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POTENTIAL OUTPUT AND THE OUTPUT GAP IN IRELAND

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ABSTRACT

This paper estimates potential output using a number of statistical trend methods and a Cobb Douglas production function. Two measures of the output gap using the Cobb Douglas production function method are estimated. One measure models technology as a linear time trend while the other method allows technology to vary over time. The relationship between the output gap and inflation is examined and the results suggest that the output gap alone is insufficient to explain inflation in the Irish economy. The Cobb Douglas production function output gap which models technology as a linear time trend is the only measure that has a significant relationship with inflation. A measure of “domestically generated” inflation (defined as the gap between the services inflation rate and the goods inflation rate) is used to capture domestic inflationary pressures arising from the Irish labour market. The results imply a stronger relationship between the output gap and “domestically generated” inflation. Estimates of the potential output growth rate of the economy are discussed and preliminary forecasts of the growth of potential output are outlined.

1. INTRODUCTION:

The performance of the Irish economy in recent years has been outstanding. Between 1994 and 2000, Ireland's economic growth, as measured by the annual percentage change in real GDP (Gross Domestic Product), has expanded at an annual average rate of approximately 9 per cent. Over the same time period, we have also experienced annual employment growth of approximately 5 per cent and capital growth of around 4 per cent. In light of this recent extraordinary performance, the aim of this paper is to provide a better understanding of the supply-side of the economy by examining the concept of potential output.

Potential output can be described as a measure of the aggregate supply of an economy. It represents the maximum sustainable level of output that can be produced given the available resources and technology, and this implies that there is full utilisation of these resources namely, labour, capital and technology. Thus, potential output is a summary measure of the production or capacity of the economy. The actual level of output produced in the economy is determined by demand over the business cycle and is measured by the level of real GDP (Gross Domestic Product). The output gap is defined as the difference between actual and potential output. A positive gap is associated with excess demand in the economy, which may lead to inflationary pressures. When the gap is negative, this suggests that potential output exceeds demand. The output gap is unlikely to persist over the long-run, as there will tend to be a wage and price adjustment process to restore equilibrium, where demand and supply are equal. Potential output is often referred to as the output level consistent with stable inflation and full employment (Kenny, 1996). Therefore potential output is associated with a desirable level of output.

Potential output and the output gap are not observed directly and must be estimated using information from other economic aggregates, which can be observed. In the present paper, statistical trend estimation methods will be examined, which includes a linear time trend, split time trends and HP filters. Output gaps will also be constructed on the basis of a Cobb Douglas production function, which relates potential output to the availability of factors of production and technological change. A simultaneous system of equations, which comprises a production function and first order conditions from optimisation of the production function is specified. Profit maximisation results in a three-equation supply-side system. This yields more reliable and plausible results than direct estimation of the production function. Part of this exercise involves estimating the NAWRU (Non-Accelerating Wage Rate of Unemployment), or the equilibrium unemployment rate, which is used to calculate potential employment. The NAWRU is derived using Elmeskov's (1993) method, which assumes that the change in wage inflation is proportional to the unemployment gap.

The sensitivity of the output gap estimates to the use of a linear time trend or HP filtered Total Factor Productivity (TFP) as a proxy for technological progress is assessed. Technological progress is treated as a linear time trend under the Cobb Douglas specification. After estimating the production function using the time trend as an explanatory variable for technical progress, a HP filter is applied to the residual implied by the first stage estimates. The result of the HP filter is used as an exogenous technology component. The system is then re-estimated. This procedure is then repeated until convergence is attained. Only one iteration was required.

The structure of this paper is as follows. In Section 2, methods for estimating potential output are discussed. In Section 3, statistical trend estimation methods are explored. In Section 4, the Cobb Douglas production function is specified, and estimation results are discussed. In Section 5, the relationship between the output gap and inflation is examined. In Section 6, a dynamic correlation analysis between inflation and the output gap are explored and the relationship between the output gap and "domestically generated" inflation is also examined. In Section 7, estimates of the potential output growth rates of the economy are assessed and compared using the different methods. In Section 8, preliminary forecasts of the growth of potential output are outlined. Section 9 concludes. In this paper annual data are taken from the AMECO database of the European Commission DG-ECFIN. Data are available from 1960 until 2000.

2. MEASUREMENT OF POTENTIAL OUTPUT:

A variety of methods can be used to estimate potential output and the output gap. The most common approach uses time-series techniques to decompose actual output into demand and supply components. It was often assumed that the productive potential of the economy grew at a fairly steady state, and thus simple time trends were used to estimate the growth rate of potential output. This implies that the level of potential output growth is constant, and all the movements in output about the time trend are interpreted as demand shocks (Claus, 2000). This approach became inappropriate in the 1970s when trend growth rates in industrial countries declined and inflation increased.

A related time-series technique, which does not imply a constant growth rate for potential output, is the peak-to-peak estimates (Klein and Summers, 1966, Kenny, 1995). This technique involves fitting linear trends between the cyclical peaks in the output series. Major peaks represent points where the economy is operating at its productive potential. The path of potential output is given by the straight line which joins the peaks in output and the trend may be extrapolated forward beyond the most recent peak (Kenny, 1995). While this approach is straightforward and avoids the assumption of a constant growth rate, it has a number of shortcomings. It defines potential output as the maximum attainable level of output in the short-run, whereas policymakers have the notion of long-run sustainability in mind (Claus, 2000). It also requires a large degree of subjective judgement in selecting the major peaks associated with full-resource utilisation (Kenny, 1995).

Other popular measures of potential output include the Hodrick-Prescott filter, which fits a trend through all the observations of real GDP. While this method is relatively simple to apply, as it requires only actual observations of real GDP, the arbitrary choice of the weighting factor (λ) determines the variance of the trend output estimate. It also has the end-point problem, which partly reflects the fitting of a trend line symmetrically through the data (Giorno et al. 1995). This will be discussed in more detail in Section 3. Another related technique is the band pass filter, which extracts cycles from output in a particular frequency band. Blanchard and Quah (1989) develop a structural vector autoregressive model that estimates potential output on the basis of structural assumptions about the nature of economic disturbances (Claus, 2000).

Finally, potential output has also been examined using aggregate production functions. This method estimates a production function, where real GDP (Gross Domestic Product) is some function of capital, labour and technology. The production function is then evaluated when the capital stock is being fully utilised and the labour force is fully employed. This method has been used by Artus (1977), Clark (1979), Perry (1977), Martin (1989), Giorno et al. (1995), Kenny (1995), De Masi (1997), Bolt (1998), Senhadji (2000), and Roeger (2001). The production function approach, while it has intuitive appeal, is difficult to estimate empirically. It also requires the estimation of potential employment using the NAWRU, which is difficult to estimate.

HP filter smoothing techniques have been used in the production function approach, to filter technical progress and potential employment (Giorno et al., 1995, Bolt et al., 1998, Fagan et al., 1998). The results for potential output from the HP filter on real GDP are then very similar to the production function approach. Roeger et al. (2001) attempt to overcome this by estimating the NAIRU based on a "hybrid" form of both Gordon's triangle model of inflation and of the bargaining framework, and trend technical progress is estimated using a simple vintage specification which attempts to explain past movements in technical progress by linking it to changes in the average age of the capital stock (Roeger, 2001). To calculate the trend labour force a HP filter is used at the level of participation rates, which they justify on the basis of the difficulty in deciding whether trends in participation rates for different countries are driven by cyclical factors or by changes in legislation. Potential employment (i.e. the level of effective labour supply) is then equal to the labour force less the NAIRU. They find that the differences between applying a HP filter to real GDP and using the production function approach described above are not that dramatic for the EU and the US for the year 2000, but note that there were minor differences between the two over the last 20 years.

In analysing the various methods for estimating potential output, it can be seen that each method has its own advantages and disadvantages. Since potential output and the NAWRU are both unobservable components, this makes the estimation even more difficult. Therefore in order to get a more reliable estimate of the output gap, various methods are used and the results are compared in Section 3 below.

3. ESTIMATING POTENTIAL OUTPUT AND THE OUTPUT GAP:

3.1 SIMPLE TIME TREND

The simplest method of estimating potential output involves a linear regression of the log of real GDP (ly_t) on a constant and a time trend:

$$ly_t = \text{constant} + \beta t + u_t \qquad (1)$$

This method builds on the basis assumption that GDP can be decomposed into a deterministic trend component and a cyclical component. Potential

Output in this equation is given by the trend component (constant + βt). This method cannot allow for any supply shocks to the system and thus is an unsatisfactory estimate of potential output. The residuals (u_t) from the regression equation provide a measure of the output gap. The results from the estimated equation are:

$$
\begin{aligned}
ly_t &= \underset{(446.62)}{9.115} + \underset{(48.59)}{0.043t} \qquad (2)\\
R^2 &= 0.98, \quad DW = 0.18, \quad \sigma = 0.067
\end{aligned}
$$

t-statistics are in parentheses. The fit of the regression is very high and both the constant and the trend term are highly significant. However the low DW statistic implies that there is autocorrelation in the residuals, which implies that equation (1) is misspecified.[1]

This specification implies a constant potential output growth rate, which is given by the estimated slope coefficient. Given the variation in employment and capital over the sample period, this is a highly questionable assumption. The constant growth rate of potential output implied by this method is approximately 4.3 per cent.[2]

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[1] Analysis of ly_t suggests that ly_t is I(1), i.e. it has a unit root, and therefore this detrending method results in a spurious regression. ly_t is part of a difference stationary process of the form: $ly_t - ly_{t-1}$ = constant + u_t. The constant is an estimate of the growth rate of potential ouput, which is estimated to be 4.8 per cent (results are available upon request). The DW statistic improves when this method is used, but R^2 declines.

[2] A quadratic trend was also examined, which allowed the potential output growth rate to vary, reaching 5.2 per cent in 2000. The estimation results were broadly similar to above, with little improvement in the autocorrelation of the residuals. The output gap implied by this method was slightly smaller and followed the same pattern as in Figure 2.

In Figure 1 in Appendix 2, the graph of actual and potential output are shown, with the corresponding output gap and inflation shown in Figure 2. In the beginning of the 1960s and throughout most of the 1970s, output was above its potential level. From 1983 and until 1995 output was significantly below its trend level. From 1996 onwards, it can be seen that output exceeds potential output. The output gap obtained via this method is large because the trend and cycle are assumed to be fully uncorrelated.

3.2 SPLIT TIME TREND:

This approach also uses time trends to model potential output but loosens the restriction of a constant potential output growth rate by imposing discrete breaks in the trend line fitted to the plot of GDP (Kenny, 1995). However, this requires substantial subjective judgement in the choice of segment endpoints.

This specification allows the estimated trend growth to change between cycles, but not within each cycle (Giorno et al., 1995). I have allowed for a break in the trend in 1967, 1975 and 1990. These breakpoints are justified on the basis that the inputs in the productive process, namely capital and labour, fluctuated around these points. Between 1960 and 1967, the growth rates of both capital and labour were relatively stable, whereas between 1967 and 1975 both inputs were on an upward trend. Between 1975 and 1990, there was a decline in the rate of growth of both capital and labour, and from 1990 to date, we have witnessed extraordinary growth in both inputs. The regression equation to be estimated is given by:

$$ly_t = \text{constant} + \alpha_1 w_{1t} + \alpha_2 w_{2t} + \alpha_3 w_{3t} + \alpha_4 w_{4t} + u_t \qquad (3)$$

where $w_{1t} = T$

and $w_{2t} = 0$ if $T \leq a$, $w_{3t} = 0$ if $T \leq b$, $w_{4t} = 0$ if $T \leq c$

thus:

$w_{2t} = T\text{-}a$ if $a < T$, $w_{3t} = T\text{-}b$ if $b < T$, $w_{4t} = T\text{-}c$ if $c < T$

With the peaks chosen as 1967, 1975, and 1990, a = 7, b = 15 and c = 30. This approach uses dummy variables to impose variation in the potential growth rate. The estimated equation is given by:

$$\underset{(371.05)}{ly_t = 9.16} + \underset{(8.04)}{0.035w_{1t}} + \underset{(2.83)}{0.018w_{2t}} - \underset{(5.48)}{0.021w_{3t}} + \underset{(10.75)}{0.038w_{4t}} \qquad (4)$$

$$R^2 = 0.995, \quad DW = 0.57, \quad \sigma = 0.033$$

The fit of the regression equation is again very high, and all coefficients are highly significant. The growth rate of potential output for each period is given by: α_1, α_2, α_3, and α_4. Between 1961 and 1967, the growth rate of potential output is estimated to have been 3.5 per cent (α_1), and increased to 5.3 per cent ($\alpha_1 + \alpha_2$) between 1968 and 1975. Between 1976 and 1990, the potential output growth rate of the economy declined to 3.2 per cent ($\alpha_1 + \alpha_2 + \alpha_3$) as a result of the oil price shocks and anaemic economic performance. From 1991 to 2000, the growth rate of potential output has increased to 7.0 per cent ($\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4$). This is similar to the results found by Kenny (1996) who noted that potential output growth declined between 1979 and 1987 as a result of labourshedding together with a significant decline in the rate of real net fixed capital formation. From 1987-1996 he found a significant upward shift in the potential growth rate of the Irish economy.

