# The output gap in Norway – a comparison of different methods

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**Are pressures in the economy strong or subdued? The answer to this question is important to a central bank operating an inflation-targeting monetary policy regime, because the degree of pressure in the economy can provide some indication of future inflation. The level of output that is at any time consistent with stable inflation is usually referred to as potential output. The output gap, which measures the difference between actual and potential output, is a commonly used measure of inflationary pressures in the economy.**

**The output gap is not directly observable, and must therefore be estimated. Different calculation methods, however, often produce different values for the output gap. In this article, a set of alternative methods for estimating the output gap are presented and compared. The different methods show a consistent pattern for the output gap, but there are also important differences. Our study shows that if the assessment of economic pressures is solely based on developments in the output gap as measured by one method, there is a risk of misjudging the economic situation. Assessments of the output gap must therefore also be based on professional judgment and supplementary indicators.**



Assessments of the state of the economy are based on continuous monitoring and analysis of a number of economic indicators that represent different aspects of the economy. In order to summarise and quantify economic pressures, the output gap has proved to be a useful starting-point. Most inflation-targeting central banks therefore publish estimates of developments in the output gap in addition to inflation projections.

In a situation where employment is high in relation to the total labour force and the capital stock is fully utilised, there will be a tendency for price and wage inflation to rise. Conversely, price and wage inflation will tend to decrease when unemployment is high and capital utilisation is low. This also means that at any given time there exists a level of resource utilisation that would be consistent with stable developments in prices and wages. The corresponding level of output is usually referred to as potential output. The output gap is the difference between actual and potential output. If actual output is higher than potential output, the output gap is positive, indicating pressures in the economy. In isolation, this is usually accompanied by rising inflation. A negative output gap indicates spare capacity and falling inflation.

The output gap is also an important variable in itself, as a measure of economic fluctuations. Over time, economic resources are utilised efficiently when economic growth is stable and the output gap remains close to zero. Employment and unemployment will then be stable.

It may be useful to think of potential output as consisting of two components. On the one hand, a *constant* rate of increase in the labour force, capital and technological progress will result in steady annual growth in potential output. This component of potential output can be represented by a smooth, deterministic trend that is solely dependent on time. On the other hand, there are a number of reasons for potential output growth to vary over time. Technological advances can result in strong productivity growth and changes in the level of potential output. The supply of natural resources can vary. The labour supply depends on factors such as preferences between work and leisure, institutional factors and demography. Capital stock depends on the level of fixed investment. Changes in these production conditions (the supply side of the economy) might result in changes in potential output beyond those indicated by purely deterministic developments. As a rule, these changes will lead to long-term or permanent shifts in potential output, (although the changes may also be temporary). When these factors are added to the deterministic trend, it becomes clear that potential output can no longer be described as a smooth trend.

If actual output is equal to potential output, the output gap will be zero. This occurs very seldom since the economy is also exposed to more short-term, cyclical disturbances, which are related to the demand side of the economy.

Actual output can thus be divided into three components:
- a deterministic trend,
- changes in production conditions (supply-side disturbances of some duration), and
- the output gap (temporary demand-side disturbances).

This division is useful for two reasons. First, the division shows that variation in economic growth over time

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may be due to disturbances (shocks) on both the supply side and the demand side of the economy. The output gap and the inflation outlook are only affected by temporary demand shocks[2]. Second, the division provides a useful guideline when calculating and interpreting the unobservable variables potential output and the output gap.

Different methods for estimating the output gap can produce different values. This has given rise to a number of studies, including some recently carried out by central banks[3]. Historical estimates of the output gap might also change when data are revised and new information emerges[4]. The problem of data revisions applies to both actual and potential output, and there is therefore uncertainty concerning both components of the output gap.

In this article, we will focus on estimating and comparing different methods for estimating the output gap and will for the present disregard the problems associated with data revision and new information. In Section 1, the different methods are explained and estimates based on Norwegian data are presented. In Section 2, we review some simple criteria for comparing the alternative estimates. Our conclusions are presented in the third and final section.

## 1. Methods for estimating the output gap

A few methods for estimating the output gap have been discussed previously in Norges Bank's quarterly *Economic Bulletin*, see Frøyland and Nymoen (2000). The issue of measuring the output gap has also been discussed in a number of boxes in Norges Bank's Inflation Report, most recently in *Inflation Report* 2/04. In this article, we will present a set of internationally recognised and commonly used methods, then estimate alternative output gaps using Norwegian data and compare the different methods.

The output gap can be defined as

$$(1) \qquad ygap_t = y_t - y^*_t$$

The variables are expressed in logarithms, with the output gap, $ygap_t$, being the percentage deviation between actual output ($y_t$) and potential output ($y^*_t$).

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

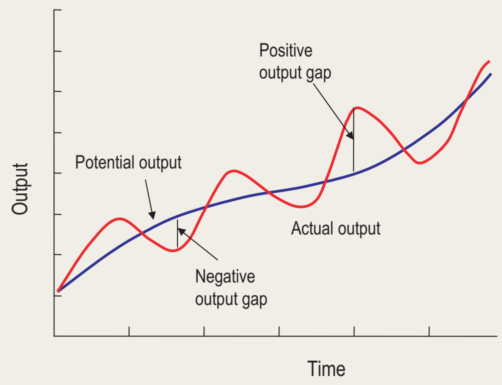



Chart 1 presents a graphical illustration[5] of the relationship between the output gap and actual and potential output.

Historically, the first, simple methods for estimating the output gap were based on the assumption that output was moving along a linear trend in the long term. The trend was interpreted as an indication of potential output. A linear trend, however, is a very strict assumption that does not allow for possible variations in potential output over time, cf. the above discussion.

Over recent decades, a number of alternative methods for estimating the output gap have been developed. The alternative methods can be categorised in several ways. We have chosen to group the methods into two main categories: univariate methods (methods that use information inherent in GDP only) and multivariate methods (methods that also use additional variables).

