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# Estimating potential output for New Zealand: a structural VAR approach


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## Abstract[1]

One of the main indicators of inflationary pressures used by the Reserve Bank of New Zealand is the output gap. A measure of potential output is obtained using a structural vector autoregression (SVAR) methodology. The assumption that movements in output are the result of cyclical shocks arising from demand-side developments, and productivity shocks arising from supply-side developments provides a set of identifying restrictions. Prior to the reforms, the New Zealand economy was in excess demand with a more prolonged and deeper recession in the early 1990s than alternative methods suggest. Evidence is provided that consumption increases in anticipation of higher future earnings.



1 I thank Ben Hunt, John McDermott, Christie Smith and other Reserve Bank colleagues. This paper has also benefited of comments from participants at the NZAE in Rotorua. The views expressed are those of the author and do not necessarily represent those of the Reserve Bank of New Zealand.

# 1 Introduction

In the Reserve Bank of New Zealand's Forecasting and Policy System (FPS), domestic inflation is largely determined by the output gap.[2] The output gap is defined as the gap between actual and potential output, where potential output is the level of output that is consistent with a stable rate of inflation given the productive stock of capital. A level of real output above productive capacity through time, ie a sustained positive output gap, is indicative of demand pressures and a signal to the monetary authority that inflationary pressures are increasing and that a policy tightening may be required. A level of real output below potential, ie a negative output gap, has the opposite implication. Potential output is not directly observable and obtaining an accurate measure presents an important challenge to the monetary authority in assessing the extent of inflationary pressures in the economy. Uncertainties continue to surround the estimate of potential output and policymakers should not place too great a reliance on one single measure.

Various methods for estimating potential output and the output gap have been developed. One general approach is to estimate a production function and calculate potential output as the level of output where all factors of production are fully utilised. This structural approach has the advantage of explicitly identifying the sources of output growth – capital, labour, productivity, and sometimes intermediate inputs. But there are, at least, two disadvantages. Namely, it is not clear what the appropriate production function is, and total factor productivity – an important source of growth – is unobservable.

Statistical methods of inferring the level of potential output and the output gap do not condition their estimates on a structural model. Instead, they use statistical criteria to decompose the trend and cyclical components of output. Potential output is then defined as the permanent (supply or stochastic trend) component of output and the output gap corresponds to the transitory (demand or cyclical) component. Mechanical filters, such as the Hodrick and Prescott (1997) filter, hereafter the HP filter, or the band-pass filter proposed by Baxter and King (1995), henceforth the BK filter, are techniques that extract a trend measure from actual output series. However, these univariate filters have been criticised. Harvey and Jaeger (1993) and Cogley and Nason (1995) find that the HP filter with (nearly) integrated data can induce spurious cyclicality. Guay and St-Amant (1996) show that both the BK and the HP filters do not accurately decompose time series into their trend and cyclical components when the data have the typical spectral (or pseudo-spectral) shape identified by Granger (1966). The typical Granger shape, ie the spectrum's peak is located at zero frequency and most of its variance is located in the low frequencies, is characteristic of nearly all macroeconomic time series. Moreover, Baxter and King (1995) find that the HP and BK filters show instability of estimates near the end of the sample period.

To overcome the limitations of univariate filters, multivariate filters that incorporate aspects of economic structure were developed to estimate potential output. This semi-structural approach is followed in the estimation of the output gap in FPS. Conway and Hunt (1997) augment the stochastic-trend estimation of the HP filter with

[2] For a discussion of the core model in the Forecasting and Policy System see Black, Cassino, Drew, Hansen, Hunt, Rose and Scott (1997).

information from a Phillips curve relationship and an Okun's Law relationship, as proposed by Laxton and Tetlow (1992), and also introduce a survey measure of capacity utilisation. Moreover, the estimate of potential output is bound to a constant growth rate at the end of the sample period to help overcome the endpoint problem, as suggested by Butler (1996). Conway and Hunt (1997) find that the semi-structural, multivariate (MV) filter provides a more reliable gauge of inflationary pressure than the HP filter. This finding is in line with Laxton and Tetlow (1992), who show that additional conditioning information improves the HP filter estimate of potential output when the cyclical component of output is highly persistent. However, the degree of improvement declines with an increasing importance of supply shocks relative to demand shocks. Gibbs (1995) provides some evidence that supply disturbances have been the dominant factor in the evolution of real output in New Zealand over the last two decades.

In this paper, an alternative estimation technique is used to obtain a measure of the output gap, namely the structural vector autoregressive (SVAR) methodology with long-run restrictions proposed by Blanchard and Quah (1989), and King, Plosser, Stock and Watson (1991).

Univariate and multivariate filters often assume that the trend component in output can be characterised as a random walk – an assumption that is not maintained in the SVAR approach. The assumption that potential output follows a random walk is difficult to reconcile with the idea that the permanent component in output is, at least in part, driven by technology shocks. Lippi and Reichlin (1994) argue that the assumption that the permanent component in output can be characterised as a random walk has some implausible implications for technical progress. The permanent component of output is often interpreted as productivity changes and within the standard production function framework, the assumption that potential output follows a random walk implies that total factor productivity also follows a random walk. This assumption rules out well-known features of technological adoption. For instance, it excludes any learning at the firm level and implies simultaneous adoption of technical innovation by all firms. Adjustment costs for capital and labour, learning, habit formation, and time to build constraints all imply more complicated dynamics for potential output than a random walk. Moreover, if the permanent component of output is assumed to be a random walk, when in fact it is not, this may lead policymakers the make false inferences about the output gap and the prevailing inflation pressures in the economy.

