Output gap in the Norwegian economy – different methodologies, same result?

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Potential output is an estimate of the level of output that is consistent over time with the highest possible utilisation of resources in the economy with stable inflation. The output gap measures the difference between actual output and potential output, and may thus provide information about inflationary pressures in the economy. However, measuring the output gap involves methodological problems. The use of the Hodrick-Prescott (HP) filter – which is a relatively mechanical method for distinguishing between trends and cycles in economic time series – requires a discretionary estimate of variations in trend output. The production function method – which is a method whereby developments in potential GDP are linked to the level of factors of production and technology innovations – requires an estimate of the level of equilibrium unemployment . We compare the results with the OECD's measure of equilibrium unemployment and a method where we model equilibrium unemployment directly. The various methods for measuring the output gap indicate that the Norwegian economy has experienced strong expansion in recent years. They provide a slightly different picture of developments in the output gap in the years ahead.

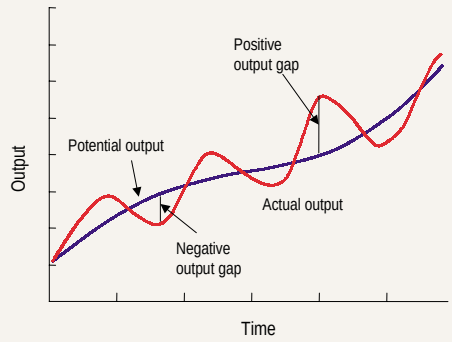
Introduction

In the analysis of monetary policy it may often be necessary to use an overall indicator of inflationary pressures in the economy. The output gap – which measures the difference between actual and potential output – is such an indicator. Potential output is an estimate of the level of production that is consistent over time with the highest possible utilisation of resources in the economy with stable inflation. The simplest estimate of potential output is the long-term trend in GDP. In business cycle theory it is commonly assumed that total output in the economy grows over time at a trend rate in line with demographic trends, productivity, etc., but that in the short term there are variations around this trend. Over time, technology and the supply of resources change, which also results in changes in potential output. It follows that potential output cannot be observed, but must be estimated. In periods, actual output will depart from trend output. For example, an increase in demand may translate into higher output in the short term, so that actual output rises at a faster rate than trend output, giving rise to a positive output gap (see Chart 1).

As the output gap is an indicator of overall capacity utilisation in the economy, a positive output gap indicates upward pressure on price inflation. Likewise, if actual output is lower than potential output, inflationary pressures would be easing. If the output gap is closed, the level of output is consistent with stable inflation.

In recent years it has become increasingly common to measure the output gap. In countries where nominal price stability is the operational objective of monetary policy, a simple indicator is needed to shed light on future inflationary pressures. The OECD and the IMF estimate output gaps for member countries. The output gap is also commonly used to estimate the Taylor rate.[2]

Chart 1. Illustration of the relationship between actual and potential output and the output gap



The Taylor rate is the interest rate that provides stable domestic output and inflation. In these calculations, a positive output gap favours, in isolation, a tightening of monetary policy.

There are different methods for estimating output gaps and the choice of method has implications for the results. It is therefore important to bear in mind the limitations of the different methodologies. Uncertainty associated with the calculations warrant caution with regard to drawing conclusions based on one simple figure.[3] Such indicator approximations do not replace the use of bigger macroeconomic models. However, an indicator such as the output gap can be a tool for simplifying the representation of more complex economic relationships.

Hodrick-Prescott filter

The Hodrick-Prescott (HP) filter is a method that is widely used to estimate the trend in an economic variable. It represented an important improvement on previ-

1 We are grateful to Yngvar Dyvi, Amund Holmsen, Gabriela Mundaca, Kai Leitemo and Ole Bjørn Røste for useful comments on an earlier version.