### *1.1 Univariate methods*

Univariate methods only use information in the time series itself (here, mainland GDP) to estimate the output gap. Most of these methods calculate a trend as an expression of potential output. Some methods model the output gap directly.

There are many alternative univariate methods, from the very simple to the relatively complicated. Three examples will be reviewed here. The estimates are based on seasonally-adjusted figures from the quarterly

[2] This interpretation of the output gap is derived from the traditional definition of the output gap as a measure of economic developments. In an alternative interpretation of the output gap, based on more recent macroeconomic theory, real demand shocks also affect potential output. Potential output is defined as the output level that would result if prices and wages were fully flexible. This definition has its foundation in welfare economics theory. The main difference between this definition and the one we have selected as our basis is the effect of demand shocks. According to our definition, an unexpected increase in, for example, public expenditure would not have any effect on potential output and would therefore have full impact on the output gap. According to the alternative definition, however, the potential output level would also increase in the short term, with a smaller increase in the output gap as a result. Our definition largely disregards effects on potential output caused by short-term disturbances.

[3] See for example Scott (2000), Citu and Twaddle (2003) and Rennison (2003).

[4] The problems of measuring the output gap in real time have received increasing attention in recent years: in any specific quarter (t), preliminary information is available concerning economic developments up to and including the previous quarter (t-1). The output gap in real time for quarter (t-1) is estimated on the basis of this information. As time passes, new information emerges and preliminary figures are revised. In final estimates, the output gap in quarter (t-1) will have a different value than that shown in the estimates from quarter (t). See for example Bernhardsen, Eitrheim, Jore and Røisland (2004) for a comparison of the output gap based on Norwegian real-time data and final data using several alternative methods.

[5] The chart is taken from Frøyland and Nymoen (2000).

national accounts for the period 1978 Q1 to 2004 Q2. In spite of seasonal adjustment of the figures, variations in the quarterly figures result in substantial, random disturbances in the output gaps. Although the calculations are based on quarterly data, in the figures presenting the various output gap, we have aggregated the quarterly figures to annual figures. For 2004, published figures for the first half of the year have been used.

### Hodrick-Prescott filter (HP)

The Hodrick-Prescott filter is a simple, widely used technical method[6]. The HP filter is a method for finding the value of potential output $yt^*$ that minimises the difference between actual output and potential output while imposing constraints on the extent to which growth in potential output can vary. The following expression is minimised:



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

The first term in the equation is the square of the difference between actual output and potential output. The second term is the square of the change in potential output growth. λ is a parameter with values between zero and infinity that determines the extent of permissible variations in potential growth. λ is determined outside the model. In the borderline case where λ is infinite, there will be minimal variation in potential growth. The result is a linear trend with a level of growth that is constant. In the opposite borderline case where λ = 0, the difference between actual output and potential output is as small as possible. These two variables will then be identical and the output gap will be zero at all times.

One advantage of the HP filter is that the method is simple to use. Flexibility in potential output growth is permitted by setting an appropriate value for λ. One disadvantage is that the level of potential output is more affected by variations in actual output at the beginning and at the end of the period than in the rest of the period. This is because the HP filter for any given point uses observations both backwards and forward in time in order to estimate potential output (two-sided filtering). At the end of the series, there are only observations backwards in time, and the two-sided filter gradually becomes a one-sided filter. The higher the value assigned to λ is, the greater the end-point problem becomes.[7] The problem can to some extent be reduced by extending the time series for GDP using estimates. Another disadvantage is that the value of λ must be determined in advance. In their study of business cycles in the US economy, Kydland and Prescott (1990) proposed a value of 1600 for quarterly figures, and this has become an international standard. They found that with this value, minimisation of (2) gave a GDP trend that was reasonable.

Charts 2a and 2b illustrate the importance of the value of λ. Chart 2a shows two output gaps estimated with λ equal to 1600 and 40 000[8] respectively. Chart 2b shows how potential growth varies with the value of λ. With λ at the lowest value, fluctuations in the output gap are smallest and there is thus more variation in potential output. This may be interpreted to mean that variations in GDP can to a lesser extent be explained by temporary disturbances on the demand side.

Although the two output gaps largely tell the same story, there are some clear exceptions: During the downturn in the first half of the 1990s, the output gap based on λ = 1600 turns and becomes less negative as early as 1989, while the output gap based on λ = 40000 does not turn until 1991/1992. Another exception is the change from 2003 to 2004, which varies considerably according to the value of λ. In our comparison of methods later on in this article, we follow international practice and use an output gap based on λ = 1600.

### Band-pass filter (BP)

The fluctuations we observe in a time series have different causes. Each cause gives rise to fluctuations that occur with regular frequency. The short-term variations in GDP, for example seasonal variations and irregular

**Chart 2a**. Hodrick-Prescott filter (HP). Output gap for various values of λ. Per cent of potential GDP

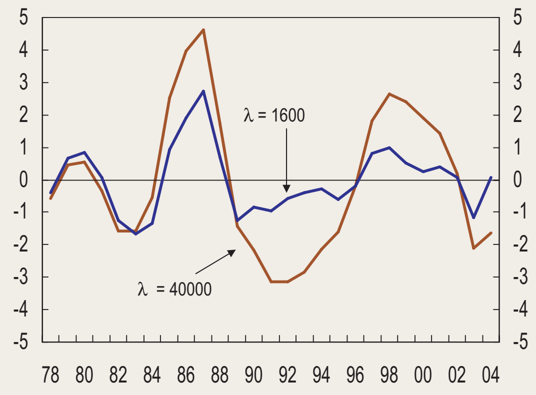
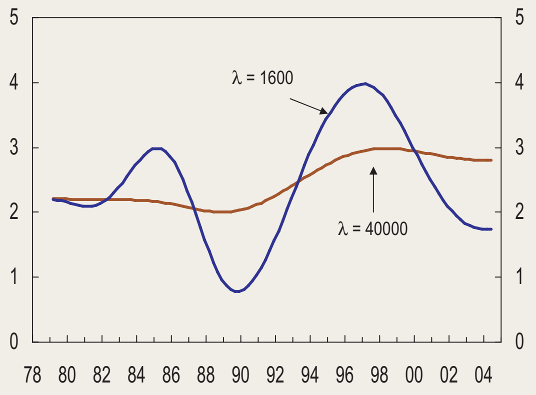



**Chart 2b.** HP filter. Potential GDP growth for mainland Norway for various values of λ. Per cent




[6] For a more detailed discussion, see Kydland and Prescott (1990).

