. The construction of these output gaps is based on the production function method to derive potential output. Subsequently, it is examined whether these constructed output gaps contain information on future inflation, using a modern version of the Phillips curve model.

In our analysis, the derivation of potential output is based on a CES production structure, which is more general than the commonly used Cobb-Douglas structure. It allows the real wage elasticity of labour demand to differ between countries. In statistical testing, the Cobb-Douglas specification is rejected for 11 out of 13 countries, Spain and the US being the exceptions. The calculated output gaps largely correspond to the output gaps published by the OECD. The differences can be partly attributed to the use of different data (real output in businesses rather than real GDP, employment in hours rather than persons), but also to the choice of the more general CES production function.

With the exception of Belgium, changes in the calculated output gaps significantly precede fluctuations in inflation in the countries considered. However, the inflation effects of the changes in the output gaps differ considerably across countries, with relatively strong effects in Italy, Sweden and the UK, against relatively modest effects in Spain, the Netherlands, Finland, Japan and Germany. Furthermore, the evidence suggests that particularly sustained changes in the output gaps may generate substantial inflation effects. Subsequently, it is investigated whether an aggregate European output gap may serve as an indicator of inflation for the EU or euro area as a whole. This proves to be the case. Interestingly, there is also evidence that the aggregate European output gap may be used as an inflation indicator in the individual countries which may further strengthen its acceptance as a policy indicator.

With regard to future research, the following points should be given attention. The production function method allows for a decomposition of potential output changes in terms of changes in potential factor inputs and total factor productivity. However, to derive the potential factor inputs the present study uses simple detrending techniques such as the HP-filter. It might be fruitful to employ more advanced techniques like the unobservable components method to derive potential output or potential factor inputs, for instance by using a Kalman filter. This would allow a further comparison between alternative methodologies. Moreover, confidence bounds of the gap’s estimate may then also be calculated. Finally, another theme for further study concerns the question whether output gap effects on inflation are non-linear. This has implications for the costs of disinflation policies and hence for the conduct of monetary policy.

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ANNEX 1

Table B1 Estimation results of labour demand equation (8)

	AU	BE	DE	DK	ES	FI	FR	IT	NL	SW	UK	JP	US
α_0	-0,25 (-2,0)	-0,12 (-2,3)	0,18 (2,0)	-0,05 (-1,2)	-0,02 (-2,9)	-0,51 (-4,0)	0,06 (0,8)	-0,13 (-2,7)	-0,24 (-3,2)	-0,08 (-1,7)	-0,15 (-5,8)	-0,10 (-1,3)	-0.14 (2,0)
α_1	-	-	-	0,82 (18,3)	0,72 (9,6)	-	-	-0,41 (-3,9)	0,14 (1,6)	0,46 (4,1)	-	0,24 (2,0)	-
α_2	0,06 (3,44)	0,27 (5,2)	0,11 (2,0)	0,05 (4,1)	-	0,15 (4,9)	0,16 (3,0)	0,01 (0,10)	0,11 (3,8)	-	0,19 (3,8)	-	0,38 (8,6)
α_3	-	-	-0,06 (-2,7)	0,02 (1,7)	0,14 (1,9)	-	-	0,10 (0,88)	-	-	-	-	0,13 (2,1)
α_4	-	-0,15 (-3,0)	-	-0,08 (-2,0)	-0,09 (-1,7)	-0,25 (-4,9)	-0,38 (-1,8)	-0,52 (-4,6)	-0,06 (-2,1)	-0,06 (-3,1)	-0,33 (-4,3)	-0,30 (-1,0)	-0,50 (-2,6)
α_5	-0,02 (-0,9)	-	-	-	-	-	-	-	-	-	-	-	-
γ_1	0,07 (4,8)	0,08 (7,7)	0,09 (3,3)	0,03 (3,4)	0,03 (2,8)	0,26 (6,6)	0,11 (3,4)	0,11 (2,8)	0,13 (5,8)	0,06 (6,4)	0,26 (6,8)	0,29 (-2,7)	0,19 (3,1)
σ	-0,24 (-0,6)	-0,78 (-5,7)	-0,53 (-2,7)	-0,61 (-1,6)	-1	-0,34 (-2,9)	-0,73 (-4,8)	-0,52 (-4,6)	-0,27 (-1,2)	-0,68 (-2,5)	-0,60 (-2,8)	-0,30 (-1,4)	-0,82 (-3,0)
β (in %)	0,58 (17,0)	0,79 (2,8)	0,67 (5,4)	0,55 (4,0)	-	0,83 (21,2)	0,86 (4,3)	0,79 (5,8)	0,57 (11,8)	0,67 (2,2)	0,44 (12,5)	0,65 (14,5)	0,16 (1,9)
SE (in %)	0,21	0,21	0,56	0,19	0,29	0,89	0,56	0,63	0,46	0,56	0,68	1,0	0,37
Adj R^2	0,95	0,74	0,95	0,89	0,90	0,95	0,47	0,83	0,77	0,59	0,70	0,71	0,62
LM(1)	0,04	0,26	0,11	-	0,82	0,55	0,90	0,03	0,75	0,17	0,17	0,04	0,93
LM(4)	0,11	0,05	0,17 *	-	0,20	0,57	0,60	0,05	0,06 *	0,03	0,43	-	0,12
#obs	71	82	86	102	84	87	83	80	81	86	85	79	84