In this paper, the vector autoregression (VAR) methodology with long-run restrictions is used to obtain an estimate of New Zealand potential output. This method does not impose restrictions on the short-run dynamics of the permanent component of output, but incorporates a process for permanent shocks that is more general than a random walk.

A measure of potential output is obtained by means of a three-variable SVAR model. The model uses quarterly data from 1970q1 to 1998q3 and includes real production gross domestic product (GDP), full-time employment and a survey measure of capacity utilisation. Employment and capacity utilisation should capture some of the information that capital and labour provide in the production function approach. Evidence is found that prior to the economic reforms, the New Zealand economy was in excess demand, with generally poor productivity growth and high inflation. Compared to the HP and MV filters, the SVAR model suggests a more prolonged and deeper recession in the early 1990s. Moreover, the output gap associated with both the HP and MV filters is more negative than the output gap derived from the SVAR estimation at the end of the sample. Finally, some evidence is provided that consumption in New Zealand increases in anticipation of higher future earnings due to productivity gains. Interestingly, the Reserve Bank of New Zealand underestimated the strength of the upturn in the business cycle following the economic reforms, which in turn led to the inflation rate exceeding the target band.

The remainder of this paper proceeds in three further sections. Section 2 outlines the SVAR approach with long-run restrictions. The assumption that movements in measured output are the result of (a) cyclical shocks arising from demand-side developments, and (b) permanent shocks arising from supply-side developments provides a set of long-run restrictions to identify the output gap. In section 3 the data are described and analysed, and the empirical results are presented. Section 4 concludes with some suggestions for further research.

## 2 The model

It is widely accepted that real output, denoted $y_t$, is reasonably characterised as a unit root process. An important implication is that it can be decomposed into a permanent and a transitory component. The structural VAR methodology with long-run restrictions proposed by Blanchard and Quah (1989) is used to obtain an estimate of the permanent and transitory components of output and is described in this section.

Suppose that employment, $l_t$, and capacity utilisation, $capu_t$, are affected by the same two shocks as output and that employment and capacity utilisation are stationary (for a discussion of the data see section 3).[3] In the moving average representation the sequences $\{y_t\}$, $\{l_t\}$ and $\{capu_t\}$ can be expressed as a linear combination of current and past structural shocks

$$\Delta y_t = \sum_{k=0}^{\infty} s_{11}(k)\,\upsilon_{1t-k} + \sum_{k=0}^{\infty} s_{12}(k)\,\upsilon_{2t\text{-}k} + \sum_{k=0}^{\infty} s_{13}(k)\,\upsilon_{3t-k} \tag{1a}$$

$$l_t = \sum_{k=0}^{\infty} s_{21}(k)\,\upsilon_{1t-k} + \sum_{k=0}^{\infty} s_{22}(k)\,\upsilon_{2t\text{-}k} + \sum_{k=0}^{\infty} s_{23}(k)\,\upsilon_{3t-k} \tag{1b}$$

$$capu_t = \sum_{k=0}^{\infty} s_{31}(k)\,\upsilon_{1t-k} + \sum_{k=0}^{\infty} s_{32}(k)\,\upsilon_{2t\text{-}k} + \sum_{k=0}^{\infty} s_{33}(k)\,\upsilon_{3t-k} \tag{1c}$$

or

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3 Employment is found to be trend stationary and capacity utilisation is stationary in levels.

$$\begin{bmatrix} \Delta y_t \\ l_t \\ capu_t \end{bmatrix} = \begin{bmatrix} S_{11}(L) & S_{12}(L) & S_{13}(L) \\ S_{21}(L) & S_{22}(L) & S_{23}(L) \\ S_{31}(L) & S_{32}(L) & S_{33}(L) \end{bmatrix} \begin{bmatrix} \upsilon_{1t} \\ \upsilon_{2t} \\ \upsilon_{3t} \end{bmatrix} \tag{2}$$

where $\upsilon_{1t}$, $\upsilon_{2t}$ and $\upsilon_{3t}$ are uncorrelated white noise disturbances and $S_{ij}(L)$ are polynomials in the lag operator, where the individual coefficients are denoted as $s_{ij}(k)$.

Equation (2) can be written as

$$x_t = S(L)\,\upsilon_t \tag{3}$$

where $x_t = [\Delta y_t \; l_t \; capu_t]'$ and $\upsilon_t = [\upsilon_{1t} \; \upsilon_{2t} \; \upsilon_{3t}]'$. The shocks $\upsilon_t$ are normalised, such that $var(\upsilon_{1t}) = var(\upsilon_{2t}) = var(\upsilon_{3t}) = 1$, ie

$$E(\upsilon_t \upsilon_t') = \begin{bmatrix} var(\upsilon_{1t}) & cov(\upsilon_{1t}, \upsilon_{2t}) & cov(\upsilon_{1t}, \upsilon_{3t}) \\ cov(\upsilon_{2t}, \upsilon_{1t}) & var(\upsilon_{2t}) & cov(\upsilon_{2t}, \upsilon_{3t}) \\ cov(\upsilon_{3t}, \upsilon_{1t}) & cov(\upsilon_{3t}, \upsilon_{2t}) & var(\upsilon_{3t}) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = I \tag{4}$$

$\upsilon_{1t}$ is an aggregate supply shock and $\upsilon_{2t}$ and $\upsilon_{3t}$ are aggregate demand shocks and the coefficients of $S_{11}(L)$, for instance, represent the impulse response of an aggregate supply shock on the change in output.