[7] See Bernhardsen, Eitrheim, Jore and Røisland (2004) for a more detailed discussion of the HP filter and the end-point problem.

[8] Statistics Norway uses λ = 40000 in its analyses of the Norwegian economy.

**Chart 3**. Band-pass filter (BP). Output gap. Per cent of potential GDP

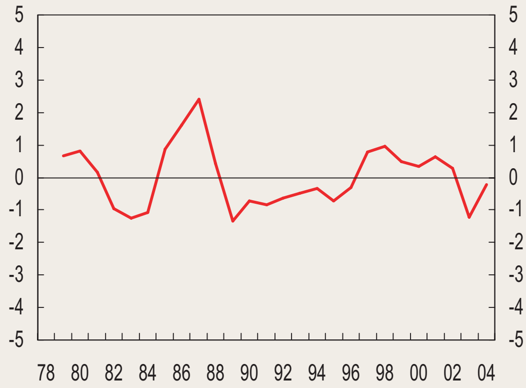
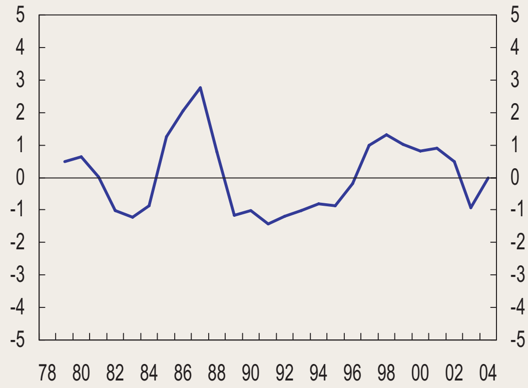



**Chart 4**. Univariate unobserved components method (UC). Output gap. Per cent of potential GDP




components, are high-frequency variations. Long-term developments in GDP, or the trend, will typically be low-frequency variations. Between these extremes lie frequencies corresponding to the length of a business cycle, normally 2-8 years. A time series such as GDP might thus comprise low-frequency long cycles (trend), medium-frequency business cycles and high-frequency seasonal variations and irregularity.

Use of the band-pass filter is based on the idea that fluctuations in a time series are composed of fluctuations from different sources. The filter largely removes the high- or low-frequency components of the GDP series, leaving the fluctuations that can be interpreted as cyclical fluctuations. This is achieved by means of a time series analysis based on an estimated moving average of GDP. This method for estimating the output gap is based on Baxter and King (1999). The band-pass filter estimates the output gap directly, while potential GDP is defined as actual GDP minus the output gap.

Like the HP filter, the band-pass filter is a two-sided filter. However, in contrast to the HP filter, the band-pass filter does not become a one-sided filter at the beginning and end of the period being analysed. Estimating the output gap for the first and last part of the period is therefore impossible. This is a drawback of this method. A common solution to the problem is to extend the time series. The estimated output gap then becomes particularly uncertain towards the end of the estimation period. In our analysis, the band-pass filter is extended by means of a simple, mechanical projection. An advantage of this filter compared with the HP filter, however, is that we can make use of historical experience with regard to the duration of business cycles (by considering the frequency of cyclical fluctuations) when estimating the output gap. Thus, we can state with some certainty that the business cycle has the length that has historically been observed for business cycles.

**Univariate "unobserved component" methods (UC)**

The "unobserved component" method is based on the premise that an observable variable is composed of two or more components that are not observable. The basic idea is that the unobservable variables can be identified by assuming that they affect the variable that can be observed. In addition, we must specify the underlying processes that are behind the unobservable variables over time. Both the unobservable variables and the observable variable are modelled and estimated as a "maximum likelihood" system using the Kalman filter[9].

Among the simplest UC models are the local linear trend models. The following equations provide an example of these models:

(1') $y_t = y^*_t + ygap_t$

(3) $y^*_t - y^*_{t-1} = \delta_{t-1} + \eta_t$

(4) $\delta_t = \delta_{t-1} + v_t$

(5) $ygap_t = \rho_1 ygap_{t-1} + \rho_2 ygap_{t-2} + \varepsilon_t$

This specification is taken from Clark (1987). We start with equation (1'), which states that GDP ($y$) can be decomposed into the unobserved variables potential GDP ($y^*$) and the output gap ($ygap$). Equations (3) and (4) determine how potential GDP grows. It is assumed here that both the level and rise in potential GDP can vary over time. To be precise, we assume that potential output follows a random walk with drift[10], where $\eta$ and $v$ are random and normally distributed residuals that are independent of each other (white noise). This specification places few constraints on permitted variations in unobservable potential output. Equation (5) says that the output gap depends on separate back-dated values and a "white noise" add factor. $\rho_1$ and $\rho_2$ are coefficients.

One advantage of this method in relation to the other univariate methods described above is that both $y^*$ and $ygap$ are modelled directly. The result, however,

[9] The Kalman filter is an estimation procedure that is particularly appropriate for estimating equation systems where one or more variables may be unobservable.