Table B1: Explanatory note

White's heteroskedasticity-consistent t-values are in parentheses. For the test on residual autocorrelation, use was made of the Breusch-Godfrey Lagrange Multiplier Test χ^2_{LM} : its significance is shown in Table B1, rows LM(1) and LM(4).

In addition, note should be taken of the following points:

1. AU: wages as 4-quarter moving average; Δl_{t-4} included as regressor (significant); no seasonal dummies; dummy for 1992:4 included (significant).

2. BE: wages as 2-quarter moving average; seasonal dummies included.

3. DE: seasonal dummies included; dummy for 1991:1 (unification) included as regressor (significant); * $\chi^2_{LM(8)}$ rather than $\chi^2_{LM(4)}$ test.

4. DK: high autocorrelation due to the use of quarterly data constructed by means of the Lisman method; wages as 2-quarter moving average; seasonal dummies included.

5. ES: wages as 4-quarter moving average; Cobb-Douglas production function; seasonal dummies included.

6. FI: seasonal dummies included.

7. FR: wages as 4-quarter moving average; Δl_{t-4} included as regressor (significant); seasonal dummies included.

8. IT: wages as 2-quarter moving average; estimation σ non-significant, so that short-term wage elasticity = long-term wage elasticity (restriction not rejected statistically) was imposed; seasonal dummies included; dummy for 1992:4 included (significant).

9. NL: wages as 4-quarter moving average; Δl_{t-4} included as regressor (non-significant); long-term restriction with $(y/l)_{t-1}$ and $(w/p)_{t-4}$; seasonal dummies included; dummies for 1979:1 (winter) and 1984:1 included (both significant); * $\chi^2_{LM(8)}$ rather than the $\chi^2_{LM(4)}$ test.

10. SW: wages as 2-quarter moving average; no seasonal dummies included; dummy for 1978:1 included (significant).

11. UK: wages as 2-quarter moving average; seasonal dummies included.

12. JP: deficient data on hours worked, therefore implausible estimation results for equation (8); estimation of error correction equation with $\Delta(y/l)$ as the variable to be explained; the estimated equation is then:

$$\Delta(y/l)_t = \alpha_0 + \alpha_1 \Delta(y/l)_{t-4} - \alpha_4 \Delta(w/p)_t - \alpha_5 \Delta(w/p)_{t-1} - \gamma_1 (y/l + \sigma w/p - (\sigma+1)\beta t)_{t-1} + \delta_1 s_1 + \delta_2 s_2 + \delta_3 s_3 + \varepsilon_t,$$

with wages as 4-quarter moving average.

13. US: wages as 4-quarter moving average; no seasonal dummies included.