To decompose output into its permanent and transitory components the following assumption is made. In accord with the natural rate hypothesis, demand-side disturbances have no long-run effect on output. On the supply side, productivity shocks are assumed to have a permanent effect on output and potential output is therefore associated with productivity shocks. If real output is unaffected by demand shocks in the long run, this implies that the cumulated effects of $\upsilon_{2t}$ and $\upsilon_{3t}$ on $\Delta y_t$ must be equal to zero, ie

$$\sum_{k=0}^{\infty} s_{12}(k)\,\upsilon_{2t-k} + \sum_{k=0}^{\infty} s_{13}(k)\,\upsilon_{3t-k} = 0 \tag{5}$$

The structural shocks, $\upsilon_t$, are not observed. To recover the supply-side and demand-side shocks, the estimation proceeds as follows. To identify the structural model, the VAR is first estimated in its unrestricted form

$$\begin{bmatrix} \Delta y_t \\ l_t \\ capu_t \end{bmatrix} = \begin{bmatrix} \Phi_{11}(L) & \Phi_{12}(L) & \Phi_{13}(L) \\ \Phi_{21}(L) & \Phi_{22}(L) & \Phi_{23}(L) \\ \Phi_{31}(L) & \Phi_{32}(L) & \Phi_{33}(L) \end{bmatrix} \begin{bmatrix} \Delta y_{t-1} \\ l_{t-1} \\ capu_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \tag{6}$$

or

$$x_t = \Phi(L)\,x_{t-1} + \varepsilon_t \tag{7}$$

As all equations in the system share the same matrix of regressors, estimation of the reduced-form model amounts to applying ordinary least squares (OLS) separately to each equation in (6), after including the optimal number of lags to eliminate serial correlation from the residuals. The estimated unrestricted model can then be inverted to the Wold moving average representation,

$$\begin{bmatrix} \Delta y_t \\ l_t \\ capu_t \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \tag{8}$$

or

$$x_t = C(L)\ \varepsilon_t \tag{9}$$

with $C(L) = (I\text{-}\Phi(L)\ L)^{-1}$.

The variance-covariance matrix of the vector of reduced-form innovations, $\Sigma$, is given by

$$E(\varepsilon_t \varepsilon_t^{'}) = \begin{bmatrix} var(\varepsilon_{1t}) & cov(\varepsilon_{1t}, \varepsilon_{2t}) & cov(\varepsilon_{1t}, \varepsilon_{3t}) \\ cov(\varepsilon_{2t}, \varepsilon_{1t}) & var(\varepsilon_{2t}) & cov(\varepsilon_{2t}, \varepsilon_{3t}) \\ cov(\varepsilon_{3t}, \varepsilon_{1t}) & cov(\varepsilon_{3t}, \varepsilon_{2t}) & var(\varepsilon_{3t}) \end{bmatrix} \tag{10}$$

$$= \begin{bmatrix} s_{11}(0)^2 + s_{12}(0)^2 + s_{13}(0)^2 & s_{11}(0)s_{21}(0) + s_{12}(0)s_{22}(0) & s_{11}(0)s_{31}(0) + s_{13}(0)s_{33}(0) \\ s_{11}(0)s_{21}(0) + s_{12}(0)s_{22}(0) & s_{21}(0)^2 + s_{22}(0)^2 + s_{23}(0)^2 & s_{22}(0)s_{32}(0) + s_{23}(0)s_{33}(0) \\ s_{11}(0)s_{31}(0) + s_{13}(0)s_{33}(0) & s_{22}(0)s_{32}(0) + s_{23}(0)s_{33}(0) & s_{31}(0)^2 + s_{32}(0)^2 + s_{33}(0)^2 \end{bmatrix}$$

$$= \Sigma$$

Under the assumption that the innovations in $\varepsilon_t$ are a linear combination of the structural disturbances in $\upsilon_t$, the structural shocks can be related to the disturbances of the reduced-form model as follows

$$\begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} = \begin{bmatrix} s_{11}(0) & s_{12}(0) & s_{13}(0) \\ s_{21}(0) & s_{22}(0) & s_{23}(0) \\ s_{31}(0) & s_{32}(0) & s_{33}(0) \end{bmatrix} \begin{bmatrix} \upsilon_{1t} \\ \upsilon_{2t} \\ \upsilon_{3t} \end{bmatrix} \tag{11}$$

or

$$\varepsilon_t = S(0)\ \upsilon_t \tag{12}$$

with

$$E(\varepsilon_t \varepsilon_t') = S(0)\ E(\upsilon_t \upsilon_t')\ S'(0) = \Sigma \tag{13}$$

Knowledge of S(0), the matrix of the contemporaneous effect of the structural disturbances $\upsilon_t$ on $x_t$, will allow to recover the structural shocks from the reduced-form innovations $\varepsilon_t$. The nine coefficients of S(0) can be identified using equations (10), (2), (8) and (11) and imposing the restriction that demand shocks only have temporary effects on output, ie the cumulated effects of demand shocks on output are equal to zero.