[10] Random walk is a process where the value of a variable at a point in time is the value of the variable in the preceding period plus a white noise residual. This means that changes in the variable are random, and historical developments cannot be used to estimate values in the future. Since economic time series usually increase over time, a trend factor is added. The process is referred to as random walk with drift. The drift can contain a deterministic trend, or it can itself consist of a random walk process. In the model presented here, λ represents the drift in a random walk process for potential GDP in equation (3). In equation (4), λ is itself modelled as a random walk process.

depends on how potential GDP and the output gap are modelled. The method also makes it possible to provide some indication of the uncertainty surrounding the estimated output gap by estimating the standard deviation.

The three methods reviewed so far are examples of methods for decomposing GDP into potential output and the output gap using variation in GDP only. Charts 2 to 4 indicate that, in qualitative terms, the different methods provide the same description of cyclical movements. For a more detailed discussion, see section 2.

## *1.2 Multivariate methods*

Multivariate models make use of a number of variables to estimate potential output and/or the output gap. The idea is that there are relationships between variation in GDP and variation in other observable variables that can be used. The term "multivariate methods" covers a wide range, and three different methods are presented here. The first method models the supply side of the economy by assuming that potential output depends on available resources and technology. The next two methods assume that the rise in prices for goods and services that are domestically produced (domestic inflation) and unemployment can contribute to explaining developments in the output gap. These two methods make use of the same explanatory variables, while the modelling of relationships and estimation methods is different.

**Production function method (PF)**[11]

This method assumes that output can be described by a production function. A production function describes the supply side of the economy, where output is determined by available technology and the input factors labour and capital. Potential output may be perceived as the resulting output level if the input factors are neither exposed to strong pressures nor partially unutilised. The difference between actual output and estimated potential output can then be interpreted as the output gap.

The aggregated production function for the economy[12] can be expressed as a Cobb-Douglas production function:

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

where $y$ is GDP, $l$ is person-hours, $k$ is capital stock, $e$ is total factor productivity and $\alpha_0$ is a constant. The coefficients $\alpha_1$ and $(1 - \alpha_1)$ are the factor shares for labour and capital respectively. Total factor productivity is calculated as the residuals from equation (6) using the least-squares method.

The potential levels of person-hours, capital and total factor productivity are then used to estimate potential output, $y^*$:

(7) $$y_t^* = \alpha_0 + \tfrac{2}{3} l_t^* + \tfrac{1}{3} k_t^* + e_t^*$$

We have inserted values for the factor income shares, which can be estimated, according to the Ministry of Finance (1997), at ⅔ for person-hours and ⅓ for capital for mainland enterprises.

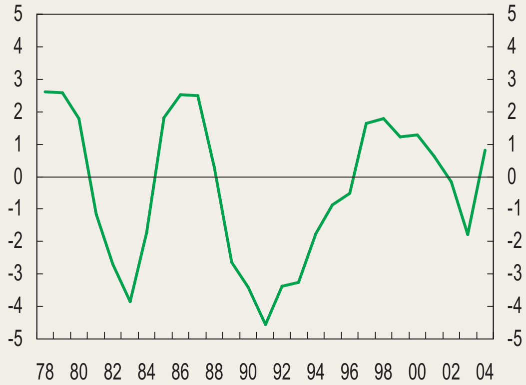
Potential use of person-hours depends on the potential level of the labour force, working hours per employee and equilibrium unemployment[13]. Potential capital stock is assumed to be the same as actual capital stock since it is difficult to determine to what extent capital stock is used in the production process. Equilibrium unemployment and the potential levels of total factor productivity, the labour force and working hours are calculated using the HP filter[14].

The advantage of this method is that it is based on a theoretical foundation and intuitively seems reasonable. It is, however, based on one of many possible types of function. The underlying data may also cause problems; measuring the capital stock is particularly uncertain. It is also a disadvantage that potential employment is unobservable and must be estimated, and that both actual and potential total factor productivity are unobservable. Since we have used the HP filter to estimate potential employment and factor productivity, the end-point problems of the HP filter also feature here.

**Multivariate "unobserved component" method (MVUC)**

The univariate "unobserved component" model can be expanded by including a number of variables that are assumed to contain information about the output gap. In

**Chart 5**. Production function method (PF). Output gap. Per cent of potential GDP



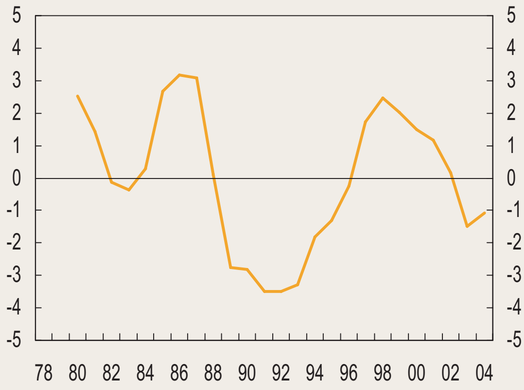

[11] Based on the description in Frøyland and Nymoen (2000).

[12] We follow the approach described in Frøyland and Nymoen (2000) and estimate a production function for the sectors manufacturing, construction, services and distributive trades. These sectors account for about ¾ of output in mainland Norway.

[13] Equilibrium unemployment can be defined as the level of unemployment that is consistent with stable wage and price developments. Alternative estimates of equilibrium unemployment are discussed in Frøyland and Nymoen (2000).

[14] The values of the parameter λ in the calculations of the potential levels are determined on the basis of what seems reasonable.

**Chart 6.** Multivariate unobserved components method. (MVUC). Output gap. Per cent of potential GDP




the model used in this article, information about unemployment and the rise in prices for goods and services produced in Norway (domestic inflation) is included in addition to GDP. It is assumed that the output gap influences domestic inflation, and that there is a relationship between labour market tightness and the output gap[15].

Labour market tightness, the "unemployment gap", is defined as the difference between actual unemployment and equilibrium unemployment. Since equilibrium unemployment is unobservable, we now have a total of three unobservable variables in the model: the output gap, potential output and equilibrium unemployment. Domestic inflation is included as an observable variable.