2 See Taylor (1993). Frøyland and Leitemo (1999) analyse the Taylor rule for Norwegian data.

3 Okun wrote 30 years ago: "The quantification of potential output – and the accompanying measure of the `gap´ between actual and potential – is at best an uncertain estimate and not a firm precise measure." Quotation from an article by Apel et. al. (1996).

ous methods, which assumed to a further extent that the variable increased with a linear trend. The HP filter is based on the assumption that a time series Y_t can be decomposed into a trend component, U_t, and a cyclical component, C_t:

$$Y_t = U_t + C_t \qquad (1)$$

The method makes it possible to distinguish between a permanent and temporary component in a time series. From a technical viewpoint, the HP filter means that trend output is estimated by minimising the following equation:[4]

$$Min\{y_t^*\}_{t=-1}^{T}\left[\sum_{t=1}^{T}(y_t - y_t^*)^2 + \lambda\sum_{t=1}^{T}\left[(y_t^* - y_{t-1}^*) - (y_{t-1}^* - y_{t-2}^*)\right]^2\right] \qquad (2)$$

where the variables are measured in logarithms. y_t and y^*_t are actual and trend output, respectively, in period t. The HP filter minimises the quadratic difference between actual and trend output – first parameter in (2) – under the assumption that the output potential does not vary excessively – second parameter in (2). λ is a positive parameter that determines the extent of variations in trend output. A high λ value means that trend growth in a borderline case may equal the average for the projection period, ie that trend output becomes a linear trend. The other extreme, λ=0, implies that all changes in actual output can be interpreted as changes in potential output.

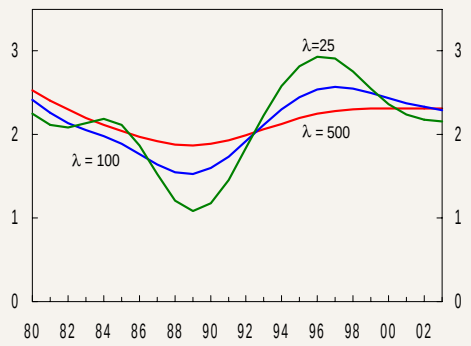
One advantage of the HP filter is that trend output can be estimated directly from actual output. However, there are several shortcomings associated with the HP filter.[5]

One disadvantage is that λ must be given a preassigned value. There are various criteria for determining this value. One proposed way is to assign a value to λ that gives a specific value for the relationship between the variance in trend and actual output. An alternative is to set λ at a value that produces the same variance in trend output in several countries. A third option is to assign a value to λ that gives a trend output that is in line with one's intuition concerning cyclical movements.[6] Hodrick and Prescott's (1997) original proposal was λ = 1600 for quarterly data, and this seems to have become an established international standard. For annual data, it is common to use λ = ε [25,200], see for example Giorno et. al. (1995).[7]

Another problem with the HP filter is that economic fluctuations at the end of the projection period may gain excessive weight in the estimation of trend output. If, for example, actual output falls at the end of the period, trend output will also fall so that it may be underestimated. This is an unfortunate feature because one is often interested in a measure of current capacity utilisation. However, the problem can be partially solved by extending the data series with estimates where economic growth picks up to the long-term potential in the economy. The drawbacks of the HP filter have, for example, been cited in discussions on output developments in the OECD area, where inflation rates have moved on a downward trend over the last 15 years. An interpretation of this is that the output gap has been negative. The use of the HP filter in this period implies, however, by definition that the output gap will be closed over time, and thereby erroneously indicates that there has not been downward pressure on inflation.

Chart 2 shows trend GDP growth for mainland Norway with different values of λ, while Chart 3 shows the output gap for the same λ values. The calculations confirm that the Norwegian economy has been in an expansionary phase over the last years, and that a slowdown will occur in the years ahead. λ = 500 for annual data in the HP filter implies that trend GDP growth is smoothed to a large extent, ranging between 1.9 and 2.5 per cent in annual, real terms since 1980. λ = 25 implies that trend GDP growth varies between 1.1 and 2.9 per cent in the same period. Pure discretionary evaluations suggest the use of λ = 100. This is in line with international practice and it also provides a reasonable picture of business cycles over the last 20 years. It allows some fluctuations in trend GDP, but without excessive fluctuations. As a result of substantial inertia in the Norwegian economy, which means that the economy may be out of balance over several years, it is unlikely that the trend potential will vary widely.