In Figure 3, the graph of actual and potential output is shown, and the accompanying output gap and inflation is in Figure 4. There are broad similarities between the simple time trend estimate and the split time trend. However it can be seen that the size of the output gap is smaller when the growth rate of potential output is allowed to vary. In 1990 the output gap is positive using the split time trend, whereas using the simple trend approach it is negative. In 1996 and 1997, actual output was less than potential output using the split time trend, and between 1998 and 2000 the gap was positive, whereas using the simple time trend, the output gap was positive from 1996 until 2000.

3.3 HODRICK-PRESCOTT FILTER:

The Hodrick-Prescott (HP) filter fits a trend through all the observations of real GDP, regardless of any structural breaks that may have occurred. This is achieved by finding a trend output estimate that simultaneously minimises a weighted average of the gap between output and trend output, at any point in time, and the rate of change in trend output at that point in time. This is achieved through the minimisation of the following objective function:

$$\sum(ly_t - ly_t^*)^2 + \lambda \sum[(ly_{t+1}^* - ly_t^*) - (ly_t^* - ly_{t-1}^*)]^2 \qquad (5)$$

where ly_t and ly_t^* are the logs of real GDP and trend output, respectively. $\Sigma(ly_t - ly_t^*)^2$ represents the sum of squared deviations of actual output (ly) from its trend (ly^*). $\Sigma[(ly_{t+1}^* - ly_t^*) - (ly_t^* - ly_{t-1}^*)]^2$ represents a penalty function which penalises the squared deviations in the growth rate of the trend component. λ is the weighting factor that controls how smooth the resulting trend line is. A low value of λ will produce a trend line that follows actual output very closely, whereas a high value of λ reduces the sensitivity of the trend to short-term fluctuations in actual output, and in the limit the trend converges to the mean growth rate of real GDP over the entire sample period, and thus approximates the linear time trend described earlier.

There are a number of problems in applying the HP filter. The choice of λ determines the variance of the trend output estimate. In the literature λ is set equal to 1600 for quarterly data, as originally chosen by Hodrick and Prescott (1980). This view was based on the ratio of the variance of the cycle to the variance of the second difference of the trend (Hodrick & Prescott, 1980). Conventionally, values of $\lambda = 400$ and 100 have been used for annual data. These values are based on adjusting the smoothing parameter at the quarterly frequency linearly or by the square of the alternative sampling frequency, respectively (Ravn and Uhlig, 1997). However, according to Roeger et al. (2001) a value of $\lambda = 1600$ for quarterly data corresponds to a value of $\lambda = 10$ for annual data, while Ravn and Uhlig (1997) recommend $\lambda = 6.25$, which is based on multiplying by the fourth power of the observation frequency ratios (Ravn and Uhlig, 1997). In this analysis in order to examine the sensitivity of the choice of λ, values of λ equal to 10, 30 and 100 are assessed.

The HP-filter also has an end-point problem. This partly reflects the fitting of a trend line symmetrically through the data. If the beginning and the end of the data set do not reflect similar points in the cycle, then the trend will be pulled upwards or downwards towards the path of actual output for the first few and last few observations (Giorno et al., 1995). To alleviate this problem, GDP projections from internal Central Bank estimates and ESRI forecasts have been used, which extends the sample out to 2005.

In Figures 5, 7 and 9, actual and potential output are shown for different values of lambda, and the corresponding output gaps and inflation are shown in Figures 6, 8 and 10. The output gap is positive between 1978 and 1982, between 1989 and 1991, and between 1997 and 2000. It is negative in the early 1970s, in 1983, from 1986 until 1988, and between 1992 and 1996.

Comparing the results for different values of lambda, it can be seen that the larger the value of lambda, the larger the output gap. The endpoint problem is also noticeable by comparing Figures 5, 7 and 9. The three estimates are broadly similar in terms of when the gap is positive and negative, until 1997. In 1998, when λ=10 and 30, the gap is negative, and the gap is positive, when λ=100. In Figure 11, the three output gap estimates using the three different values of lambda are shown. As can be seen from the graph, the results are broadly similar, but the size of the output gap is much larger when λ=100. For different values of λ, we get different estimates of the growth rate of potential output. Between 1994 and 2000 when λ=10, the growth rate is 8.1 per cent, when λ=30, the growth rate is 7.7 per cent and when λ=100, the growth rate of potential output is approximately 7.2 per cent.

4. COBB DOUGLAS PRODUCTION FUNCTION:

The methods described above to estimate the output gap, attempt to break the series of output into a trend component and deviations from that trend. There is no attempt made to examine the inputs of the productive process, namely capital, labour and technology, and thus they do not represent a particularly appropriate measure of potential output in the Irish context. Below, I use a Cobb Douglas production function to estimate potential output, which involves estimating potential employment on the basis of the NAWRU (Non-Accelerating Wage Rate Of Unemployment).

Direct single equation estimation of a production function typically gives implausible results. This is because one cannot really treat capital and labour as independent variables and proceed to estimate by Ordinary Least Squares (OLS), because the inputs are chosen in some optimal fashion by the producers and therefore the exogeneity assumptions required for OLS will not hold (Griliches and Mairesse, 1995). Bernanke and Gurkaynak (2001) note that estimates of the production function coefficients are not always reasonable and problems with the estimation of production relationships are not uncommon. Thus, a simultaneous system of equations is set up, which consists of first order conditions from optimisation of the production function. Under the assumption of competitive factor markets and imperfect competition in the product market, profit maximisation results in a three-equation supply-side system. In this paper only the Cobb Douglas production function results are presented.[3]

Technological progress can be treated as a linear trend or alternatively as HP filtered total factor productivity (TFP). To estimate the HP filtered technical progress, an iterative approach is used. Firstly the production function is estimated using the time trend as a proxy for technical progress. Then a HP filter is applied to the residual (excluding the linear trend) from the first estimation. The HP-filtered TFP is then used as an explanatory variable for technical progress. This procedure is then repeated until close convergence is attained.

After estimating the production function and using the NAWRU to estimate potential employment, estimates for potential output and the output gap are attained. The sensitivity of the output gap to the use of the linear time trend or the HP-filtered TFP as a measure for technical progress are assessed.

a) MODEL DESCRIPTION:

The Cobb Douglas production function is given by:

$$Y_t = A.K_t^{\beta} L_t^{(1-\beta)} e^{(1-\beta)\alpha.t} \qquad (6)$$

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[3] This methodology can be applied to a CES production function, but results were implausible in the Irish context.

where Y_t is real GDP at constant (1995) market prices, K_t is the capital stock, L_t is the number of people employed, t is a time trend, and A is a scale factor. Equation (6) assumes constant returns to scale. β is the capital share and α is the rate of growth of labour-augmenting, Harrod-neutral technological progress.

To simplify the derivations, it is easier to utilise a variable cost function. From duality theory, technology can be described by a variable cost function:

$$VC_t = A^{-1/(1-\beta)}.W_t.Y_t^{\ 1/(1-\beta)}K_t^{-\beta/(1-\beta)}e^{-\alpha.t} \qquad (7)$$

where VC_t is variable cost and W_t is the nominal aggregate wage rate, which is defined as compensation of employees divided by total employment. Assuming imperfect competition, output prices will be determined as a mark-up over marginal costs. Differentiating equation (7) with respect to output yields an equation for marginal cost which is:

$$MC_t = 1/(1-\beta).A^{-1/(1-\beta)}.W_t.Y_t^{\beta/(1-\beta)}K_t^{-\beta/(1-\beta)}e^{-\alpha.t} \qquad (8)$$

Thus profit maximisation implies that the price equation can be written as:

$$p_t=\varepsilon.MC_t= \varepsilon.1/(1-\beta).A^{-1/(1-\beta)}.W_t.Y_t^{\beta/(1-\beta)}K_t^{-\beta/(1-\beta)}e^{-\alpha.t} \qquad (9)$$

where the mark-up (ε) is equal to $\eta/(\eta-1)$, where η is the representative firm's elasticity of demand. Thus under perfect competition $\varepsilon = 1$ and under imperfect competition $\varepsilon > 1$. p_t is the GDP Deflator.

From the variable cost function, the short-run demand curve for labour can be derived using Sheppard's lemma or alternatively by inverting the production function:

$$L_t = A^{-1/(1-\beta)} Y_t^{1/(1-\beta)} K_t^{-\beta/(1-\beta)} e^{-\alpha.t} \qquad (10)$$

Finally using the envelope theorem, we can derive the marginal shadow value of capital (ρ) by differentiating (7) with respect to capital. This yields:

$$\rho = -\beta/(1-\beta).A^{-1/(1-\beta)} W_t.Y_t^{1/(1-\beta)} K_t^{-1/(1-\beta)} e^{-\alpha.t} \qquad (11)$$

The three equations estimated in this system are: the price equation (9), the labour demand function (10), and the investment equation (11). In log-linear form these three equations are:

$$\begin{aligned} \mathrm{Log}(p_t) = \mathrm{Log}(\varepsilon) - [\mathrm{Log}(1-\beta)+\mathrm{Log}(A)/(1-\beta)] + \mathrm{Log}(W_t) \\ + \beta/(1-\beta)\mathrm{Log}(Y_t/K_t) - \alpha t \end{aligned} \qquad (12)$$

$$\mathrm{Log}(L_t/Y_t) = -\beta\mathrm{Log}(K_t/L_t) - \mathrm{Log}(A) - (1-\beta)\alpha t \qquad (13)$$

$$\mathrm{Log}(CC_t) = \mathrm{Log}(\beta/(1-\beta))+\mathrm{Log}(W_t) - \mathrm{Log}(K_t/L_t) \qquad (14)$$

where CC_t is the user cost of capital. The parameters of the three equations are then estimated jointly in log-linear form using non-linear least squares, taking into account the cross-equation restrictions. Before examining the results, the measurement of the user cost of capital and the NAWRU will be outlined.

b) THE USER COST OF CAPITAL:

To calculate the geometric depreciation rate (δ), the methodology adopted by Frain (1990) is used. This yields an annual depreciation rate of 4.5 per cent. The user cost of capital is defined as:

$$CC_t = ITD_t.(r_t + \delta_t - (ITD^e_{t+1} - ITD_t)/ITD_t) \qquad (15)$$

where ITD is the investment goods deflator, r_t is the nominal cost of borrowing funds and δ_t is the depreciation rate. The final component represents the expected rate of inflation in the investment goods deflator, which is approximated using an exponential smoothing technique. Two measures of the nominal cost of borrowing funds are used, the long-term government bond rate and the short-term interest rate. The user cost of capital is then defined as the average cost of capital obtained from the long-term interest rate measure (CC_1) and the short-term interest rate measure (CC_2):

$$CC_t = (CC_1 + CC_2)/2 \qquad (16)$$

In Figure 12, it can be seen that real interest rates were negative in 1964 and between 1970 and 1978 (apart from 1974, when they were approximately 8.5 per cent) and again in 1998. Therefore the real interest rates used will not correctly reflect the marginal cost of financing. To correct for this, the system of equations (12) – (14) were estimated, where the negative user cost of capital was replaced by missing values in 1973, 1974, 1975 and 1999. The results were then used to calculate the shadow cost of capital, and the system of equations were re-estimated.

c) THE NAWRU:

Potential employment is estimated on the basis of the NAWRU concept. The NAWRU is the unemployment rate at which nominal wage inflation is constant. Elmeskov's (1993) method is used to construct a time-varying NAWRU. This approach has also been used by Bolt and van Els (1998) to estimate the output gap for 11 EU countries, the United States. and Japan and by Giorno et al. (1995). This method assumes that the change in wage inflation is proportional to the gap between actual unemployment and the NAWRU:

$$u_t - u_t^N = \lambda \Delta^2 w_t, \quad \lambda < 0 \qquad (17)$$

where w and u are the levels of wages and unemployment respectively, and Δ^2 is the second difference operator. Equation (17) implies that if the actual unemployment rate is below the NAWRU, this translates into an increase in wage inflation. It is assumed that the NAWRU changes only gradually over time, so $\Delta u_t^N \approx 0$. While this method is very straightforward and simple to apply, it has numerous drawbacks. Assuming that the NAWRU is unchanged in an Irish context may not be plausible, since the actual unemployment rate has fallen from a peak of 16.8 per cent in 1985 and 1986 to its lowest level of approximately 4.2 per cent in 2000. Fitzgerald and Hore (2001) examine wage determination in Ireland, Spain and Portugal. In the case of Ireland and Spain, they note that the labour market has been very slow to clear, and, therefore, the explanation for the path of wages cannot be found by modelling labour demand and supply. In particular, in the case of Ireland, they find that labour supply is infinitely elastic in the long-run through migration, which implies that there will be no long-run Phillips curve effect. They note that changes in unemployment may have a negative effect on wages in the short-run, but in the long-run, workers will emigrate, which will reduce unemployment and therefore eliminate any downward pressure on wages. Thus domestic unemployment does not influence wage rates as excess supply of labour results in emigration. However, they note that the shape of the labour supply curve is changing rapidly. While they estimated a very elastic labour supply curve between 1960 and the late 1990s, they point out that it is now much less elastic, and thus the traditional Phillips curve relationship may be relevant in the future. The Elmeskov method is used here as an approximation. Taking left and right first differences of (17) yields:

$$\lambda = \Delta u_t / \Delta^3 w_t \tag{18}$$

Substituting (18) into (17) yields:

$$u_t^N = u_t - (\Delta u_t / \Delta^3 w_t).\Delta^2 w_t \tag{19}$$

Equation (19) implies that the NAWRU follows actual unemployment and the difference depends on fluctuations in unemployment and wage inflation. The resulting series is then smoothed to eliminate erratic movements using the HP filter.[4] Elmeskov (1993) shows that measures of the NAWRU based on this concept come close to results which use Okun's curve as a starting point. Potential employment is then estimated on the basis of:

$$L_t^{*} = LFN - u_t^{N*} \qquad (20)$$

where LFN is the labour force and u_t^{N*} is the HP-filtered NAWRU. Unlike Giorno et al. (1995) and Bolt (1998), I do not apply the HP filter to the labour force, because the Irish labour force series is relatively smooth.