An advantage of the MVUC method over univariate methods is that it uses more information. In addition, the method makes it possible to give some indication of the uncertainty associated with the estimated output gap. In order to make use of the extended information, however, some assumptions have to be made about the relationship between the different variables. The quality of the estimated output gap will depend on how realistic these assumptions are.

**"Structural vector autoregression" (SVAR) model**

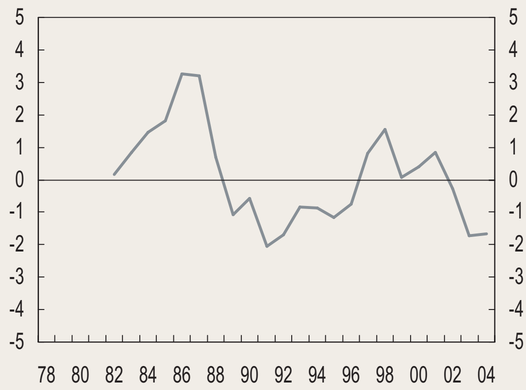
The SVAR method uses information from a number of variables that have a high degree of correlation, such as GDP, unemployment and domestic inflation, to estimate potential GDP and the output gap. In contrast to many methods where the output gap is calculated as the difference between actual GDP and estimated potential GDP, the SVAR method is similar to the UC method in that potential output and the output gap are determined simultaneously in the model[16].

The basic idea behind this method is to split GDP into three components: a deterministic trend, a component determined by disturbances, or shocks, that have a permanent effect on the supply side of the economy, and a component determined by temporary shocks that affect demand in the short term. The first two components represent potential GDP, while the latter can be interpreted as the output gap.

The method used to identify the SVAR model is based on an article by Blanchard and Quah (1989), which showed how a priori restrictions can be imposed on long-term multipliers in a model of endogenous variables in order to identify underlying structural shocks. Blanchard and Quah distinguished primarily between demand and supply shocks. By estimating a model consisting of GDP and unemployment, they assumed that only supply shocks can have a long-term effect on the level of GDP. Demand shocks can have an effect on GDP in the short term, but the effect of these shocks will vanish in the long term. Since unemployment is assumed to be stationary[17], no shock can (by definition) have a long-term effect on the level of unemployment. The assumption that demand shocks cannot have a long-term effect on the level of GDP (and unemployment) is fully consistent with a standard aggregated demand and supply model, where the supply curve becomes vertical in the long term.

In our analysis here, we expand the model of Blanchard and Quah to include domestic inflation. Moreover, since employment increased in the course of our estimation period (1982 Q1 to 2004 Q2), some of the shocks must also be able to affect equilibrium unemployment over time. With three variables, we can identify three shocks: two demand shocks and one supply shock. We assume that none of the demand shocks can have a long-term effect on unemployment. However, one of the demand shocks is allowed to have a long-lasting effect on GDP. [18] This has been done to permit the possibility that some demand shocks can have substan-

**Chart 7.** Structural vector autoregressive method (SVAR). Output gap. Per cent of potential GDP




[15] The model is described in more detail in the appendix to this article.

[16] The model is described in more detail in the appendix to this article. See Bjørnland, Brubakk and Jore (2005) for a comprehensive technical explanation (to be published). See also Bjørnland (2004) for a more detailed application of SVAR models to the Norwegian economy.

[17] A stationary variable fluctuates around its average, and these fluctuations do not increase or decrease over time.

[18] It may for example be argued that demand shocks can result in temporary changes in potential output due to changes in capital accumulation. This effect is, however, expected to be small, since capital accumulation is slow. Impulse responses also show that the effect on GDP of this demand shock disappears in the medium term (4-6 years).

tial effects on output in the medium term, although without permanent changes in unemployment as a result.[19] The supply shock can have a long-term effect on both GDP and unemployment, resulting in unemployment at a permanently higher level.

The SVAR method has the advantage of imposing relatively few constraints on the relationship between the variables in the system. These models are therefore often regarded as being data-driven. The SVAR method also has the advantage that there are no end-point problems apart from those caused by data revisions.

The few restrictions imposed on the SVAR model are taken from economic theory. If these restrictions are not consistent with how the economy actually works, however, this might produce misleading results. The assumption that demand shocks only affect developments in the output gap and do not affect potential output may be an example of a restriction that is too stringent. We have, however, introduced somewhat more flexibility in the model by taking into account that some shocks can in periods affect both the output gap and potential output.

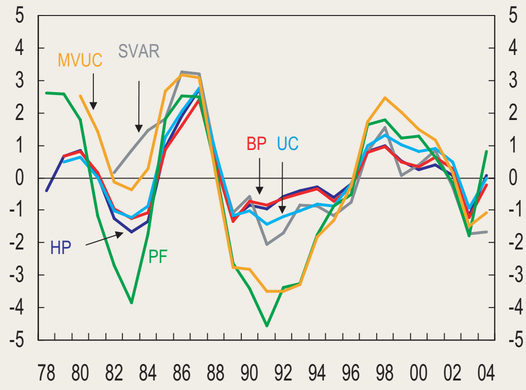
## 2. Comparison of methods

For an overall picture of the differences between the methods, all the output gaps are shown in Chart 8.

The different output gaps describe the main economic fluctuations as they are commonly referred to, with two downturns starting in the 1980s, an upturn from the mid-1990s and a downturn over the past couple of years. Nonetheless, the PF method differs from the other methods in estimating a considerably more negative output gap during the downturn in the early 1980s. Like the MVUC method, the PF method also estimates a more severe downturn at the beginning of the 1990s than the other methods. From around 1995 to 2003, the output gaps correspond fairly closely, particularly from 2001. The output level in 2003 is approximately 1 - 1¾ per cent lower than its potential level. From 2003 until (the first half of) 2004, the methods show varying degrees of increase in the output gap. The increase is particularly large for the PF method, which finds that the output gap will be clearly positive in 2004.