Chart 2. Trend GDP growth for mainland Norway for various values of λ as a percentage of trend output. Hodrick-Prescott filter



Sources: Statistics Norway and own calculations based on data from *Inflation Report* 2000/1

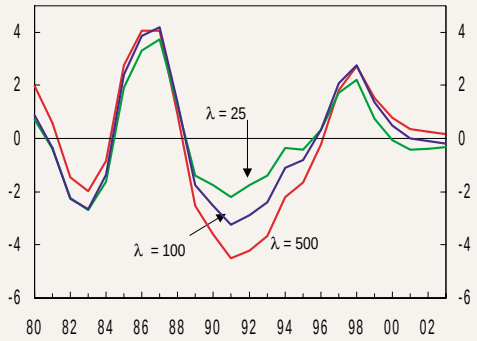
[4] See for example Hodrick and Prescott (1997). They also refer to the method as the "Whittaker-Henderson" method, which has been used since 1923 in the insurance industry to estimate mortality tables.

[5] For an overview of the more formal objections to the HP filter, see for example Harvey and Jaeger (1993) and Guay and Amant (1996). According to Guay and Amant (1996) the sources of error could be substantial if most of the variation in production is due to fluctuations in trend components and there is a large degree of persistence in this contribution to output. Harvey and Jaeger (1993) demonstrate that the HP filter provides a spurious cyclical component if the method is used for a variable that is a "random walk" process.

[6] Kydland and Prescott (1990) have among other thing suggested that the trend component in production should be consistent with the curve that students of economics would draw.

[7] In this study λ=25 is used for most OECD countries including Norway, with the exception of the UK (λ=100) and Canada (λ=200).

Chart 3. Output gap for various values of λ. Hodrick-Prescott filter



Sources: Statistics Norway and own calculations based on data from *Inflation Report* 2000/1

Production function method

Estimating potential output and the output gap using the production function method is linked to the underlying structure in the economy to a greater extent than for the HP filter. The trend levels for labour, capital and available technology are inserted in a further specified production function. Potential output may then be perceived as the supply side in the economy, determined by the factor inputs mentioned. A number of other institutions, among them the OECD and the Swedish Riksbank, use the production function method to estimate the output gap. In the following, we describe how this is done for Norway using the calculation method from the OECD, see Giorno et. al. (1995). The calculations are based on a production function for the sectors *manufacturing, construction, services and distributive trades*.[8] The aggregated production function for the economy, at time t, is assumed to be:

$$y_t = \alpha_0 + \alpha_1 l_t + (1-\alpha_1)k_t + e_t \qquad (3)$$

where the variables are measured in logarithms. y_t value added, λ_t person-hours, k_t capital stock, et total factor productivity and a_0 a constant.[9]

For given factor share (a_1), the growth in total factor productivity is calculated as the residuals from equation (3) using the least squares method. The residuals show considerable fluctuations and we have smoothed the series using a Hodrick-Prescott filter to find trend factor productivity, which was around 1.0 per cent on average in the 1990s.

We assume here that potential capital stock corresponds to actual capital stock, ie that capital stock is fully utilised at any given time. Using economic statistics, it would be difficult in any case to determine the extent to which capital stock is utilised in the production process. It should thus be noted that the historical figures for capital stock are shrouded in a high degree of uncertainty.

Potential labour input measured in person-hours is a function of three variables: The level of the labour force, unemployment and average working time per employee, where the variables are measured in equilibrium (or trend level). Below, we discuss in detail the estimation of the level of unemployment that gives a balanced labour market. On the basis of the calculations for equilibrium unemployment, we can estimate potential employment as:

$$N_t^* = AS_t(1-U_t^*) - N_t^{IM} \qquad (4)$$

where AS_t is trend growth in the overall labour force[10], U^*_t is the estimated equilibrium rate of unemployment and N_t^{IM} is non-modelled employment. We see that an increase in equilibrium employment results in reduced potential employment.

It is difficult to determine how fluctuations in activity levels influence average working time. In our calculations, we have therefore assumed that there are no cyclical variations in average working hours.[11]

Trend total factor productivity, e*, actual capital stock, k, and potential person-hours-employment, l*, are then used to calculate potential production, y*:

$$y_t^* = \alpha_0 + \alpha_1 l_t^* + (1-\alpha_1)k_t^* + e_t^* \qquad (5)$$

As illustrated in the discussion above, one advantage of the production function method is that the total effect of potential output can be distributed by the contribution from each input. For example, if unemployment is lower than equilibrium unemployment, this will in isolation imply higher employment than potential employment and hence a positive output gap.