Using the above results, potential output in logs is defined as:

$$Log(Y_t^{*}) = Log(A) + \beta Log(K_t) + (1-\beta)Log(L_t^{*}) + (1-\beta)\alpha t \qquad (21)$$

Finally, the output gap is defined as:

$$Gap_t = Log(Y_t) - Log(Y_t^{*}) \qquad (22)$$

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[4] The HP filter is applied to u_t^{N} using λ=25 as adopted by Elmeskov (1993) and forecasts are extended to 2005 to take account of the endpoint problem.

An alternative to using a linear trend (t) as a determinant of technological progress is also examined and Total Factor Productivity is calculated as a Solow Residual, i.e.:

$$TFP_t = Log(Y_t) - \beta^* Log(K_t) – (1-\beta^*)Log(L_t) \qquad (23)$$

where β^* is the estimate of β obtained when the system of three equations (12)-(14), is estimated, when the trend is used as a proxy for technical progress. Since productivity growth changes over time, a linear trend may be inappropriate, and thus TFP_t is HP-filtered (TFP_t^*), with lambda=25. To be consistent, the same value of lambda for the NAWRU and TFP are used. $Log(A) + (1-\beta)\alpha t$ is then replaced in equations (12)-(14) by TFP_t^*, and is subsequently re-estimated to see if the estimates of ε and β are similar to the estimates obtained when using the linear trend. This procedure is repeated until convergence is attained. In this case only one iteration was needed. Thus the system of equations becomes:

$$Log(p_t) = Log(\varepsilon) – Log(1-\beta) –1/(1-\beta)TFP_t* + Log(W_t) \\ + \beta/(1-\beta)Log(Y_t/K_t) \qquad (24)$$

$$Log(L_t/Y_t) = - \beta Log(K_t/L_t) – TFP_t* \qquad (25)$$

$$Log(CC_t) = Log(\beta/(1-\beta))+Log(W_t) – Log(K_t/L_t) \qquad (26)$$

Potential output in logs based on this method is:

$$Log(Y_t^*) = \beta Log(K_t) + (1-\beta)Log(L_t^*) + TFP_t^* \qquad (27)$$

The results are then compared when the linear trend is used to approximate potential output.

d) ESTIMATION RESULTS:

The results for equations (12)-(14) and equations (24)-(26) are shown in Tables 1 and 2 respectively, in Appendix 1. Examining Table 1, ε is estimated to be 1.6, and thus the product market is described by imperfect competition, which is what one would expect, and this effect is very significant. The scale parameter A is estimated to be 4.29, and is also significant. β is the income share of capital and is estimated to be 0.24, which implies a labour share of 0.76. This estimate is quite close to the GDP share of compensation to employees, which is approximately 0.53 per cent between 1960 and 2000, and 0.71 per cent when account is made for the self-employed.[5] α reflects the rate of growth labour-augmenting, Harrod-neutral technological progress and is approximately 3.7 per cent per annum and is statistically significant. As can be seen from Table 1, the standard error of the investment equation is quite high. This may reflect the uncertainty associated with the measurement of the user cost of capital. The fit of both the price and labour demand equations are quite high, while the investment equation has a lower R^2. All variables were tested for a unit root using Phillips Perron and Augmented Dickey Fuller tests and were found to be I(1). The DW statistics for all three equations are quite low. The stationarity of the residuals is examined using Phillips Perron tests, and as can be seen in Table 1, the results for the price, labour demand and investment equation imply that the residuals of all three

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[5] A Growth Accounting exercise will be explored in a later paper, where this will be discussed.

equations are stationary. Thus there is statistical evidence to suggest that a cointegrating relationship exists.

In Table 2, the results are shown for equations (24)-(26), where the HP-filtered Solow residual replaces log(A) + $(1-\beta)\alpha t$. This is done to examine whether technological progress should be modelled as a deterministic linear time trend. As can be seen, the results for the parameter estimates are almost identical. However, the results for the price equation now imply non-stationarity of the residuals at the 1% significance level. The DW statistics are again quite low, but improve for the labour demand equation. Thus the use of HP-filtered TFP appears to support the labour demand and investment equations, while the results for the price equation disimprove.

In Table 3 in Appendix 1, the results are shown for equations (12)-(14), when GNP is used as the appropriate measure of output (which excludes profit repatriations by foreign multinationals). As can be seen in Table 3, the results are broadly similar. ε is estimated to be approximately 1.55, implying imperfect competition in the product market, as before. The scale parameter A is approximately 4.67 and is statistically significant. β measuring the capital share increases from approximately 0.24 to 0.25 when GNP is used as the appropriate measure of output, implying that the income share of labour falls from 0.76 to 0.75. α reflects the rate of growth of technical progress and declines from 3.7 per cent to 2.8 per cent per annum. Thus excluding the effects of multinationals implies that the impact of labour and technology declines to some extent, while that of capital increases. The Phillips Perron tests imply that the residuals of the three equations are stationary and thus the statistical evidence suggests that a cointegrating relationship exists.

In Table 4, the results are shown when GNP is used as the measure of output in equations (24)-(26), and technology is modelled as HP-filtered TFP. The parameters estimates are again almost identical. The fit of the labour demand and investment equation increase significantly, and we fail to reject non-stationarity in the residuals. At the 1% significance level, however, the residuals of the price equation appear to be non-stationary. Thus the results are similar to those when GDP was used.

Using the parameter estimates from equations (12)-(14) in Table 1, potential output can be derived as in equation (21). The graph of potential and actual output is shown in Figure 13. Figure 14 shows the corresponding output gap and inflation. The series follows closely the movements of the previous methods used to calculate potential output. However, the output gap was positive in the early 1970s, while it was negative using all the other methods. Inflation declined from a peak of 21 per cent in 1975 to 7.6 per cent in 1978, while the output gap increased from 3.6 per cent to 5.0 per cent over this time period, which appears inconsistent with what theory would suggest. Part of this may reflect rationing being imposed on the economy and as a result those observations have been excluded to account for the negative user cost of capital, as discussed above. Over the remaining period there appears to be a consistent relationship between inflation and the output gap. The output gap is negative from 1981 until 1988 and from 1991 until 1996. The gap is positive from 1997 until 2000 when inflation increased from 1.4 per cent to 5.6 per cent. This result suggests a similar pattern to the simple linear time trend approach in equation (1), due to the way in which technology is modelled.

In Figure 15, the graph of actual and potential output according to equation (27), using the parameter estimates from equations (24)-(26) in Table 2 are shown. The corresponding output gap and inflation are shown in Figure 16. Again the pattern is quite similar to the results of previous methods. The gap is positive in the early 1970s, it is negative between 1974 and 1976, becomes positive between 1977 and 1980. It subsequently stays negative between 1981 and 1988. It is positive between 1989 and 1991, and then becomes negative again between 1992 and 1996. It is then positive from 1997 until 2000. This is very similar to the results from the HP filter approach discussed earlier in equation (5), again due to the way in which technology is modelled. This highlights the importance of how technology is measured, and may warrant future research.

The relationship between inflation and the output gap will now be examined in more detail.

5. THE OUTPUT GAP AND INFLATION:

Table 5 in Appendix 1 displays the contemporaneous correlation for the period 1963-2000 between the annual percentage change in the consumer price index (CPI) and the seven output gap series. Six of these measures exhibit a positive correlation with inflation, consistent with the expected relationship between inflation and the output gap. However, the Cobb Douglas production function gap with HP filtered TFP exhibits a negative correlation with inflation. The HP filter output gap with λ=100 displays the strongest correlation (0.35).

The sample has been divided into sub-samples to examine whether or not the correlations display any stability. Between 1963 and 1984, two of these measures were weakly negatively correlated with inflation. All other methods were positively correlated, while the HP filter output gap with $\lambda = 10$ was only weakly positively correlated with inflation. Between 1984 and 2000, all measures were positively correlated with inflation. The split time trend displayed the strongest correlation over this time period. Thus from the Table 5, it can be seen that the split time trend and the Cobb Douglas production function with HP filtered TFP output gaps do not appear to display any stability since these measures are not consistently positively correlated with inflation across sub-sample periods. Part of the reason for this may be that during the period in which the correlation was negative changes in the output gap may have lead changes in inflation. This is examined in Table 6. The correlation between the Cobb Douglas production function output gap and inflation was consistently positive across sub-samples, but it has weakened considerably in the final sub-period.

Table 6 shows the correlation between the lagged output gap and inflation. Over the entire period, all measures are positively correlated with inflation. The HP filter output gap with λ=100 again displays the highest correlation (0.50). Between 1964 and 1984, all measures again displayed positive correlation, and the simple time trend output gap displayed the strongest correlation (0.58). Between 1984 and 2000, five measures were positively correlated with inflation, while the two Cobb

Douglas output gap measures were weakly negatively correlated with inflation. Thus the correlation between the output gap and inflation appears to have weakened significantly in the final sub-period as the economy has become more open. The results suggest a weak relationship between inflation and the output gap. However no conclusions can be reached from this analysis concerning whether the output gap leads or lags inflation, and therefore a dynamic correlation structure will now be examined.

6. DYNAMIC CORRELATION ANALYSIS:

Figures 17-23 in Appendix 2 presents the dynamic cross correlations of the current output gap measures with leads and lags of inflation between 1966 and 1997. In Figure 17, it can be seen that the simple time trend output gap co-moves positively with current, future and lagged inflation. The contemporaneous correlation coefficient over this period of 0.6 indicates strong correlation, although the correlation is strongest between the contemporaneous output gap and inflation two and three periods ahead (0.7). Backward lags of inflation indicate weak correlation, although it is still relatively high with 1 lag of inflation (0.48).

In Figure 18, it can be seen that the contemporaneous correlation between the HP filter (λ=10) output gap and inflation is weak at 0.2. The correlation is highest between the contemporaneous output gap and inflation two periods ahead (0.31). Backward lags of the output gap appear uncorrelated with the output gap.

In Figure 19, the contemporaneous correlation between the HP filter (λ=30) output gap and inflation is higher than when λ=10, at 0.3. It co-moves positively with current, future and lagged inflation. The correlation is strongest between the contemporaneous output gap and inflation two periods ahead (0.41). Backward lags of inflation are relatively weakly correlated with the contemporaneous output gap.

In Figure 20, the contemporaneous correlation between the HP filter output gap and inflation rises to 0.52, when λ=100, and as the graph indicates it is strongly correlated with forward and lagged inflation. This suggests that the arbitrary choice of the value of λ can lead one to rather conflicting conclusions. Choosing λ=10 would imply very weak correlation between forward lags of inflation and the contemporaneous output gap and backward lags of inflation would appear uncorrelated. However, choosing λ=100 would imply strong correlation between forward and lagged inflation and the contemporaneous output gap. Ravn and Uhlig (1997) suggest that the appropriate value for λ is 6.25 for annual data and this would imply very weak correlation between inflation and the output gap.

In Figure 21, the contemporaneous correlation between inflation and the split time trend output gap is relatively weak at 0.2. It co-moves positively with forward and lagged inflation. The correlation is strongest between the contemporaneous output gap and inflation two periods ahead (0.27). Backward lags of inflation are weakly correlated with the contemporaneous output gap, however the correlation is stronger between the contemporaneous output gap and three backward lags of inflation (0.3).

In Figure 22, the contemporaneous correlation between the Cobb Douglas output gap and inflation is 0.4. The correlation is strongest between the contemporaneous output gap and inflation three periods ahead (0.74). Backward lags of inflation are weakly positively correlated with the contemporaneous output gap.