Developments in the different output gaps from 2003 to 2004 reflect to a certain extent the properties of the individual methods. With the SVAR and MVUC methods, it is assumed that there is a relationship between the output gap and developments in domestic inflation: a fall in inflation implies that the output gap is negative. With these methods, the fall in domestic inflation through 2003 and in the first half of 2004 therefore pushes up potential output and pushes down the output gap. Most of the increase in GDP growth from 2003 to the first half of 2004 is thus interpreted by these methods as an increase in potential output.

**Chart 8.** Output gaps, all methods. Per cent of potential GDP




As mentioned above, the PF method is the only method that shows a clearly positive output gap in 2004. The increase in GDP growth is largely interpreted as an increase in the output gap. With this method potential GDP is determined by potential levels in employment, real capital and total factor productivity. Since these explanatory factors show little change[20] from 2003 to 2004, potential GDP will also remain approximately unchanged.

The three univariate methods show similar developments through the period, including from 2003 to 2004. With two of these methods, the HP and BP filters, the estimate for the output gap is particularly uncertain towards the end of the period. This problem does not apply to the third univariate method, the UC method. The reason why the three methods nonetheless show the same result is that the output gap is close to zero. End-point problems are therefore less important.

Tables 1 to 4 contain a statistical summary of the different methods for the period 1982 to 2004.[21]

Table 1 compares some key properties of the output gap. One reasonable criterion is that the average value of the output gap should over time be close to zero. The PF method differs from the other methods here, with an average value for the output gap of -0.8. Another criterion that may indicate whether the output gaps are reasonable is the degree of fluctuation, measured by the standard deviation and highest and lowest values. However, we have no objective measures here, beyond indicating that the output gaps should not be "too wide" or "too narrow". One end of the scale implies that poten-

**Table 1.** Statistical summary for the output gap, 1982 to 2004

| Method | HP | BP | UC | PF | MVUC | SVAR |
|---|---|---|---|---|---|---|
| Average | -0.05 | -0.06 | 0.03 | -0.70 | -0.17 | 0.10 |
| Standard deviation | 1.07 | 0.96 | 1.18 | 2.17 | 2.11 | 1.46 |
| Lowest value | -1.7 | -1.4 | -1.4 | -4.6 | -3.5 | -2.1 |
| Highest value | 2.7 | 2.4 | 2.8 | 2.5 | 3.2 | 3.3 |

[19] We have also tested whether this demand shock can have a long-term effect on unemployment, but find that most of the effect applies to unemployment in the short term.

[20] The HP filter was used to calculate potential employment and potential total factor productivity. Alternative values for the smoothing parameter λ affect developments in these variables. We have assessed different values of λ. Allowing for a reasonable range of variation, potential output is not affected to any substantial extent.

[21] In this period, the output gap was calculated using all the methods.

| **Table 2.** Correlation between output gaps calculated by different methods, 1982 to 2004 | | | | | | |
|---|---|---|---|---|---|---|
| Metode | HP | BP | UC | PF | MVUC | SVAR |
| HP | 1 | 0,99 | 0,95 | 0,81 | 0,75 | 0,68 |
| BP | | 1 | 0,96 | 0,86 | 0,80 | 0,74 |
| UC | | | 1 | 0,91 | 0,88 | 0,78 |
| PF | | | | 1 | 0,87 | 0,65 |
| MVUC | | | | | 1 | 0,86 |
| SVAR | | | | | | 1 |

**Table 4.** Turning points

| Period \ Method | HP | BP | UC | PF | MVUC | SVAR |
|---|---|---|---|---|---|---|
| Upturn mid-1980s | 1987 | 1987 | 1987 | 1986 | 1986 | 1986 |
| Downturn early 1990s | 1989 | 1989 | 1991 | 1991 | 1991/92 | 1991 |
| Upturn late 1990s | 1998 | 1998 | 1998 | 1998 | 1998 | 1998 |
| Downturn early 2000s | 2003 | 2003 | 2003 | 2003 | 2003 | 2003 |

tial GDP grows at a relatively steady pace and that changes in GDP growth are mainly due to demand, resulting in wide variations in the output gap. At the other extreme, changes in GDP are dominated by supply-side conditions, and variations in the output gap are therefore small. On the basis of these assessments, it cannot be concluded that any of the output gaps are clearly unreasonable. With the PF and the MVUC methods, however, the calculations show deeper cyclical troughs than with the other methods and the largest standard deviations.

Table 2 shows the correlation coefficients between the different methods. As expected from looking at the charts, the correlation between the alternative output gaps is generally high, particularly between the univariate methods. The correlation coefficients are lowest between the SVAR and PF methods.

The share of periods where the output gap is positive (negative) when calculated by the different methods is an alternative measure of the correlation between the different output gaps. This is of particular interest in analyses where the focus is on whether the gap is positive or negative. Table 3 confirms the impression from the charts and Table 2 that the alternative methods provide similar descriptions of cyclical developments.

It is also interesting to investigate whether the different methods yield the same conclusion as to when an upturn or a downturn begins. Table 4 shows the year pinpointed by the different methods as the turning point in the business cycle. A turning point may be defined as the year the output gap reaches its highest (or lowest) absolute value within a period generally regarded as an upturn (or downturn). We have not included the trough in the early 1980s since calculations of the output gap using the SVAR method start in 1982.

| **Table 3.** Share of periods where different output gaps are positive (negative) in pairs, 1982 to 2004 | | | | | | |
|---|---|---|---|---|---|---|
| Method | HP | BP | UC | PF | MVUC | SVAR |
| HP | 1 | 0.96 | 0.96 | 0.96 | 0.91 | 0.78 |
| BP | | 1 | 1.00 | 0.91 | 0.96 | 0.83 |
| UC | | | 1 | 0.91 | 0.96 | 0.83 |
| PF | | | | 1 | 0.87 | 0.83 |
| MVUC | | | | | 1 | 0.87 |
| SVAR | | | | | | 1 |

The different methods are in relative agreement in indicating that the upturn in the mid-1980s peaked in 1986/1987. This is in line with the general perception of the business cycle (see for example Bjørnland (2000) and Johansen and Eika (2000)). However, the methods pinpoint different dates for the trough in the early 1990s. The HP and BP methods date the turning point as early as 1989, while the MVUC method indicates 1991/1992. In the rest of the period, the methods concur: the upturn ended in 1998 and the subsequent downturn troughed in 2003.