One problem associated with the production function method is that it is very data-intensive. In addition, there is substantial uncertainty associated with estimating normal levels for total factor productivity and the level of equilibrium unemployment (see discussion below). There are also methodological problems since one assumes that it is reasonable to describe output in terms of equation (3). If this structure is oversimplified, the estimations of among other things total factor productivity will be erroneous.

Different measures of equilibrium unemployment in the production function method

The discussion above shows that the estimate for equilibrium unemployment that is used in the production function method is important for the results. We will dis-

[8] These sectors account for about ¾ of production for mainland Norway measured in terms of basis value.

[9] Formally, this is a Cobb-Douglas production function with constant returns to scale. This means that the elasticities of value added with regard to labour and real capital are constant and add up to 1. Elasticities are given by the factor income shares of the two production factors. The weights can according to the Ministry of Finance (1997) be estimated at ⅔ for person-hours and ⅓ for real capital for mainland enterprises.

[10] Trend growth in the labour force is found using the Hodrick-Prescott filter.

[11] This implies that $L_t^* = (N_t^*)H_t$, where H_t is actual average working at time t.

cuss how the various measures of equilibrium unemployment influence the estimations of the output gap using the OECD's measure of equilibrium unemployment and a new method for estimating equilibrium unemployment.

Equilibrium unemployment measured by main course unemployment, NAIRU and NAWRU

In Norway equilibrium unemployment has been estimated using the so-called main course model for wage formation, see Aukrust (1977).[12] Aukrust's model for wage and price formation in a small open economy distinguishes between the exposed sector (K) and the sheltered sector (S). In both sectors K and S wages and prices must over time be adjusted so that profitability is maintained at a level that is sufficiently high to attract investors. In the K sector, costs cannot be passed on to product prices. Wages must thus be adjusted to foreign prices and productivity, which combined constitute the so-called main course for wage developments.

The main course theory is in principle not a theory for determining equilibrium unemployment, but can first be used for this when linked with the Phillips curve. Simplifying, we will in the following identify sector K as manufacturing. The estimation of main course unemployment uses a Phillips curve relationship for manufacturing, see Stølen (1985):

$$\Delta w_t = a_0 - a_1 U_t + a_2 \Delta p_t + a_3 \Delta q_t + a_4 \Delta w_{t-1} + a_5 \Delta z_t \qquad (6)$$
$$a_1 \geq 0,\ 0 < a_2 + a_3 + a_4 \leq 1,\ 0 \leq a_5 \leq 1$$

where the variables are measured in logarithms. w_t is nominal wages in manufacturing in the period t, p_t the consumer price index, z_t average labour productivity, q_t the producer price index and U_t the unemployment rate. Since w, p, q and z are measured in logarithmic scale, equation (6) expresses the growth rate for manufacturing wages. We see that increased labour market pressures, measured by a lower U, result in higher wage growth. In the same way, higher cost of living, measured by higher Δ_p, and improved earnings in manufacturing, measured by higher Δ_q and Δ_z, lead to an increase in wage growth. Finally, the previous year's wage growth is incorporated to take account of the adaptation of wage growth to these explanatory variables with some lag.

Main course unemployment can be derived from equation (6) when we assume a hypothetical equilibrium situation where the wage share in manufacturing is constant from one period to the next. The expression for main course unemployment U^{hk}, becomes[13] :

$$U^{hk} = \left[\frac{a_0}{a_1} + \frac{a_2 + a_3 + a_4 - 1}{a_1} \pi_p + \frac{a_4 + a_5 - 1}{a_1} \pi_z \right] \qquad (7)$$

where π_z is a constant growth rate for productivity in manufacturing and π_p is a constant rate of increase for producer prices (and import prices).