In Figure 23, the Cobb Douglas output gap when technical progress is modelled as HP filtered TFP, is uncorrelated with inflation. Forward lags of inflation are positively correlated with the contemporaneous output gap and the correlation is highest two periods ahead (0.32). Backward lags of inflation are negatively correlated with the output gap and three backward lags of inflation are uncorrelated with the contemporaneous output gap.

Therefore the results suggest that inflation is procyclical, i.e. the contemporaneous correlation between inflation and the output gap is positive. Forward lags of inflation indicated the highest correlation with the contemporaneous output gap. Therefore inflation lags the measured output gaps series and thus the output gap measures lead inflation, consistent with the Phillips curve theory.

Therefore the above measured output gaps do appear to have performed reasonably well as leading indicators of inflation, however no conclusions concerning causality can be drawn from this analysis. To examine further the significance of the output gap in explaining inflation, I will proceed and run a Granger causality regression of the following form:

$$P_t = \gamma + \Sigma\phi_i P_{t-i} + \Sigma\mu_j G_{t-j} + \varepsilon_t \qquad (28)$$

where P_t and P_{t-i} represent inflation and lagged inflation respectively, G_{t-j} represents lagged output gaps. If the μ_j coefficients on lagged values of the output gap are significant, then the measured gap is a significant factor in explaining inflation. The results from the F-tests are reported in Table 7. If the reported p-values are less than 0.05, this implies that we reject the null hypothesis, and conclude that the output gap is significant in explaining inflation. i refers to the lag of inflation, while j refers to the lag of the output gap.

The simple time trend output gap has a statistically significant role in explaining inflation in the presence of lagged inflation but its significance declines when the second lag of inflation is added to the regression equation. When both lags of inflation and the output gap are included in the regression it has an insignificant role. The HP filtered output gap measures are insignificant in explaining inflation, and as in the trend measure, their significance declines as more lags of both variables are included. The split time trend measured output gap is also insignificant in explaining inflation in all cases. The Cobb Douglas production function, using the linear time trend as a proxy for technology, has a significant role to play in explaining inflation in the presence of lagged inflation and when the second lag of inflation is added to the regression equation. It is also significant when lags of both variables are included. The Cobb Douglas production function output gap, which uses HP filtered TFP as a measure of technology, is significant in explaining inflation in the presence of lagged inflation, but it is insignificant when lags of both variables are included. Therefore the Cobb Douglas production function output gap appears to be the only measure that has a significant role in explaining inflation.

The results indicate that there is weak relationship between inflation and the output gap, primarily because external factors are also impacting on our inflation rate. Drawing from Meyler (1999), a measure of "domestically generated" inflation (defined as the gap between the services inflation rate and the goods inflation rate) will now be used and its relationship with the output gap will be examined. This measure of inflation will capture domestic inflationary pressures arising from the labour market (Meyler, 1999). The results of the Granger causality test are shown in Table 8. As can be seen from the Table, the results indicate a much stronger relationship between domestic inflation and the output gap. All measures of the gap are significant in explaining inflation. The simple time trend, split time trend and the HP filtered measures (λ=10) are insignificant when both lags of inflation and the gap are added to the regression equation, while all other measures are significant. The contemporaneous correlation coefficient between domestic inflation and the output gap varies between 0.5 and 0.6 for all measures and the HP filtered measures display the strongest correlation. The dynamic correlation analysis indicated that the correlation was highest with one forward lag of inflation for all measures, and thus the output gap leads domestic inflation. In Figure 24, the graph of the Cobb Douglas output gap and domestic inflation are shown, as an example[6]. It is clear from the graph that there is a stronger degree of consistency between the two, with a decline in the rate of domestic inflation accompanied by a fall in the output gap and vice versa. Therefore there appears to be a closer relationship between the above output gap measures and domestic inflation.

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[6] This graph is drawn to the same scale as previous graphs to facilitate comparison. The graph relates to the period 1977-2000 because the breakdown of CPI data prior to

7. ESTIMATES OF THE POTENTIAL OUTPUT GROWTH RATE:

In Table 9, the estimates of the potential output growth rate implied by these methods discussed above are shown. All of these methods exhibit a broad degree of consistency. The potential output growth was relatively stable between 1960 and 1980 at approximately 4 – 4.5 per cent. Between 1981 and 1990, there was a sharp contraction in the growth rate of potential output in the range of 3 – 3.5 per cent. This is consistent with the decline in employment growth over this period of approximately -0.2 per cent, and capital growth also declined from 5.4 per cent between 1970 and 1980, to approximately 3.3 per cent from 1981 to 1990. For the remaining period 1991-2000, potential output growth has risen to approximately 6 - 7 per cent. Over this period, employment growth has risen to 3.5 per cent and productivity growth has also increased to 3.6 per cent. Employment growth accounted for approximately 38 per cent of output growth between 1991 and 2000, compared to 4.3 per cent between 1964 and 1980. TFP's growth contribution has remained relatively stable at approximately 42 per cent, while capital's contribution has declined from 58 per cent to 20 per cent over the same time periods. This confirms the belief that the recent acceleration in economic growth has in large part been accounted for by increases in employment.

The actual growth rate of output has exceeded the potential output growth rate since 1997 and this implies an erosion of spare capacity in the economy. These results are consistent with estimates taken from Giorno et al. (1995) and Kenny (1996) who estimate that between 1987 and 1996, the potential output growth rate falls within the 4 - 5 per cent range.

1975 was unavailable.

Giorno et al. (1995) finds that the estimated growth rate of potential output in Ireland is higher than that of many other OECD countries, which reflects higher total factor productivity. Between 1996 and 2000 there has been a significant upward shift in the potential output growth rate of the Irish economy to approximately 7 per cent. This is consistent with OECD (2001) estimates who note in their most recent Economic Outlook, that GDP growth is expected to slow to 7.75 per cent in 2001, which is closer to its estimated current potential rate.

In Table 10, the estimates of the potential output growth rate when GNP is used as the appropriate measure of output are shown. A similar pattern emerges as in Table 9. The growth rate was stable at approximately 4 per cent between 1961 and 1980. There was a contraction in the growth rate between 1981 and 1990 to approximately 2.5 per cent. Between 1991 and 2000, the growth rate of potential output is in the range of 6 per cent.

8. FORECASTS OF THE POTENTIAL OUTPUT GROWTH RATE:

In light of the recent performance of the Irish economy and the high growth rate of potential output in recent years, it is useful to analyse what direction potential output will take in the future. Drawing, inter alia, on estimates from ESRI (1999) *"Medium Term Review 1999-2005"* and internal Central Bank of Ireland estimates, estimates for the growth rate of potential output based on the methods discussed above are shown in Tables 9 and 10. This forecast assumes that the next National Plan will provide for a major increase in public investment and infrastructure. It also assumes that the next two budgets will provide indexation of tax bands and allowances to wage rates and that once the economy has slowed down, it allows for major cuts in taxation over a period of years. As can be seen from Table 9, the growth rate of potential output is estimated to decline to approximately 5 - 6 per cent between 2001 and 2005. This forecast is based on average GDP growth of approximately 5 per cent, employment and capital growth of around 2 per cent over this time period. Potential output growth is estimated to have peaked in 1999 at around 8 per cent, and is projected to decline thereafter from 7.5 per cent in 2001, to 5.5 per cent in 2003 and to 5.0 per cent by 2005. In the case of GNP, a similar pattern emerges in Table 10, with potential output growth declining to approximately 5.0 per cent between 2001 and 2005. It is forecast to decline from approximately 6.5 per cent in 2001, to 6.0 per cent in 2003 and to 5 per cent by 2005. These estimates should be treated with caution however, and are highly contingent on the estimates of the variables discussed above. If employment growth continues its most recent performance, we would see a higher potential output growth rate, and thus these estimates are only a preliminary guideline. All of these forecasts imply that the output gap will decline in the future and will be negative in 2004, which implies that the economy will be producing below its productive capacity.

Few, if any, could have foreseen the very substantial increases in employment during the 1990s, and thus *ex ante* estimates of growth potential for this decade would have been substantially less than the 6 - 7 per cent growth potential estimates made looking backwards at this point. More generally, historical estimates of growth potential are closely related to actual growth performance during the relevant period and thus a higher potential output growth rate was achieved in the last decade than could have been forecast. Thus the estimates given above are highly contingent on the forecasts for GDP, employment and capital growth, which may not be realised.

9. CONCLUSION:

This paper has examined several methods to estimate potential output and the output gap. Various measures were examined due to the uncertainty associated with measuring potential output. A broad degree of consistency was found to exist between all measures, in terms of the sign of the output gap and the estimate of the potential output growth rate. Therefore all measures agree about when the economy was operating above/below potential. Since 1997 the output gap has been positive, which implies that there is excess demand in the economy, leading to inflationary pressures.

The paper also examined the relationship between inflation and the output gap. A positive gap, where demand pressures on resources are present, tended to be associated with an increase in inflation. All output gap measures, excluding the Cobb Douglas production function with HP filtered TFP, displayed a positive contemporaneous correlation with inflation. This correlation was negative between 1963 and 1984, using two measures of the output gap and positive for all others. It was procyclical for the remaining period in all cases. The dynamic correlation structure indicated that in all cases the output gap leads inflation, which is consistent with the Phillips curve theory. This suggests that the current change in inflation should depend positively on the lagged output gap. This was tested using the Granger causality test, which found a positive relationship in all cases. The results indicated however, that only the

Cobb Douglas production function output gap was significant in explaining inflation.

Since our overall inflation rate is subject to external factors, such as a depreciation of the euro, high oil prices etc., the output gap alone is insufficient to explain inflation. Thus the relationship between "domestically generated" inflation and the output gap were examined. In this case the Granger Causality test indicated that all measures of the output gap were significant in explaining domestic inflation and only the split and simple time trends and HP filtered (λ=10) output gaps were insignificant when more lags were added to the regression equation. Thus the output gap appears to perform reasonably well as a leading indicator of domestic inflation.

All estimates of potential output and the corresponding output gap are subject to a large margin of error, and should be treated with caution. The production function estimate is contingent on an estimate of the NAWRU to calculate potential employment. Elmeskov's (1993) method, while simple to apply, may not be appropriate in the Irish context. Achieving a consistent estimate of the NAWRU would result in more reliable estimates of potential output. This may warrant future research.

The statistical evidence suggested that a long-run cointegrating relationship existed when the Cobb Douglas production function was estimated, when technology was measured as a linear time trend. The results for the price equation disimproved when technology was modelled as HP filtered TFP. As noted above, TFP accounted for approximately 42 per cent of output growth between 1991 and 2000, and thus represents an important variable. This highlights the importance of how technology is measured and may need to be examined in more detail.

Estimates of the potential output growth of the economy were discussed. The growth rate was relatively stable between 1960 and 1980 and subsequently declined between 1981 and 1990.   It is estimated to have peaked in 1999 and is forecast to decline thereafter reaching approximately 5 per cent by 2005. However, this forecast is conditional on a decline in employment and real GDP, which may not be realised. If economic growth were to continue its most recent trend, then potential output growth could continue to rise. However, given the recent slowdown in the U.S. technology sector and the domestic consequences of the foot and mouth scare on the Irish economy, it is unlikely that we will experience the rapid growth in employment which has been witnessed in recent years. The most likely scenario is a stabilisation of the potential output growth rate. This implies that the output gap will remain positive until 2003, which implies excess demand in the economy. The gap is projected to become negative in 2004, when a more sustainable level of output is achieved.

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APPENDIX 1

TABLE 1: ESTIMATES OF THE PARAMETERS OF THE COBB DOUGLAS PRODUCTION FUNCTION: EQUATIONS (12)-(14), USING GDP: 1963-2000

	Coefficient	t-statistic
ε	1.601	(29.74)
A	4.289	(12.25)
β	0.241	(10.68)
α	0.037	(84.67)
SEE(y)	0.071	$R^2_y = 0.994$
SEE(l/y)	0.034	$R^2_{(l/y)} = 0.992$
SEE(cc)	1.216	$R^2_{cc} = 0.472$
PP(y_res)	-4.478	DW_y = 0.133
PP(l/y_res)	-6.018	DW_l/y = 0.457
PP(cc_res)	-19.878	DW_cc = 0.931

SEE(y), SEE(l/y), SEE(cc) refer to the standard errors of the estimated price, labour demand and investment equations, respectively. PP(y_res), PP(l/y_res) and PP(cc_res) refer to the Phillips-Perron tests for stationarity in the residuals. The critical values for the Phillips-Perron test statistics at the 1%, 5% and 10% significance level are approximately –3.58, -2.93 and –2.60, respectively. R^2_y, $R^2_{(l/y)}$, and R^2_{cc} refer to the R^2 of the estimated equations. DW_y, DW_l/y and DW_cc refer to the Durbin-Watson statistics of the estimated equations.