Equation (10) gives the following six equations in the nine unknowns

$$\mathrm{var}(\varepsilon_{1t}) = s_{11}(0)^2 + s_{12}(0)^2 + s_{13}(0)^2 \tag{14a}$$

$$\mathrm{var}(\varepsilon_{2t}) = s_{21}(0)^2 + s_{22}(0)^2 + s_{23}(0)^2 \tag{14b}$$

$$\mathrm{var}(\varepsilon_{3t}) = s_{31}(0)^2 + s_{32}(0)^2 + s_{33}(0)^2 \tag{14c}$$

$$\mathrm{cov}(\varepsilon_{1t},\varepsilon_{2t}) = s_{11}(0)\, s_{21}(0) + s_{12}(0)\, s_{22}(0) \tag{14d}$$

$$\mathrm{cov}(\varepsilon_{1t},\varepsilon_{3t}) = s_{11}(0)\, s_{31}(0) + s_{13}(0)\, s_{33}(0) \tag{14e}$$

$$\mathrm{cov}(\varepsilon_{2t},\varepsilon_{3t}) = s_{22}(0)\, s_{32}(0) + s_{23}(0)\, s_{33}(0) \tag{14f}$$

Equations (2), (8) and (11) imply

$$\begin{bmatrix} S_{11}(L) & S_{12}(L) & S_{13}(L) \\ S_{21}(L) & S_{22}(L) & S_{23}(L) \\ S_{31}(L) & S_{32}(L) & S_{33}(L) \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix} \begin{bmatrix} s_{11}(0) & s_{12}(0) & s_{13}(0) \\ s_{21}(0) & s_{22}(0) & s_{23}(0) \\ s_{31}(0) & s_{32}(0) & s_{33}(0) \end{bmatrix} \tag{15}$$

or

$$S(L) = C(L)\, S(0) \tag{16}$$

Making S(L) lower triangular, which imposes the restrictions that demand shocks will only have temporary effects on output and that the cumulated effects of demand shocks on output must therefore be equal to zero, provides three additional equations.

$$C_{11}(L)\, s_{12}(0) + C_{12}(L)\, s_{22}(0) + C_{13}(L)\, s_{32}(0) = 0 \tag{17a}$$

$$C_{11}(L)\, s_{13}(0) + C_{12}(L)\, s_{23}(0) + C_{13}(L)\, s_{33}(0) = 0 \tag{17b}$$

$$C_{21}(L)\, s_{13}(0) + C_{22}(L)\, s_{23}(0) + C_{23}(L)\, s_{33}(0) = 0 \tag{17c}$$

One advantage of the Blanchard and Quah (1989) approach is that potential output is *not* restricted to follow a random walk. Instead the approach allows for a transitory effect of permanent shocks to output. In the moving average representation (equation 1a), the change in output can be expressed as a linear combination of the current and past structural shocks

$$\Delta y_t = S_{11}(L)\, \upsilon_{1t} + S_{12}(L)\, \upsilon_{2t} + S_{13}(L)\, \upsilon_{3t} \tag{18}$$

or

$$\Delta y_t = s_{11}(0)\,\upsilon_{1t} + s_{11}{*}(L)\,\upsilon_{1t} + S_{12}(L)\,\upsilon_{2t} + S_{13}(L)\,\upsilon_{3t} \tag{19}$$

where $s_{11}{*}(L)$ represents the transitory effect of permanent shocks to output, with $S_{11}(L) = s_{11}(0) + s_{11}{*}(L)$. This transitory component of permanent shocks accounts for the gradual adjustment of permanent shocks into potential output. It reflects factors associated with the adjustment in the supply side of the economy following a permanent shock to output, such as learning, habit formation, time to build constraints, adjustment costs for capital and labour.

The change in output that can be attributed to potential output is defined by

$$\Delta y_t^p = S_{11}(L)\,\upsilon_{1t} = s_{11}(0)\,\upsilon_{1t} + s_{11}{*}(L)\,\upsilon_{1t} \tag{20}$$

The cyclical part of output due to demand-side shocks is defined as the output gap

$$gap_t = S_{12}(L)\,\upsilon_{2t} + S_{13}(L)\,\upsilon_{3t} \tag{21}$$

An estimate of potential output and the output gap is obtained for New Zealand using the structural VAR methodology. The results are presented in the next section.

## 3 Data and estimation

This section discusses the data and analyses their time-series properties. The results from decomposing output into permanent and transitory shocks are presented.

Output is measured by real production GDP. The model uses quarterly data from 1970q1 to 1998q3 and also includes full-time employment and a survey measure of capacity utilisation. All variables are seasonally adjusted.[4]

Blanchard and Quah's (1989) model for the United States includes real output and unemployment. Full-time employment is used in this paper because the New Zealand unemployment rate from the Household Labour Force Survey was found to be stationary around an upward sloping trend over the estimation period. The assumption of an upward sloping trend in the unemployment rate is difficult to reconcile with the labour market reforms initiated by the Employment Contracts Act (1991). Alternatively, unemployment could have been included as deviations from a centred moving average. A centred moving average is symmetric, but becomes a one-sided weighted average at the beginning and end of a sample and therefore would introduce an "endpoint problem" similar to two-sided filters. For these reasons employment is used rather than the unemployment rate.

Capacity utilisation is included, as it is observable information that is conceptually close to the notion of potential output. A description and plots of the data can be found in appendix 1.

4 Seasonally adjusted data for full-time employment and capacity utilisation are constructed using the model-based seasonal adjustment in Stamp (see Koopman, Harvey, Doornik and Shephard 1995).

Phillips (1998) shows that impulse responses in VAR models with (near) unit roots give inconsistent estimates and tend to random variables. The time series properties of the data are examined to determine the order of integration of the variables included in the model. A series is said to be integrated of order d, denoted I(d), if the series becomes stationary or I(0) after being differenced d times. The augmented Dickey and Fuller (Said and Dickey 1984) test and the Phillips and Perron (1988) $Z_\alpha$ test are performed. Both the augmented Dickey-Fuller (ADF) and the Phillips-Perron $Z_\alpha$ statistics allow one to test formally the null hypothesis that a series is I(1) against the alternative that it is I(0). The results from both tests can be found in appendix 2. The results from the ADF and $Z_\alpha$ tests confirm the widely accepted view that GDP is a difference stationary process.[5] Both the ADF and $Z_\alpha$ tests reject the null hypothesis of a unit root in the level of capacity utilisation, while the ADF test suggests that employment is trend stationary in levels.[6]

The three-variable VAR model is estimated including output in log difference, capacity utilisation in levels and the employment variable enters as log deviations from a deterministic time trend. Including a sufficient number of lags to eliminate serial correlation from the residuals is crucial as using a lag structure that is too parsimonious can significantly bias the estimation of the structural components. Testing down the lag structure of the reduced form model using likelihood ratio tests at the ten percent level, as proposed by DeSerres and Guay (1995), chose a lag length of four. The initial number of lags in the lag length test was set equal to eight.