According to equation (7), a fall in price inflation abroad, π_p, will increase main course unemployment if $a_2 + a_3 + a_4 < 1$. This assumption is consistent with the falling slop of the long-term Phillips curve. Reduced productivity growth in manufacturing, π_z, increases main course unemployment if $a_4 + a_5 < 1$. A productivity fall implies in isolation a deterioration in profitability. Higher main course unemployment indicates that wages must be reduced to offset the fall in productivity[14].

The concept main course unemployment is in many ways akin to NAIRU. NAIRU is defined as the level of unemployment that is consistent with constant inflation.[15] If $a_2 + a_3 + a_4 = 1$, we see from equation (7) that lower international price inflation does not affect main course unemployment. This is consistent with the case where the long-term Phillips curve is vertical.[16] In accordance with equation (7) we thus define NAIRU as:

$$U^n = \left[\frac{a_0}{a_1} + \frac{a_4 + a_5 - 1}{a_1} \pi_z \right] \qquad (8)$$

Empirical tests on both Norwegian and foreign data show, however, that the Phillips curve formulation is an over-simplified description of how the economy functions in this area, see Rødseth and Nymoen (1998) for a description of wage formation in the Nordic countries. The main problem is not the assumption of a constant wage share in the long term, but rather which mechanisms that maintain wage growth within the main course corridor. The Phillips curve relationship includes only one such mechanism: Unemployment must increase if wage growth is excessively high, and decline if it is too low. The main course will, however, be maintained in many other ways. Empirical studies show for example that profitability in manufacturing has an independent explanatory power for wage growth. The results imply that the standard method for estimating equilibrium unemployment loses its fundament: Unemployment cannot be determined based on the assumption that the main course will apply in the long term, see Naug (1992).

[12] This method has dominated in Norway, and the estimates for main course unemployment are used in several key official reports in the 1980s and 1990s, see NOU reports (1988a), (1988b) and (1992).

[13] See appendix for derivation of main course unemployment .

[14] Graphically, a fall in productivity could be represented by a positive horizontal shift in the long-term Phillips curve so that main course unemployment will increase to a given foreign rate of increase in prices.

[15] NAIRU is an acronym for "non accelerating inflation rate of unemployment" and is credited to Tobin (1975). As the definition is linked to constant inflation a correct designation would be "non increasing inflation rate of unemployment" (NIIRU), but the acronym NAIRU has taken root in the profession.

[16] Some authors argue that there are substantive differences between NAIRU and natural unemployment but in applications it is common to define natural unemployment as the unemployment rate that follows from a vertical Phillips curve. The concept natural unemployment has its origin in works by Friedman (1968) and Phelps (1967).

The OECD's NAWRU method, see Elmeskov and McFarland (1993) and Elmeskov (1994), can also be easily understood using main course unemployment. This method is based on the assumption that a change in wage growth is proportional to the difference between actual unemployment and NAWRU:

$$\Delta^2 w_t = \eta\left(U_t - U_t^{NAWRU}\right) \qquad \eta < 0 \qquad (9)$$

where w_t is the logarithm for the wage level[17] and U_t is the number of registered unemployed as a percentage of the labour force. U_t^{NAWRU} is the level of unemployment that makes unemployment stable in relation to (9).[18] Since we see that developments in the estimated NAWRU from equation (9) is highly volatile from one year to the next, the OECD uses the Hodrick-Prescott filter to smooth the series. Chart 4 below shows estimated NAWRU.

We see that the wage relationship used in the NAWRU method is a special case of equation (6). The two models are convergent if $a_2=a_3=a_5=0$ and $a_4=1$, and one assumes that NAWRU is stable over time.[19] According to equation (8) we can then write $U^{NAWRU} = [a_0/a_1]$. But since we have argued that equation (7) is an erroneously specified model for wage formation, the uncertainty of the empirical status of main course unemployment will be even greater for NAWRU. Holden and Nymoen (1999) test the NAWRU estimates for the Nordic countries, and conclude that the method is not suitable for determining developments in equilibrium unemployment.[20]

Equilibrium unemployment measured directly

In the calculations above main course unemployment and NAIRU are based on an equation that explains wage inflation, which is then used to determine the equilibrium value of another variable, ie unemployment. This is thus an indirect method and as we have seen builds on a number of assumptions concerning the relationship between wages and unemployment, see Kolsrud and Nymoen (1998) and Jansen and Nymoen (1994).