TABLE 2: ESTIMATES OF THE PARAMETERS OF THE COBB DOUGLAS PRODUCTION FUNCTION: EQUATIONS (24)-(26), USING GDP: 1963-2000

	Coefficient	t-statistic
ε	1.608	(95.749)
β	0.238	(397.82)
SEE(y)	0.066	$R^2_y = 0.995$
SEE(l/y)	0.016	$R^2_{(l/y)} = 0.998$
SEE(cc)	1.133	$R^2_{cc} = 0.541$
PP(y_res)	-2.915	DW_y = 0.124
PP(l/y_res)	-12.207	DW_(l/y) = 1.264
PP(cc_res)	-19.878	DW_cc = 0.928

TABLE 3: ESTIMATES OF THE PARAMETERS OF THE COBB DOUGLAS PRODUCTION FUNCTION: EQUATIONS (12)-(14) USING GNP: 1963-2000

	Coefficient	t-statistic
ε	1.549	(24.38)
A	4.665	(10.82)
β	0.248	(9.75)
α	0.028	(49.80)
SEE(y)	0.095	$R^2y = 0.990$
SEE(l/y)	0.041	$R^2(l/y) = 0.984$
SEE(cc)	1.214	$R^2cc = 0.473$
PP(y_res)	-4.079	DW_y = 0.102
PP(l/y_res)	-5.817	DW_l/y = 0.278
PP(cc_res)	-19.878	DW_cc = 0.934

TABLE 4: ESTIMATES OF THE PARAMETERS OF THE COBB DOUGLAS PRODUCTION FUNCTION: EQUATIONS (24)-(26), USING GNP: 1963:2000

	Coefficient	t-statistic
ε	1.565	(81.61)
β	0.241	(447.62)
SEE(y)	0.087	$R^2 y = 0.992$
SEE(l/y)	0.015	$R^2 (l/y) = 0.998$
SEE(cc)	1.132	$R^2 cc = 0.542$
PP(y_res)	-3.266	DW_y = 0.081
PP(l/y_res)	-14.926	DW_l/y = 1.301
PP(cc_res)	-19.878	DW_cc = 0.931

TABLE 5: CORRELATION OF OUTPUT GAP WITH INFLATION

	1963-2000	1963-1984	1984-2000
Simple	0.22	0.37	0.01
Hp_10	0.11	0.05	0.35
Hp_30	0.19	0.15	0.34
Hp_100	0.35	0.35	0.36
Split time trend	0.12	-0.02	0.38
Cobb Douglas	0.24	0.14	0.00
Cobb Douglas, HP TFP	-0.02	-0.10	0.22

TABLE 6: CORRELATION OF LAGGED OUTPUT GAP WITH INFLATION

	1964-2000	1964-1984	1984-2000
Simple	0.43	0.58	0.10
Hp_10	0.23	0.24	0.04
Hp_30	0.34	0.33	0.17
Hp_100	0.50	0.48	0.33
Split time trend	0.21	0.08	0.35
Cobb Douglas	0.48	0.42	-0.12
Cobb Douglas, HP TFP	0.16	0.20	-0.09

TABLE 7: P-VALUES FROM F-TEST: H_0: $\mu_j = 0$ IN EQUATION (28)

	i=1, j=1	i=2, j=1	i=1, j=2	i=2, j=2
Simple	0.03	0.06	0.12	0.14
Hp_10	0.14	0.41	0.42	0.71
Hp_30	0.09	0.25	0.32	0.52
Hp_100	0.06	0.12	0.25	0.29
Split time trend	0.24	0.35	0.56	0.64
Cobb Douglas	0.00	0.01	0.00	0.02
Cobb Douglas, HP TFP	0.04	0.20	0.11	0.40

TABLE 8: P-VALUES FROM F-TEST: H_0: $\mu_j = 0$ IN EQUATION (28) USING DOMESTIC INFLATION

	i=1, j=1	i=2, j=1	i=1, j=2	i=2, j=2
Simple	0.03	0.08	0.15	0.23
Hp_10	0.04	0.09	0.13	0.24
Hp_30	0.01	0.03	0.05	0.10
Hp_100	0.01	0.02	0.04	0.09
Split time trend	0.01	0.03	0.04	0.07
Cobb Douglas	0.00	0.00	0.00	0.00
Cobb Douglas, HP TFP	0.00	0.00	0.02	0.02

TABLE 9: POTENTIAL OUTPUT GROWTH RATES: GDP BASIS

	Simple	Hp_10	Hp_30	Hp_100	Split trend	Cobb Douglas	Cobb Douglas, HP TFP
1961-1970	4.3	4.0	4.1	4.2	4.0	3.8	4.2
1971-1980	4.3	4.5	4.5	4.3	4.2	4.7	4.6
1981-1990	4.3	3.2	3.2	3.5	3.2	3.4	3.1
1991-2000	4.3	7.1	7.0	6.7	7.0	6.3	7.1
1961-2000	4.3	4.7	4.7	4.7	4.6	4.6	4.8
2001-2005	4.3	5.9	6.5	7.1	5.9	4.8	5.6
1965	4.3	3.5	3.8	4.0	3.5	3.6	3.5
1975	4.3	4.8	4.7	4.5	5.3	4.8	4.8
1985	4.3	2.6	2.8	3.1	3.2	1.9	1.6
1995	4.3	7.2	7.1	6.8	7.0	6.3	7.1
2000	4.3	8.4	8.0	7.5	7.0	7.3	8.6
2005	4.3	4.7	5.9	6.9	5.0	3.8	4.4

TABLE 10: POTENTIAL OUTPUT GROWTH RATES: GNP BASIS

	Simple	Hp_10	Hp_30	Hp_100	Split trend	Cobb Douglas	Cobb Douglas, HP TFP
1961-1970	3.7	4.0	4.0	4.1	3.9	3.2	4.1
1971-1980	3.7	3.9	3.8	3.6	3.6	4.1	3.9
1981-1990	3.7	2.3	2.4	2.6	2.3	2.8	2.3
1991-2000	3.7	6.2	6.2	5.9	6.3	5.6	6.3
1961-2000	3.7	4.1	4.1	4.1	4.0	4.0	4.2
2001-2005	3.7	5.8	6.0	6.3	6.5	4.8	5.7
1965	3.7	3.5	3.8	4.0	3.5	2.9	3.5
1975	3.7	4.2	4.1	3.9	4.9	4.1	4.2
1985	3.7	1.6	1.8	2.2	2.3	1.2	0.6
1995	3.7	6.2	6.2	6.0	6.3	5.6	6.2
2000	3.7	7.6	7.2	6.8	6.3	6.6	7.6
2005	3.7	4.9	5.3	6.0	6.5	4.1	5.0