Figure 1 shows the output gap calculated from the VAR methodology together with the Hodrick-Prescott and the multivariate filter estimates.[7] The output gap from the MV filter is only available from 1983q1 due to data limitations. Figure 1 yields some interesting results. The estimates of the VAR model suggest that throughout most of the “pre reform” period the New Zealand economy was in excess demand. Productive capacity was insufficient to meet demand, which in turn led to increasing inflationary pressures. Indeed consumer price inflation was at double-digit rates during this period except for the price and wage freezes in 1983-84 (see figure 2).

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5 However, the results of the ADF test also provide some evidence that GDP is trend stationary; that is, the series becomes stationary after subtracting a deterministic time trend.

6 The $Z_\alpha$ test rejects the null hypothesis that the level of employment is trend stationary.

7 The smoothness parameter, $\lambda$, is set at 1,600 for the HP filter over the estimation period.

**Figure 1: Output gaps -- SVAR, HP and MV filters**

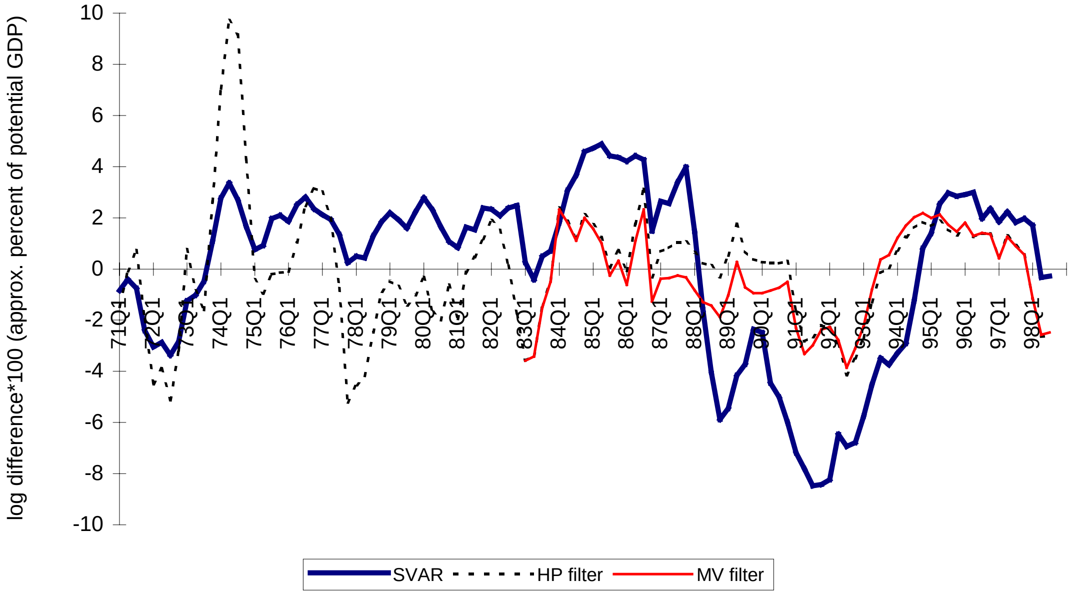
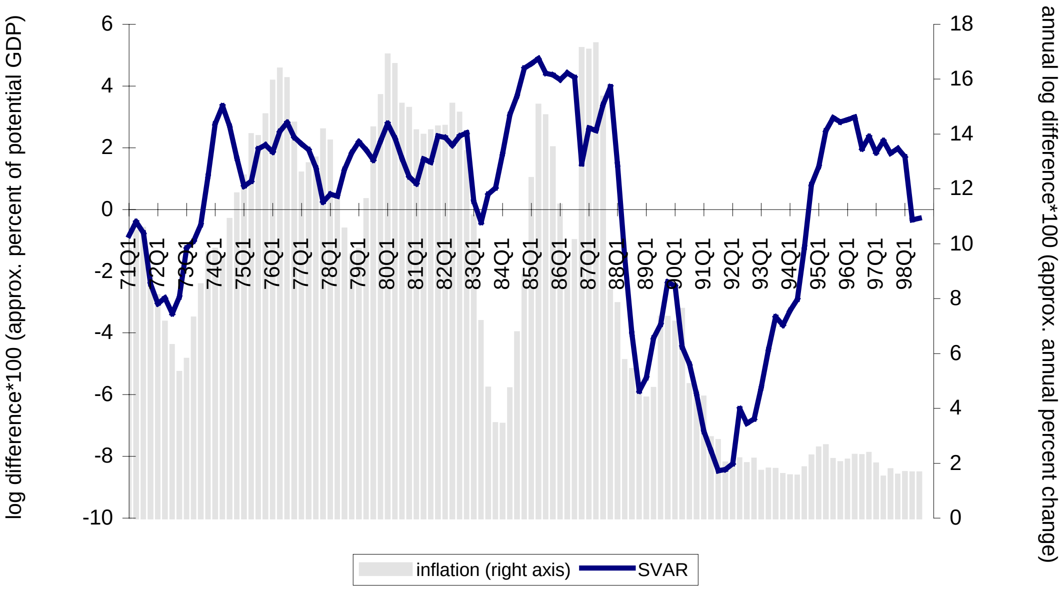