An alternative approach is to derive an estimate for equilibrium unemployment from a model that is designed to explain developments in the unemployment rate itself. To illustrate this we start with:

$$U_t = \alpha_0 + \alpha_1 U_{t-1} + \beta X_t + \varepsilon_t \qquad |\alpha_1| < 1 \qquad (10)$$

where X_t represents a set of variables that explains unemployment. It is natural to look at expectations of U_t as a function of the historical developments in unemployment, U_0, and a given value X* of the explanatory variable:

$$E\left[U_t \mid X^*, U_0\right] = \frac{\alpha_0(1-\alpha_1^t)}{(1-\alpha_1)} + \frac{(1-\alpha_1^t)}{(1-\alpha_1)}\beta X_t^* + \alpha_1^t U_0 \qquad (11)$$

When t increases towards infinity the importance of historical developments declines, and long-term equilibrium unemployment is:

$$U_t^{eq\text{-}x} = E\left[U_t \mid X^*\right] = \frac{\alpha_0}{(1-\alpha_1)} + \frac{\beta}{(1-\alpha_1)} X_t^* \qquad (12)$$

Measured in this way, equilibrium unemployment depends on the assumptions concerning X*, ie the long-term value of the explanatory variables in X_t. We have carried out a few illustrative calculations where X_t includes mainland GDP growth, the wage share in manufacturing and the scale of labour market measures. Equilibrium unemployment is calculated using a five-year moving average for GDP growth and profitability. From year to year, GDP growth is heavily influenced by demand conditions, but it is reasonable that the average growth rate over a somewhat longer period reflects supply side conditions. The wage share in manufacturing represents a profitability indicator and is also a supply side variable. Labour market programmes are smoothed over whole decades to capture the long-term structural element in such measures.

As shown in Chart 4, when using the direct method equilibrium unemployment is on the whole lower than NAWRU in the whole period from 1975 to 1991, while they have been more similar in the 1990s. In 1999, registered unemployment was 2.6 per cent. Equilibrium unemployment measured by the direct method is estimated at 3.7 per cent, while NAWRU is estimated at 3.5 per cent that year. In the years ahead, the difference between the two estimates is relatively small.

Up to 1981, there is no significant difference between actual unemployment and unemployment estimated using the direct method. The increase in unemployment in 1982 is not offset by an increase in equilibrium unemployment, and it is reasonable to attribute this period of unemployment to a temporary drop in demand. When unemployment rises again at the end of the 1980s, we see that there is also a substantial increase in the estimated rate of equilibrium unemployment, which primarily reflects an increased wage share and thus weaker profitability in manufacturing, but also lower growth rates in the economy as a whole. We emphasise that

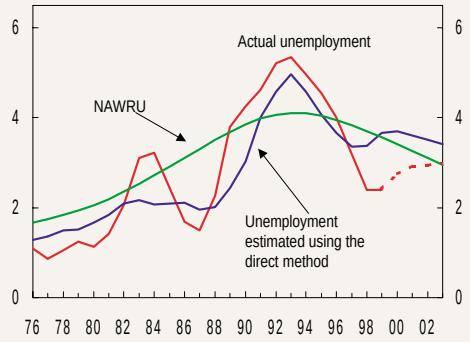
[17] Unlike in equation (6), we have used the wage level in mainland Norway.

[18] For a detailed description of how one can estimate NAWRU, see Holden and Nymoen (1998) or Giorno et. al. (1995).

[19] With the symbols from equation (6) this implies that $-h*UNAWRU=a_0$.

[20] Fluctuations in underlying productivity growth are a candidate for creating fluctuations in equilibrium unemployment, see Gordon (1998). With our notations, the parameter a_0 may not necessarily be constant over time, but depends on different supply side factors.