APPENDIX 2

Figure 1: Actual Output and Trend Potential Output, 1960-2000

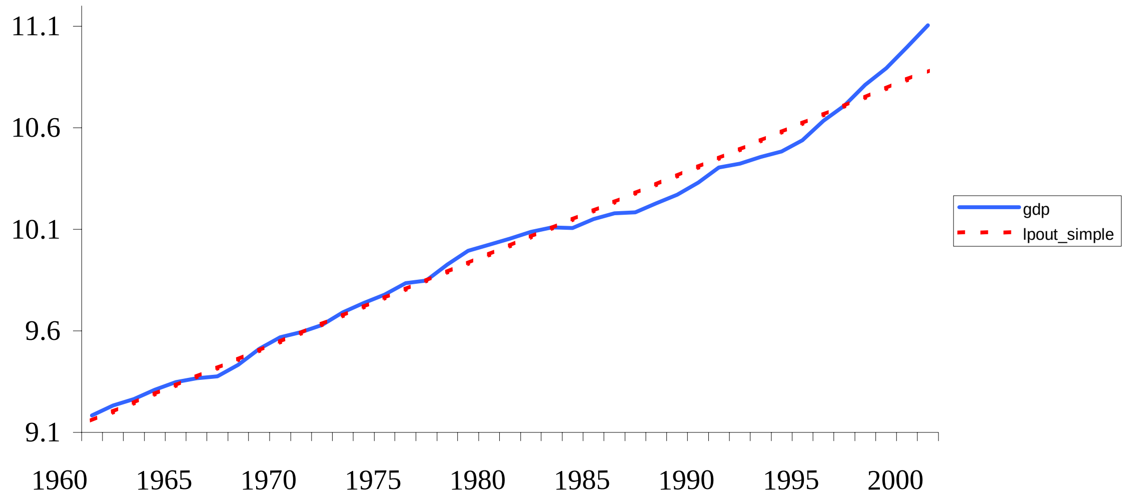


Figure 2: Trend Output Gap and Inflation: 1960-2000

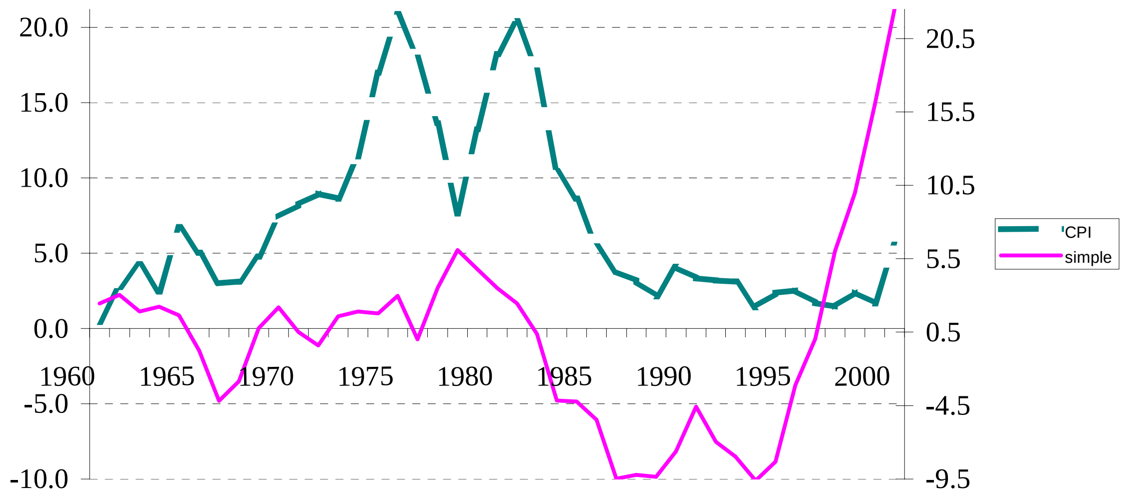


Figure 3: Split Time Trend Potential and Actual Output: 1960-2000

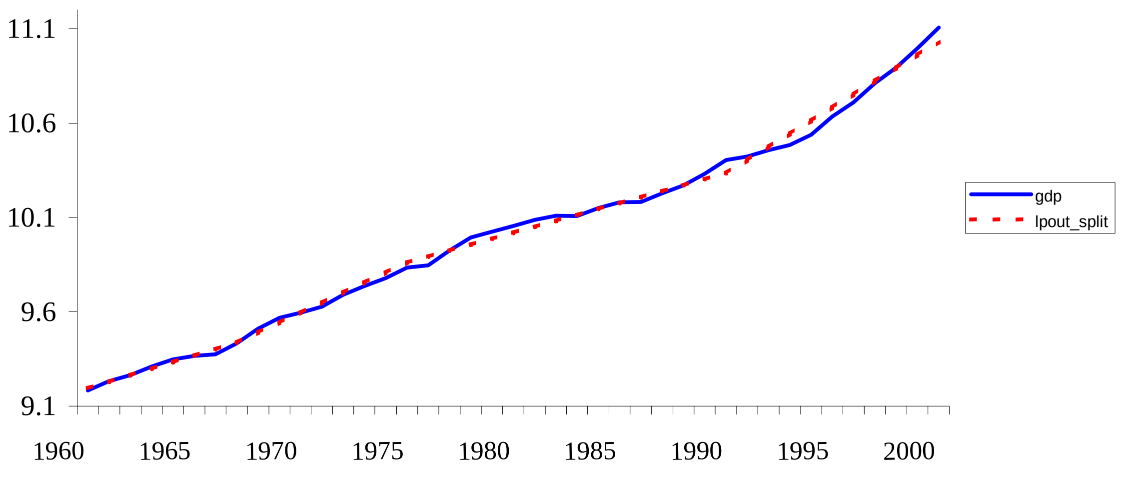


Figure 4: Split Time Trend Output Gap and Inflation: 1960-2000

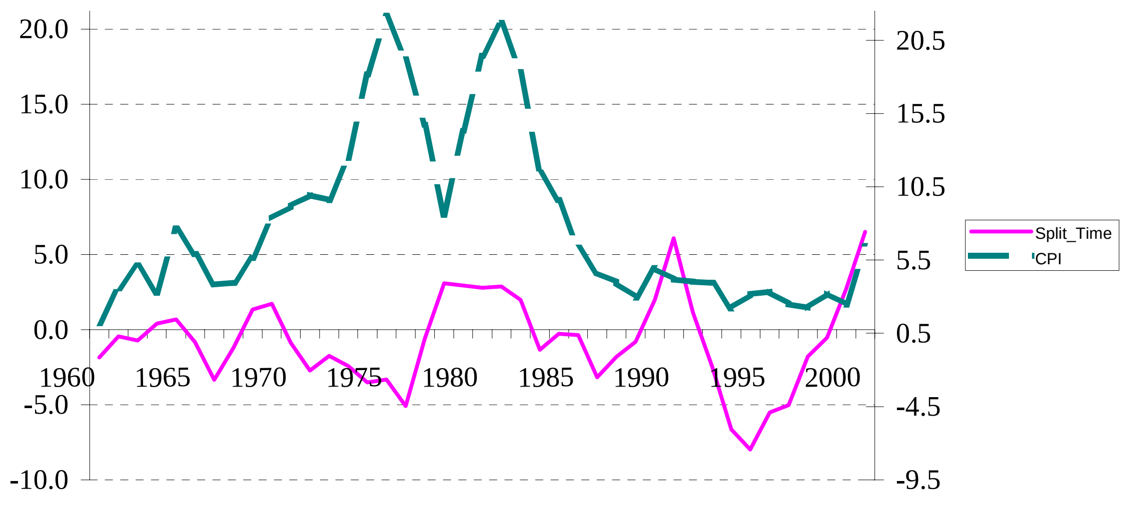


Figure 5: HP Filter (lambda=10) Potential Output and Actual Output: 1960-2000

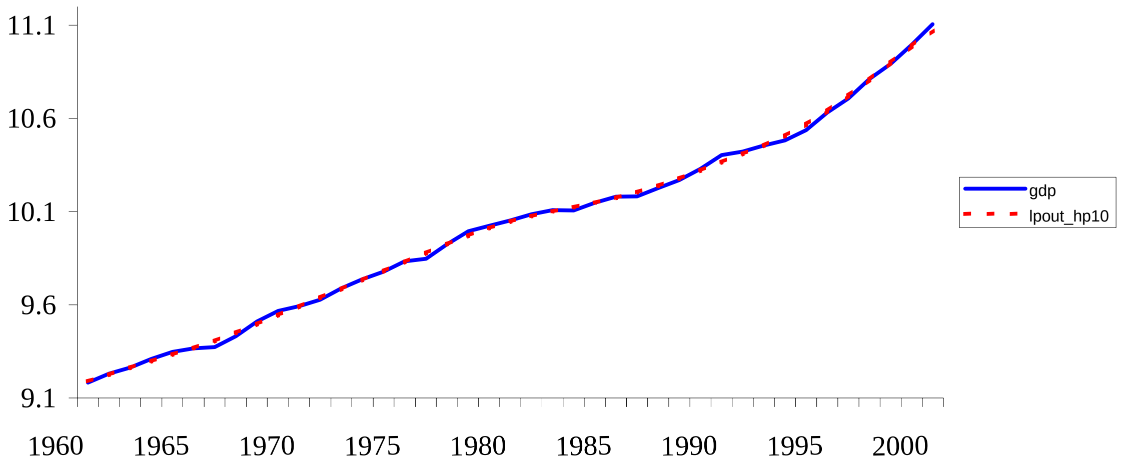


Figure 6 : HP Filter(lambda=10) Output Gap and Inflation: 1960-2000

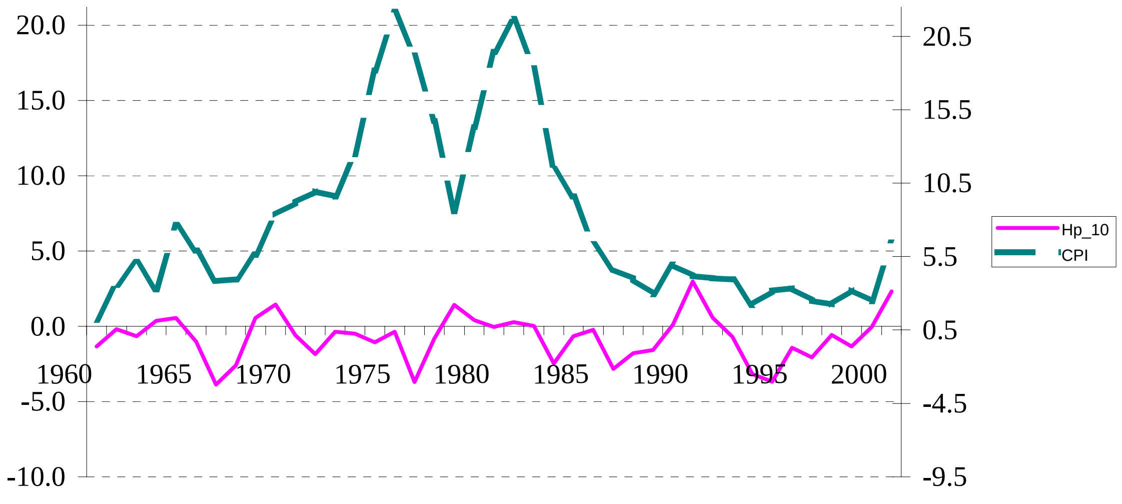


Figure 7: HP Filter (lambda=30) Potential and Actual Output: 1960-2000

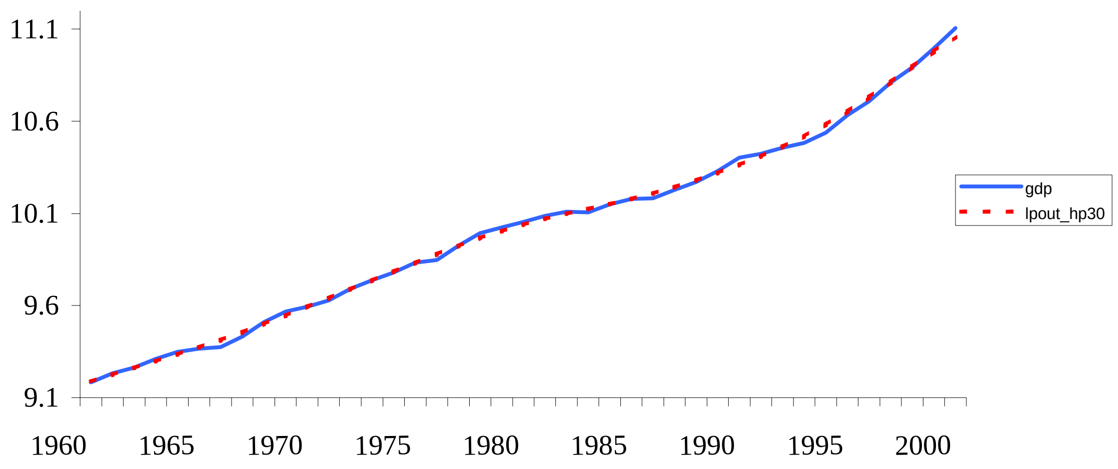


Figure 8: HP Filter (lambda=30) Output Gap and Inflation: 1960-2000

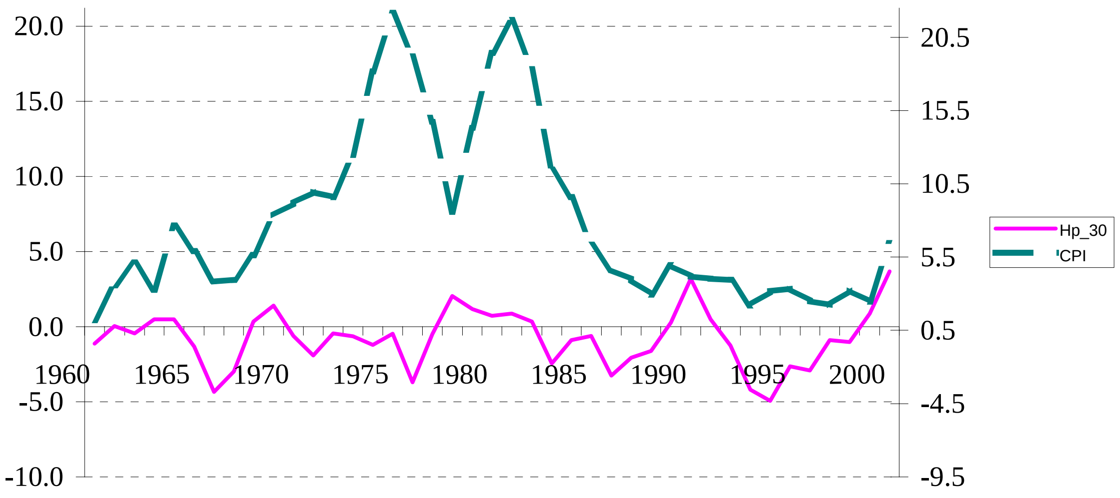


Figure 9 : HP Filter (lambda=100) Potential and Actual Output: 1960-2000