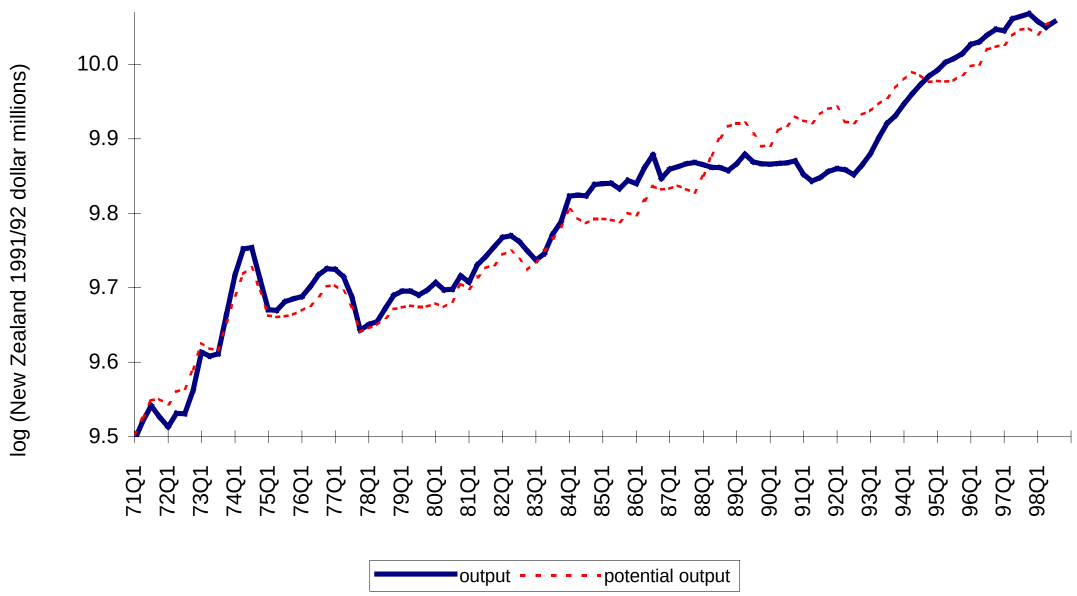

Figure 3 plots actual output and the estimate of potential output from the VAR methodology. The estimate of potential output, which in the VAR model is interpreted as productivity shocks, is in line with Lawrence and Diewert's (1999) study of New Zealand's recent productivity performance. Productivity growth during the 1970s was generally poor. This was followed by some growth in productivity over the first half of the 1980s and then a subsequent levelling off until 1993. After 1993 there was a productivity surge. An increase in the level of potential output from the SVAR model also suggests some productivity growth in 1988.

**Figure 2: SVAR output gap and consumer price inflation**



The VAR model suggests a more prolonged and deeper recession in the early 1990s than the HP and MV filters (see figure 1). Moreover, the output gap associated with both the HP and MV filters is more negative than the output gap derived from the VAR estimation at the end of the sample. Note, however, that this level difference in the estimated output gaps is in part due a "starting point" problem inherent in the SVAR model.[8] The output gap in the VAR model is calculated by cumulating the transitory shocks under the assumption that the economy is in equilibrium, ie that the output gap is zero in the initial period.[9]

**Figure 3: Actual versus potential output**




Baxter and King (1995) note that two-sided filters, such as the HP and MV filters, become ill defined at the beginning and end of samples. For this reason, they recommend discarding three years of quarterly data at both ends of the sample when using two-sided filters. This is obviously a serious limitation to policymakers interested in estimating the current level of the output gap.

Although the VAR methodology theoretically overcomes the "endpoint problem", substantial uncertainty surrounding the estimate of the output gap remains, in part because of the large number of parameters in the model. Bias and skewness in small-sample distributions can also render confidence intervals inaccurate. Unfortunately, since estimated output gaps are rarely presented with confidence bands, it is difficult to assess whether the SVAR approach leads to estimates that are more or less precise than those obtained from other methodologies.

Estimating the VAR model involves highly non-linear functions, which makes direct linear computations of standard errors unfeasible. Runkle (1987) proposes using

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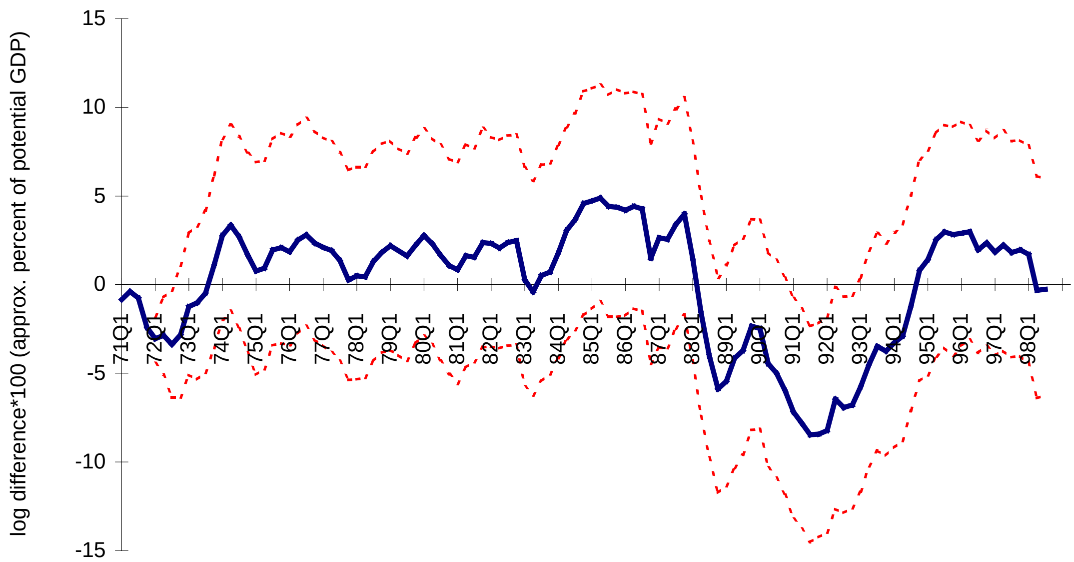
8 Re-estimating the VAR model over the same period as the Reserve Bank's multivariate filter reduces this level difference.