Chart 4. Actual unemployment rate, NAWRU and unemployment estimated using the direct method. As a percentage of working age population



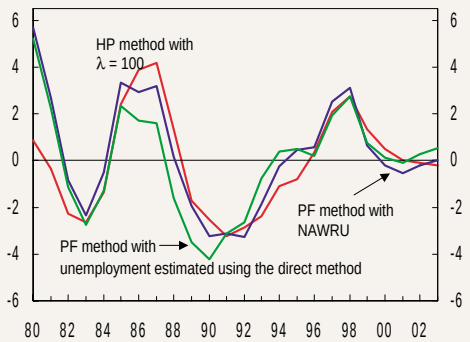
Sources: Statistics Norway and own calculations based on data from *Inflation Report* 2000/1

these calculations are only to serve as an illustration and must not be considered as Norges Bank's assessment of equilibrium unemployment in Norway.

Chart 5 shows developments in the output gap using the production function method with various measures of equilibrium unemployment. The estimates are very similar.

As was the case with the results using the HP filter, the production function method also shows that the Norwegian economy has been in an expansionary phase in recent years. In contrast to the HP method, the output gap is positive at the end of the calculation period, measured by direct equilibrium unemployment. The production function method using the direct method for measuring equilibrium unemployment shows a somewhat more positive output gap at the end of the period as this estimate for equilibrium unemployment is slightly higher than NAWRU estimates.

Chart 5. Comparison of output gap estimates arrived at by different methods, as percentages of trend output



Sources: Statistics Norway and own calculations based on data from *Inflation Report* 2000/1

Summary and further work

The Hodrick-Prescott filter and the production function method should be considered as complementary rather than alternative methods for estimating the output gap. The Hodrick-Prescott filter is a simple but relatively mechanical way of estimating the output gap. Variations in trend output will to some extent depend on the discretion of the user. In addition, there is substantial uncertainty associated with the estimates for the output gap obtained using the HP method at extreme points. The production function method is based on a more theoretical approach, but requires among other things estimates for equilibrium unemployment. We have shown that measures of unemployment in equilibrium may to some extent change the estimate for the output gap. Moreover, the calculation of trend factor productivity requires that the production function used is a valid representation of the economy.

A shortcoming inherent in the methods is that neither takes full account of supply shocks. An example of a supply shock is explosive growth in the use of the Internet. Some analysts have suggested that this may have increased potential output in the US economy, see for example Claussen (1999). If a positive supply shock leads to a sudden increase in potential output – for a given actual output – the true output gap may be overestimated to the extent that the above methods do not capture this. This may result in erroneous overpredictions of inflationary pressures in the economy. In the event of a negative supply shock that reduces potential output, the true output potential will decline with the attendant risk of underestimating inflationary pressures.

In recent years, new methods for estimating the output gap have been developed, which remedy some of the shortcoming of the methods used in this article. The Reserve Bank of New Zealand uses a method where the HP filter is supplemented with information provided by a Phillips curve and capacity utilisation data, see Conway and Hunt (1997). They find that this broadening significantly improves the explanatory power of the output gap with regard to changes in inflation compared with the HP method. The Swedish central bank's inflation report includes output gap estimates obtained using a simultaneous model for the output gap, equilibrium unemployment and inflation, see for example Apel et. al. (1996) and Apel and Jansson (1997). This simultaneous model ensures consistency between developments in inflation and the level of production and unemployment where inflation is constant. Norges Bank is currently testing these methods on Norwegian data.

Appendix. Derivation of main course unemployment

Main course unemployment can be derived from equation (6) when we assume a hypothetical equilibrium situation where the wage share in manufacturing is constant from one period to another:

$$\Delta w_t - \Delta p_t - \Delta z_t = 0 \qquad (13)$$

Furthermore, equilibrium is characterised by an increase in producer prices in pace with import prices, which increase at a constant rate π_p ;

$$\Delta q_t = \Delta pi_t = \pi_p \qquad (14)$$

Finally the growth rate for productivity is constant, and designated as p_z. All in all, these assumptions imply that: In equilibrium, wage growth follows a main course consisting of foreign price inflation and productivity growth in manufacturing.

Main course unemployment is defined as the unemployment rate that brings wage growth into line with the main course. When we in addition to equations (13) and (14) write the consumer price index p_t as a weighted sum of the producer price index q_t and the import price index pi_t:

$$p_t = \Phi q_t + (1-\Phi)\, pi_t \qquad 0 < \Phi < 1 \qquad (15)$$

we obtain the expression for main course unemployment, U^{hk}, in equation (7) in this article.

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