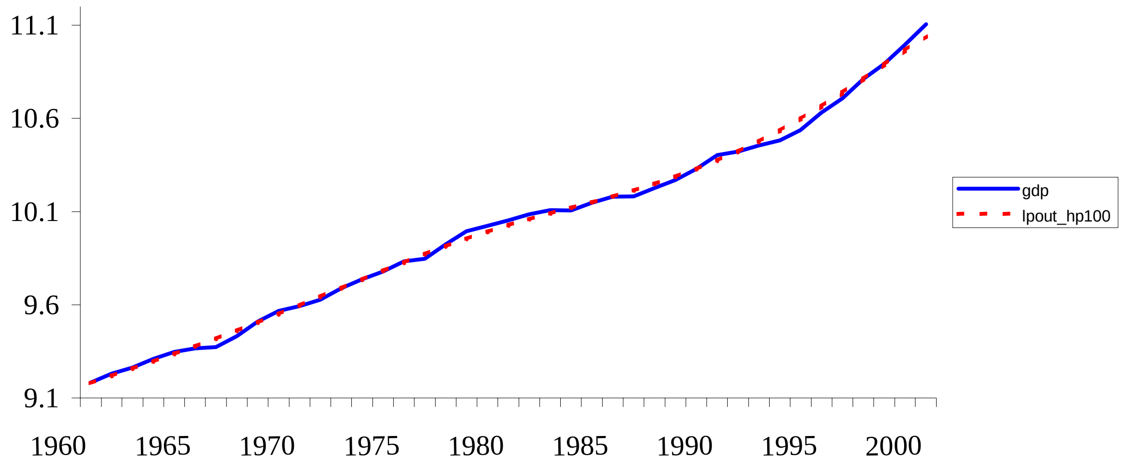


Figure 10: HP Filter (lambda=100) Output Gap and Inflation: 1960-2000

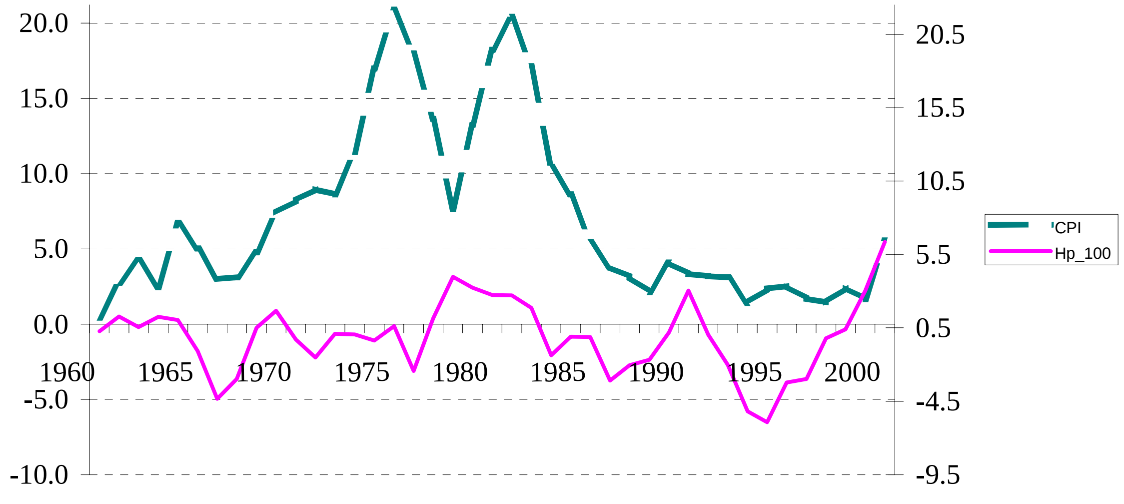


Figure 11: HP Filter Output Gaps: 1960-2000

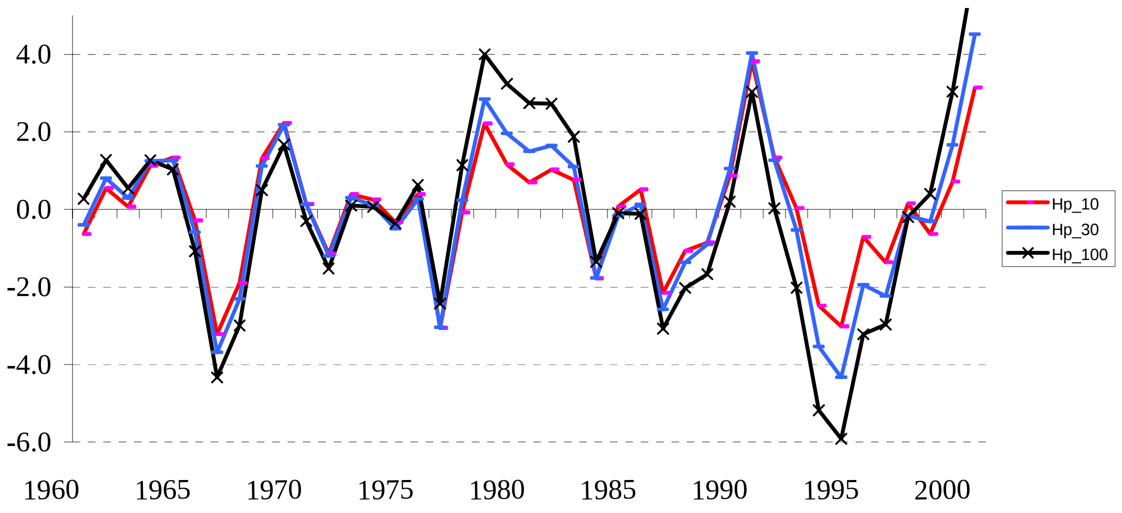


Figure 12: Long and short-term real interest rates

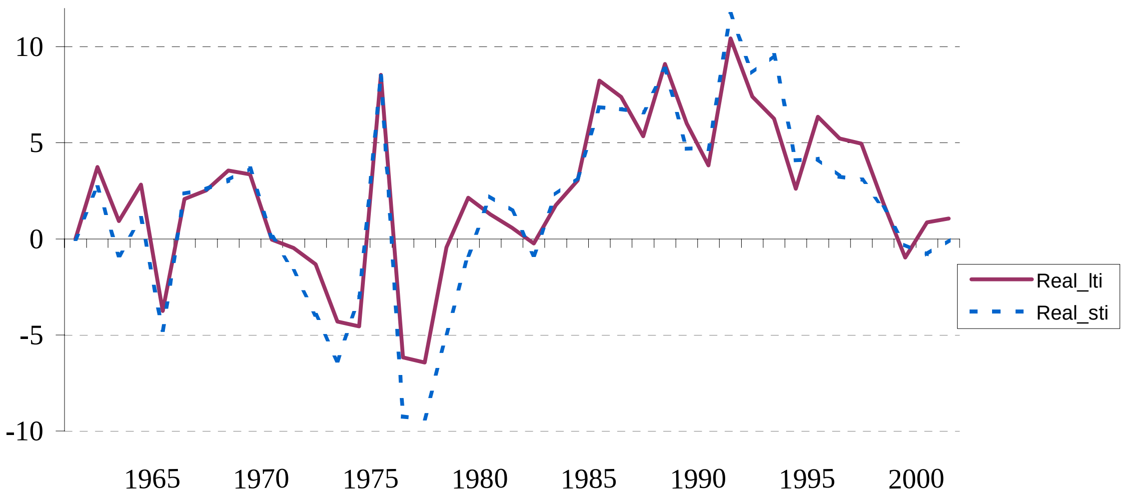


Figure 13: Actual and Potential Output (Cobb Douglas): 1963-2000

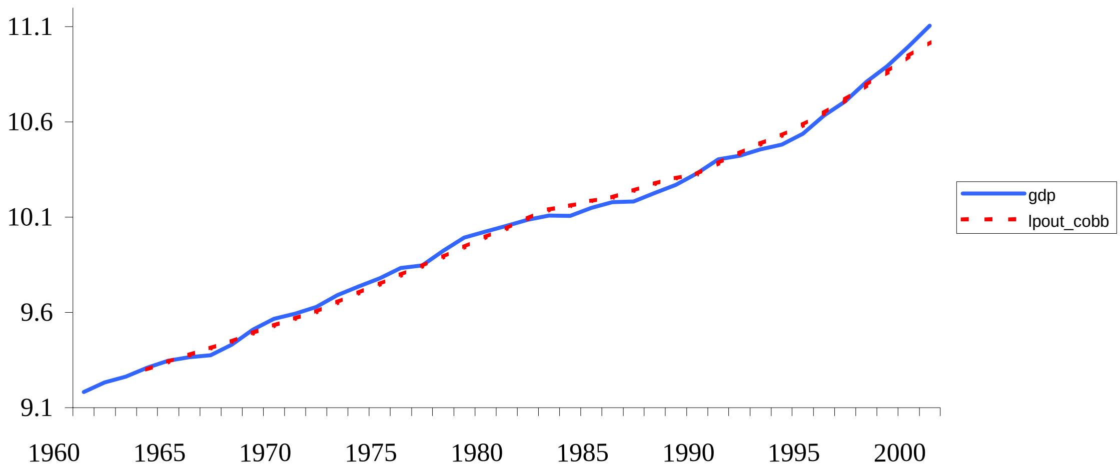


Figure 14: Cobb Douglas Output Gap and Inflation: 1963-2000

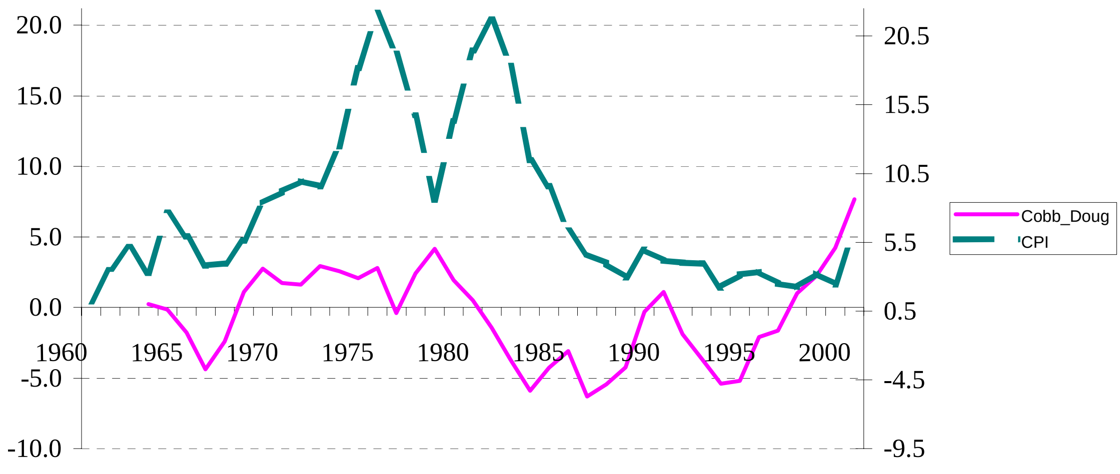


Figure 15: Actual and Potential Output (Cobb Douglas_HP TFP): 1963-2000

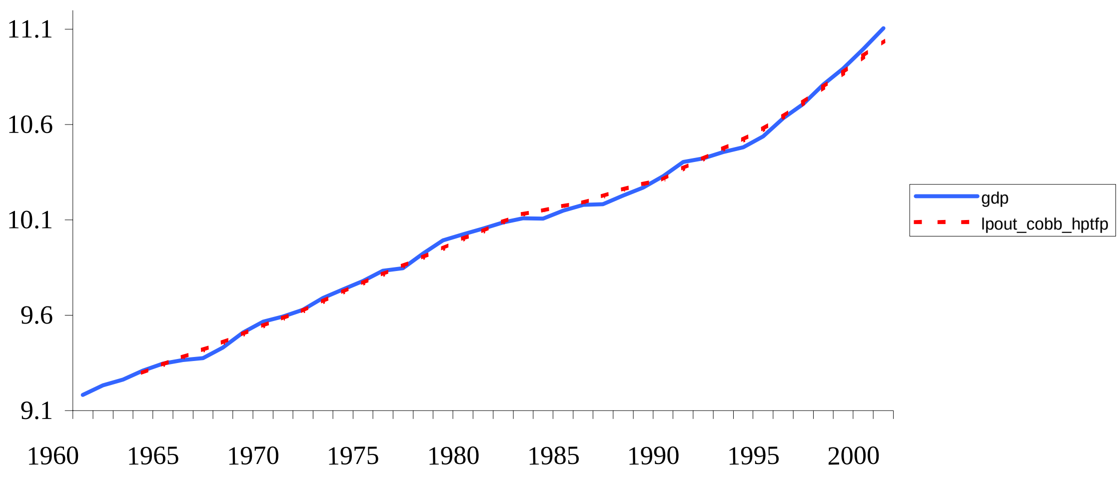


Figure 16: Cobb Douglas (HP TFP) Output Gap and Inflation: 1963-2000

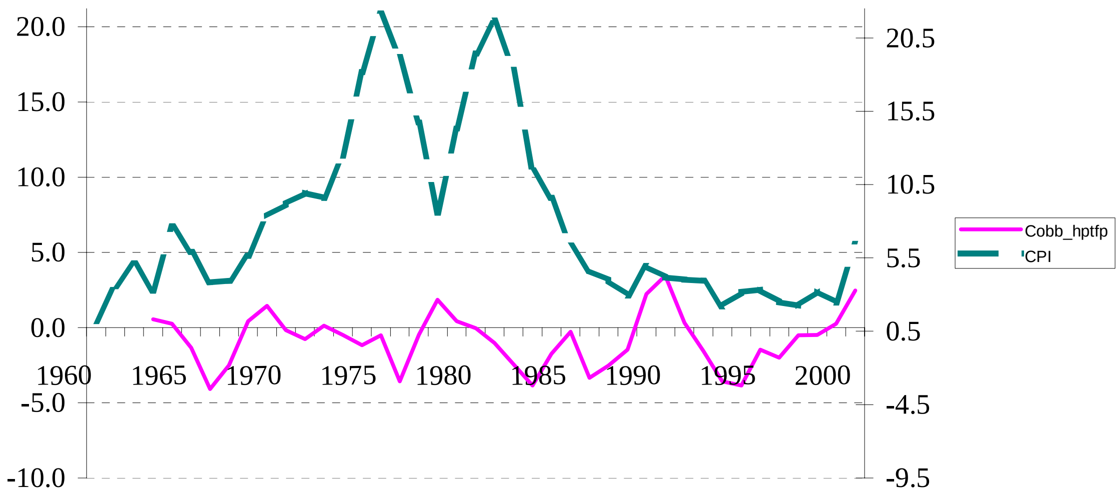


Figure 17: Cross Correlation between simple time trend output gap and inflation

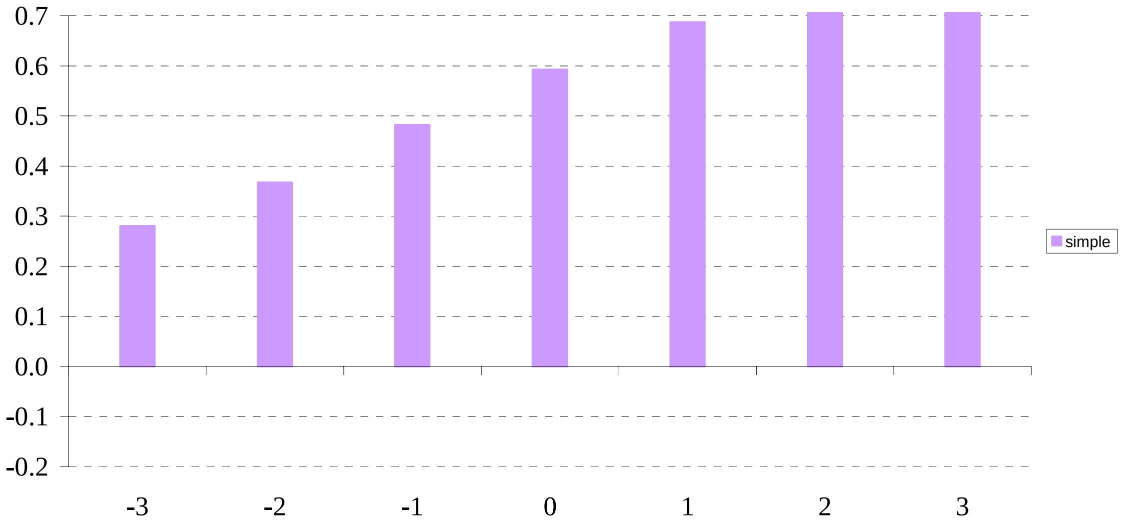


Figure 18: Cross Correlation between HP filter (lambda=10) output gap and inflation