If we regard the different output gaps qualitatively through the period as a whole, the univariate methods indicate that the three downturns in the period have been equally severe. This is in contrast to the more common view that the downturn in the first half of the 1990s was more severe than the other two. The unemployment rate was clearly higher in this downturn than in the other two. The reason why the output gap is not more negative in this period is that the lower growth rate over a number of years markedly reduces the rate of growth in potential GDP. Since unemployment can also change due to supply-side shocks, this is not necessarily unreasonable, even though it may conflict with the traditional view.

On the whole, the SVAR method presents a picture that is in line with the univariate methods with regard to the magnitude of the business cycles. The output gap in 2003 is at the same level as during the previous downturn. As indicated above, this is not necessarily unreasonable since the SVAR method explicitly allows unemployment to increase permanently following a supply-side shock. The output gaps as measured by the PF and the MVUC methods correspond most closely through the period with the general view of cyclical fluctuations, in the sense that the downturn in the early 1990s is regarded as the most severe.

So far, we have compared some properties of the different output gaps. An alternative approach is to test to what extent they contribute to explaining inflation developments. More formally, this involves estimating an equation for inflation that includes the output gap as an explanatory variable. To shed some light on this, we have used a simple Phillips curve relationship between domestic inflation and the output gap:

(8) $$\pi_t = \alpha + \sum_{j=1}^{4} \beta_j \pi_{t-j} + \sum_{j=0}^{4} \lambda_j ygap_{t-j} + \varepsilon_t ,$$

**Table 5.** Estimation and prediction results

| Evaluation \ Method | HP | BP | UC | PF | MVUC | SVAR |
|---|---|---|---|---|---|---|
| $R^2$ | 0.81 | 0.81 | 0.81 | 0.82 | 0.82 | 0.83 |
| F(5.71) | 1.87 [0.11] | 1.92 [0.10] | 2.17 [0.07] | 2.24 [0.06] | 2.68 [0.03]* | 3.21 [0.01]* |
| RMSE (4-step) | 0.314 | 0.300 | 0.304 | 0.310 | 0.298 | 0.286 |

$R^2$ indicates the goodness-of-fit properties of the model. F(5.71) is a test to establish whether the output gap contributes to explaining inflation developments. The figure in brackets is the significance level of the test. * indicates that a hypothesis stating that the output gap does not contribute to explaining inflation can be rejected at the 5 per cent level. RMSE (Root Mean Square Error) measures the predictive properties of the model. We have estimated all the models up to 1999 Q4 and then predicted inflation four quarters ahead. The model was then re-estimated up to 2000 Q1, and we again predicted inflation four quarters ahead. This procedure is repeated until the end of the period.



where $\pi$ is domestic inflation. $\alpha$, $\beta$ and $\lambda$ are coefficients and $\varepsilon$ is a white noise add factor. Current inflation is expressed as a linear function of past inflation and current and past output gaps. Four lags are included in the estimation.[22] We have estimated one model for each output gap, for the period 1983 Q1 to 2004 Q2. Some estimation and prediction results based on this model are included in Table 5.

$R^2$ indicates that all the models have good properties with regard to goodness-of-fit, and that the three multivariate output gap models are only marginally better than the univariate output gap models. Output gaps computed using the multivariate methods SVAR and MVUC explain domestic inflation better than the other models. This is not surprising since when calculating the output gap, SVAR and MVUC also use domestic inflation in the estimation procedure. The other methods of measuring the output gap can also be said to contain some information about inflation. Naturally, the two multivariate models SVAR and MVUC also have the best predictive properties, based on RMSE.

It may also be interesting to compare these results with a model where domestic inflation is solely determined by back-dated inflation values. Such a model yields an RMSE of 0.36, which is greater than all the values reported in Table 5. Including the output gap in the Phillips curve as specified in equation (8) therefore yields a better prediction of future inflation than a model that excludes the output gap.

## 3. Conclusion

Assessments of pressures in the economy and the inflation outlook are issues that are important to most central banks. The output gap is frequently used as a measure for summarising such assessments. The purpose of this article is to provide an overview of some commonly used methods for computing the output gap.

Our comparison of the methods illustrates that although output gap calculations are uncertain, alternative calculations describe qualitatively the same historical path for the output gap. There is also a high degree of correlation between the methods in the period as a whole. However, in some periods, some methods diverge from the others both with regard to the magnitude of fluctuations and the dates of the turning points. The PF method in particular differs from the other methods. For example, the output gap is calculated by this method at close to ¾ per cent towards the end of 2004, while the other methods compute output gaps that are close to zero or negative. With regard to the usefulness of the output gap in predicting inflation, the multivariate methods SVAR and MVUC show the best results.

In certain periods, however, some methods generate different results from the others. Uncertainty is particularly pronounced at the very end of the calculation period. If the assessment of pressures in the economy is solely based on developments in the output gap as measured by one method, there is a risk of misjudging the economic situation.

A central bank would never base its assessment of pressures in the economy on simple, mechanical calculations of the output gap. Developments in the output gap must be viewed in conjunction with a number of other types of analysis and information about the economy, such as information concerning special conditions that cannot easily be captured in specific figures for the output gap. Alternative calculations of the output gap might, however, provide useful support in these assessments.

22 More complicated models can of course be used. We have decided to focus on this simple model, however, in order to allow us to establish the precise contribution from the output gap. Bjørnland, Brubakk and Jore (2005) provide a more exhaustive analysis with results from alternative models.