9 Clark, Laxton and Rose (1995) show that asymmetry in the inflation-output process implies that the measure of excess demand, which is appropriate in estimating a Phillips curve, cannot have a zero mean.

Monte Carlo simulations to generate confidence intervals. Confidence intervals can then be computed using either a Normal approximation or bootstrapped resampling. Figure 4 shows the output gap together with the 90 percent confidence interval using bootstrapped resampling. In the moving average representation (equation 1a), the change in output can be expressed as a linear combination of the current and past structural shocks and the output gap can be calculated from the cumulative transitory shocks. To obtain some measure of the parameter uncertainty in the moving average representation, random shocks are drawn from the estimated structural shocks, $\upsilon_t$. The method to construct the confidence bands is outlined in detail in appendix 3. The results suggest that substantial uncertainty surrounding the estimate of the output gap remains.[10]

**Figure 4: SVAR output gap with 90 percent confidence interval**




Staiger, Stock and Watson (1996) find a similar degree of imprecision for estimates of the natural rate of unemployment – another variable that is not directly observable and conceptually similar to potential output. The authors investigate the precision of estimates of the non-accelerating inflation rate of unemployment (NAIRU) in the United States. Their main result is that the natural rate is measured quite imprecisely. For instance, they find a typical value of the NAIRU of 6.2 percent in 1990 with a 95 percent confidence interval of 5.1 to 7.7 percent. Because of this imprecision the authors suggest caution in using the NAIRU to guide monetary policy. Although there are no comparable studies for New Zealand, it is very unlikely that the results would be more accurate and more reliable than for the United States. Nevertheless, Gordon (1996) rejects the argument that the band of statistical uncertainty surrounding the NAIRU is so broad as to render the concept useless for the conduct of policy. The NAIRU is determined by the microeconomic structure and behaviour of the economy and should thus shift only slowly. As a result Gordon (1996) proposes evaluating

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[10] The output gap together with the 90 percent confidence interval using the method of Normal approximation, which draws shocks to the unrestricted model from a Normal distribution, is plotted in appendix 4. The variance of the output gap is approximated by the variance of the output gaps generated from the Monte Carlo simulations. The confidence intervals were constructed from 1,000 replications.

alternative NAIRU estimates for any given measure of inflation based on smoothness rather than a statistical criterion. A similar argument can be made for potential output.

**Figure 5: Output response to a productivity shock with 95 percent confidence interval**

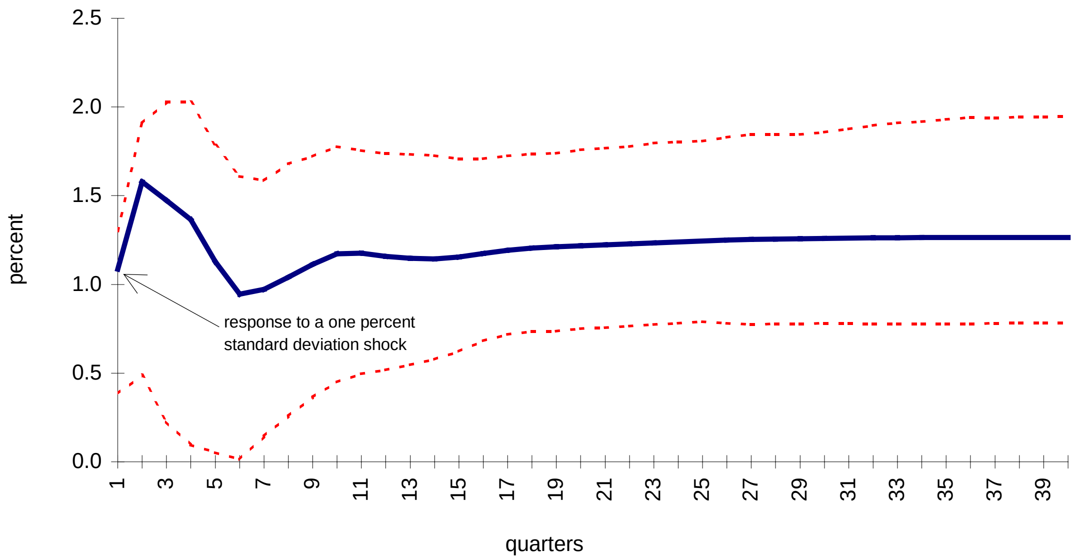


Figure 5 presents the impulse response of output to a productivity shock of one standard deviation in size where the horizontal axis represents the number of quarters.[11] Figure 5 suggests that permanent shocks are characterised by an adjustment process, that is, permanent shocks have more complicated dynamics than a random walk.[12] In other words, permanent shocks feed into output and have an effect on the level of output that cumulates over time, although figure 5 suggests that the adjustment of potential output in New Zealand is quite rapid.