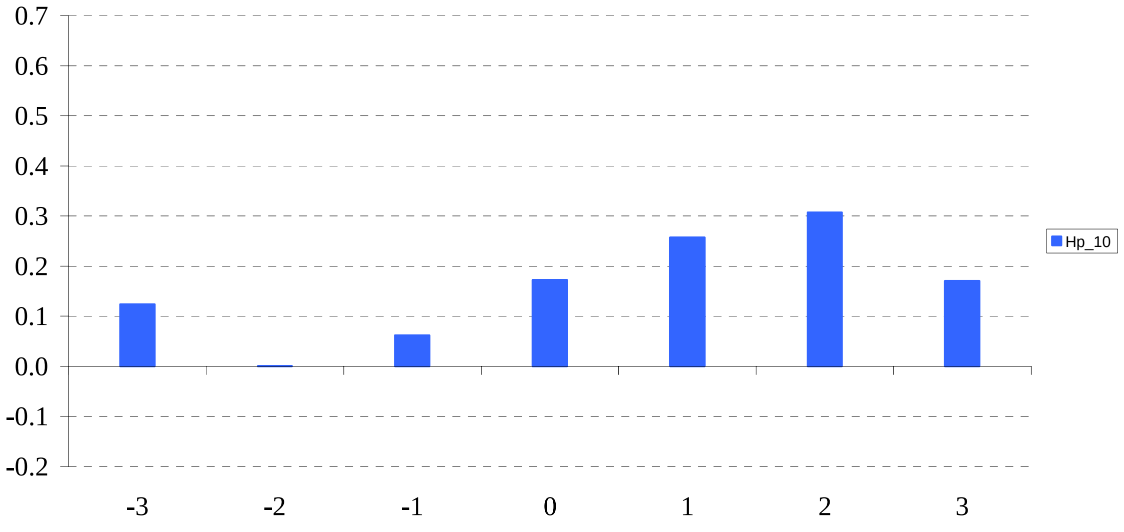


Figure 19: Cross Correlation between HP filter (lambda=30) output gap and inflation

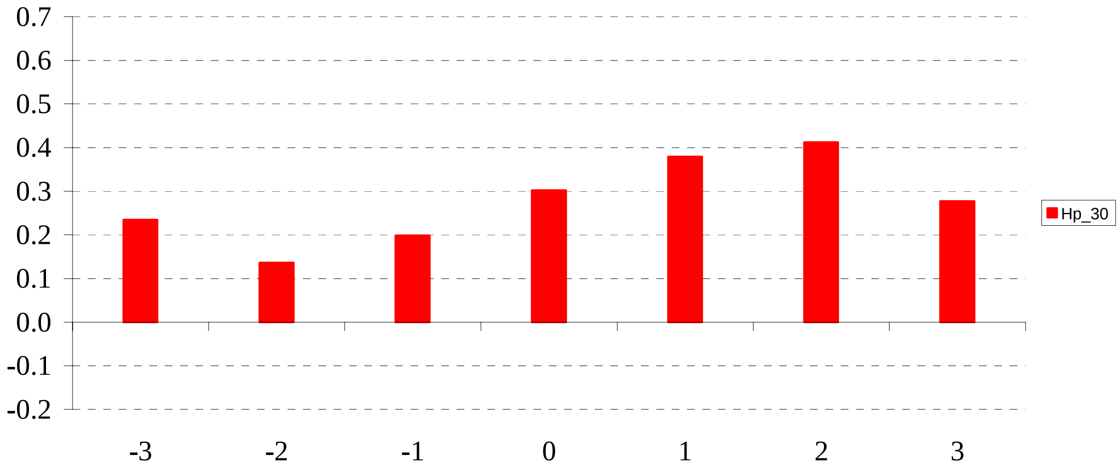


Figure 20: Cross Correlation between HP filter (lambda=100) output gap and inflation

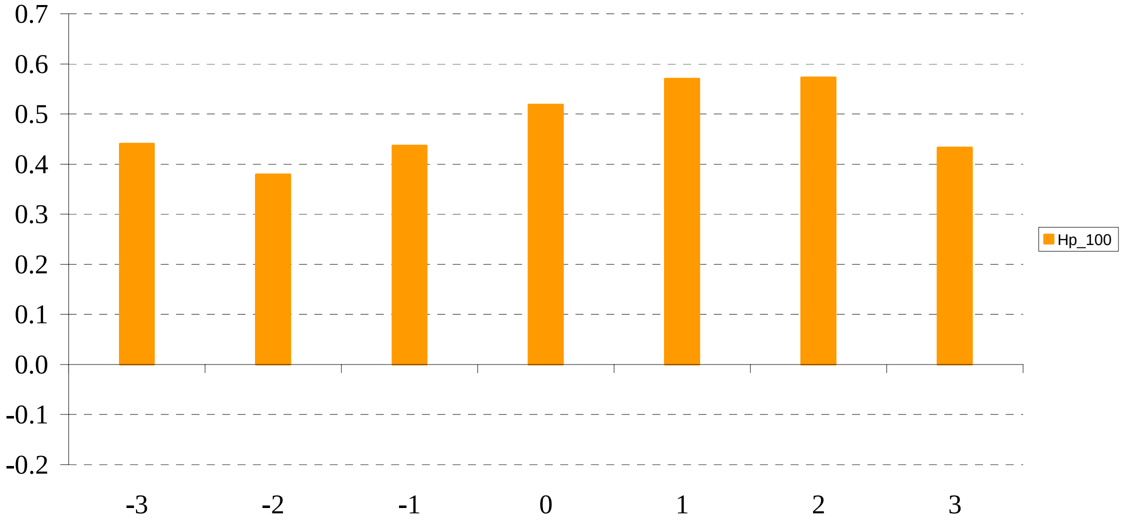


Figure 21: Cross Correlation between split time trend output gap and inflation

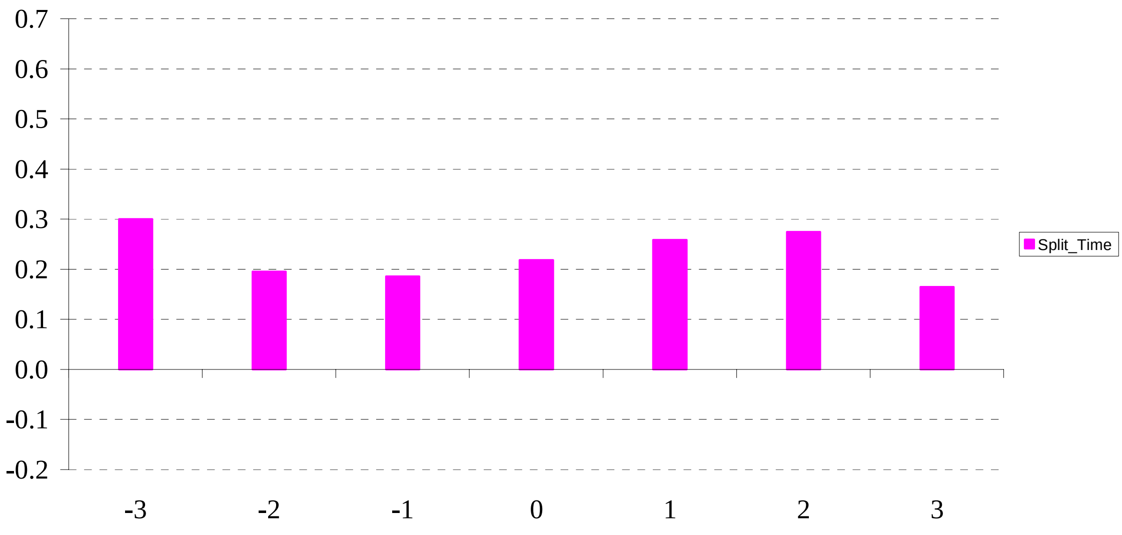
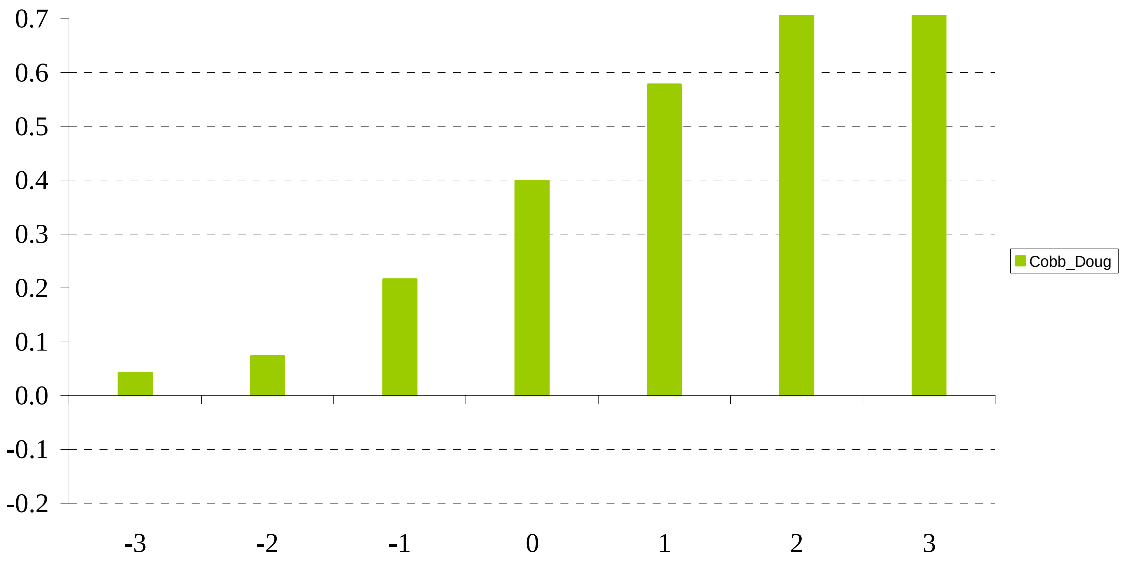


Figure 22: Cross Correlation between Cobb Douglas output gap and inflation



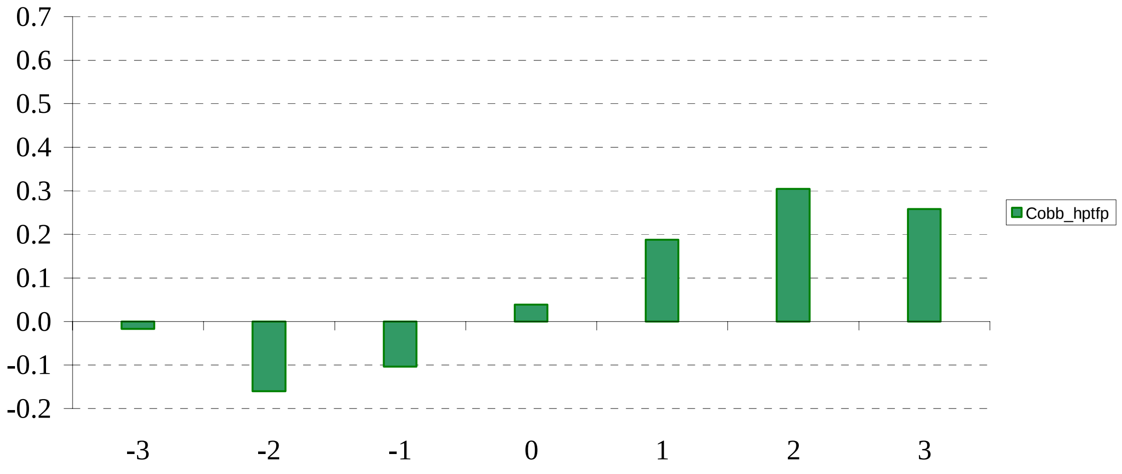


Figure 23: Cross Correlation between Cobb Douglas (HP_TFP) output gap and inflation

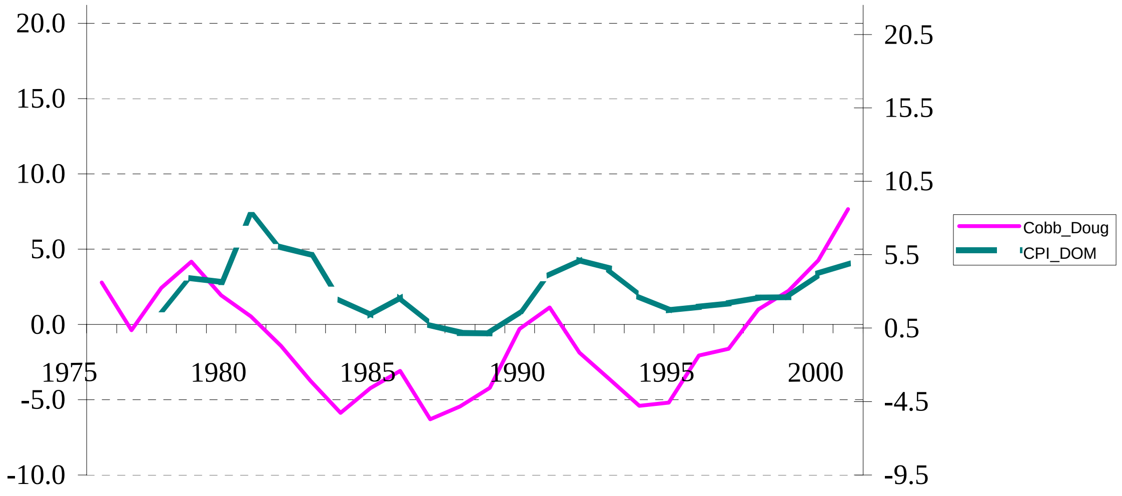


Figure 24: Cobb Douglas Output Gap and Domestic Inflation: 1977-2000