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# Appendix: Detailed description of the MVUC and SVAR models

**Multivariate "unobserved component" model (MVUC)**
The MVUC model is an example of so-called state-space models. The literature on applications of state-space modelling in macroeconomics is reviewed in Basdevant (2003).

The model is described by the following equations[23]:

$$(1') \quad y_t = y_t^* + ygap_t$$

$$(9) \quad \Delta y_t^* - \Delta y_{t-1}^* = \mu_{t-1} + \varepsilon_t^{y^*}$$

$$(10) \quad \mu_t = \mu_{t-1} + \varepsilon_t^{\mu}$$

$$(11) \quad u_t - u_t^* = \beta_1 \left(u_{t-1} - u_{t-1}^*\right) + \beta_2 ygap_{t-1} + \varepsilon_t^u$$

$$(12) \quad u_t^* - u_{t-1}^* = \gamma_{t-1} + \varepsilon_t^{u^*}$$

$$(13) \quad \gamma_t = \gamma_{t-1} + \varepsilon_t^{\gamma}$$

$$(14) \quad \pi_t = \alpha_1 \pi_{t-1} + \alpha_2 \pi_{t-2} + \alpha_3 ygap_{t-1} + \varepsilon_t^{\pi}$$

$$(15) \quad ygap_t = \rho_1 ygap_{t-1} + \rho_2 ygap_{t-2} + \varepsilon_t^{y_g}$$

Again, our starting point is the definitional relationship in equation (1). The change in the growth rate of potential GDP follows a random walk process[24] given by (9) and (10). These two equations correspond to equations (3) and (4) in the univariate unobserved component model, indicating how the level and rise in potential GDP varies. In the multivariate model, the process is modelled with even greater flexibility, cf. equations (3) and (9). Equation (11) shows that there is a relationship between variation in the output gap and variation in the unemployment gap. The coefficient preceding *ygap* is negative. It is assumed that the change in unobservable equilibrium unemployment follows a random walk process given by (12) and (13). This is a relatively flexible specification, allowing equilibrium unemployment to change level in the estimation period. Equation (14) can be interpreted as a Phillips curve with backward-looking inflation expectations. The underlying process for the output gap in equation (15) is the same as in the univariate model. All the residuals, $\varepsilon_t^i$, are assumed to be independent and normally distributed.

The model is estimated with maximum likelihood by using the Kalman filter[25,26], and the estimation period is 1980 Q3 to 2004 Q2.

**"Structural vector autoregression" (SVAR) model**
The idea used to identify the SVAR model is based on an article by Blanchard and Quah (1989), which showed how a priori restrictions can be imposed on long-term multipliers in a model in order to identify underlying structural shocks.

If we let $z$ be a vector of three stationary variables $(\Delta u_t, \Delta y_t, \Delta p_t)'$ where $\Delta$ denotes quarterly changes, $u_t$ is unemployment, $y_t$ is GDP and $p_t$ is the domestic price level, the variables can be written as a function of the underlying structural shocks

$$(16) \quad z_t = B_0 \varepsilon_t + B_1 \varepsilon_{t-1} + B_2 \varepsilon_{t-2} + \ldots = \sum_{j=0}^{\infty} B_j \varepsilon_{t-j}$$

where B is a (3x3) matrix of coefficients and $\varepsilon_t$ is white noise residuals that capture demand and supply shocks.[27] The model described above identifies three structural shocks: two demand shocks and one supply shock. We assume that none of the demand shocks can have a long-term effect on unemployment, but that they allow for a more persistent effect on GDP from one of the demand shocks. This demand shock can then be interpreted as having more real effects than the other demand shock, which can be interpreted as a purely nominal demand shock. The supply shock can have a long-term effect on both GDP and unemployment.

By systematising the three uncorrelated structural shocks as:

$\varepsilon_t = (\varepsilon_t^{AS}, \varepsilon_t^{RD}, \varepsilon_t^{AD})'$, where $\varepsilon_t^{AS}$ is an aggregated supply shock, $\varepsilon_t^{RD}$ is a real demand shock and $\varepsilon_t^{AD}$ is an aggregate demand shock, we can write the change in GDP as follows:

$$(17) \quad \Delta y_t = \sum_{j=0}^{\infty} \beta_{21,j} \varepsilon_{t-j}^{AS} + \sum_{j=0}^{\infty} \beta_{22,j} \varepsilon_{t-j}^{RD} + \sum_{j=0}^{\infty} \beta_{23,j} \varepsilon_{t-j}^{AD} \ ,$$

where the subscript numbers 21, 22 and 23 refer to the place of $\Delta y$ in the $z$ vector.

We calculate the effect on the level of GDP by accumulating the shocks. The restriction that aggregate demand shocks cannot have a long-term effect on the level of GDP is implemented by imposing $\sum_{j=0} \beta_{23,j} = 0$. Similarly, we impose restrictions that neither of the two demand shocks can have a permanent effect on unemployment.

In the SVAR model, potential GDP (the long tem trend) will be represented by the first term in (17), which is accumulated supply shocks, while the output gap is the share of GDP that is explained by the two demand shocks.[28] The estimated model implies that the two demand shocks increase GDP and reduce unemployment temporarily, while prices gradually rise.[29] In total, the demand shocks explain 60-70 per cent of GDP developments in the first year, with a subsequent gradual decline in impact.

23 The model specification is based on standard economic theory, which is often used in research on monetary policy issues. See, for example, Gerlach and Smets (1999)

24 See footnote 10

25 See footnote 10

26 The estimation results are presented in Bjørnland, Brubakk and Jore (2005).

27 A constant is also included in the estimation.

28 Here we have assumed that the real demand shock that can have a lasting impact on GDP will influence the output gap in the first two years. Thereafter the real demand shock contributes to developments in trend growth (potential output).

29 The VAR model contains 5 lags. Goodness-of-fit properties are satisfied.