Relaxing the assumption that potential output follows a random walk allows for adjustment costs for capital and labour, learning, habit formation, and time to build constraints. If the permanent component of output is assumed to be a random walk, when in fact it is not, this may actually lead policymakers to make false inferences about the output gap and the prevailing inflation pressures in the economy.[13] This implies that the assumption of a random walk may be too restrictive. In theory,

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11 The impulse response of output to a transitory shock can be found in appendix 5. Confidence intervals were generated using the Normal approximation method with 1,000 replications.

12 Confidence intervals confirm that the adjustment process is statistically significant at conventional levels of significance.

13 Recall from equation (19) that the change in output can be decomposed into a permanent and a transitory component: $\Delta y_t = s_{11}(0)\,\upsilon_{1t} + s_{11}^*(L)\,\upsilon_{1t} + S_{12}(L)\,\upsilon_{2t} + S_{13}(L)\,\upsilon_{3t}$, where $s_{11}^*(L)\,\upsilon_{1t}$ represents the transitory effect of permanent shocks to output. If potential output is assumed to follow a random walk, ie $\Delta y^p_t = s_{11}(0)\,\upsilon_{1t}$, when in fact permanent shocks only feed gradually into potential output ($\Delta y^p_t = s_{11}(0)\,\upsilon_{1t} + s_{11}^*(L)\,\upsilon_{1t}$), then the output gap becomes $gap_t = s_{11}^*(L)\,\upsilon_{1t} + S_{12}(L)\,\upsilon_{2t} + S_{13}(L)\,\upsilon_{3t}$, where $s_{11}^*(L) = S_{11}(L) - s_{11}(0)$. Re-writing the gap yields: $gap_t = S_{11}(L)\,\upsilon_{1t} - s_{11}(0)\,\upsilon_{1t} + S_{12}(L)\,\upsilon_{2t} + S_{13}(L)\,\upsilon_{3t}$. This implies that the output gap will be negative ($gap_t < 0$) following a positive shock to output ($\upsilon_{1t}, \upsilon_{2t}, \upsilon_{3t} > 0$) when the lag effects are smaller than the contemporaneous effect ($S_{11}(L)\,\upsilon_{1t} + S_{12}(L)\,\upsilon_{2t} + S_{13}(L)\,\upsilon_{3t} < s_{11}(0)\,\upsilon_{1t}$). Assuming that potential output follows a random walk could therefore be misleading and lead to deceptive signals about inflationary pressures in the economy.

relaxing the assumption that potential output follows a random walk should therefore improve the estimate of potential output and the output gap.

Figure 5 indicates some "overshooting" in the response of output to a permanent output shock with the peak response taking place after two quarters. In other words, actual output rises by more than potential output following a positive productivity shock. This possibly reflects increased current consumption in anticipation of higher future earnings as a result of the productivity gain. Interestingly, following the economic reforms in New Zealand, the Reserve Bank of New Zealand underestimated the strength of the upturn in the business cycle. This in turn led to the inflation rate exceeding the target band and required monetary policy to be held firmer for longer (see Drew and Orr 1999). The overshooting effect stabilises after ten quarters. Blanchard and Quah (1989) find a similar overshooting effect of permanent shocks to output for the United States.

## 4 Concluding remarks

One of the main indicators of inflationary pressures used by the Reserve Bank of New Zealand is the output gap. Obtaining a reliable measure of potential output is important for the conduct of monetary policy. Uncertainties continue to surround the estimate of potential output and policymakers should not place reliance on one single measure. In this paper, a structural VAR methodology with long-run restrictions was applied to obtain an estimate of New Zealand's potential output.

The results of the VAR model suggest that prior to the reforms the New Zealand economy was in excess demand. Productive capacity was insufficient to meet demand and the period coincides with double-digit consumer price inflation and generally poor productivity growth. Compared to the HP and MV filters, the VAR model suggests a more prolonged and deeper recession in the early 1990s. Moreover, the output gap associated with both the HP and MV filters is more negative than the output gap derived from the VAR estimation at the end of the estimation period. Finally, consumption in New Zealand appears to increase in anticipation of higher future earnings due to productivity gains.

One advantage of the VAR method is that it does not impose restrictions on the short-run dynamics of the permanent component of output, but rather incorporates an estimated adjustment process for permanent shocks that can differ from a random walk. Moreover, it theoretically overcomes the "endpoint problem" inherent in two-sided filters. Nevertheless, substantial uncertainty surrounding the estimate of the output gap remains and alternative measures of potential output need to be estimated. One alternative technique is the multivariate unobserved components model estimated via the Kalman filter and maximum likelihood (see Scott 2000).

The properties of output gap measures for New Zealand from alternative estimation techniques, such as filters, structural VAR methodology and unobserved components models, need to be analysed. Different measures of the output gaps could be evaluated based on how well they actually predict inflationary pressures. Coe and McDermott (1997) test the gap model for a group of thirteen developing, newly industrialised, and industrial Asian economies including New Zealand using annual data. The authors find that for New Zealand, the change in inflation is closely related to the change in the output gap, where the output gap is based on a non-parametric estimation procedure. The gap model could be tested with quarterly data using the output gap from the SVAR and other techniques.

Dupasquier, Guay and St-Amant (1997) estimate the spectra of output gaps that are obtained from different methodologies in the frequency domain using data for the United States. They find that only a structural VAR methodology with long-run restrictions generates an output gap with a peak at business cycle frequencies as defined by Burns and Mitchell (1946); that is, cycles lasting between 6 and 32 quarters. Alternative measures of New Zealand output gaps could be evaluated in the frequency domain.

Finally, policy rules that account for the imprecision in the estimation of potential need to be evaluated.

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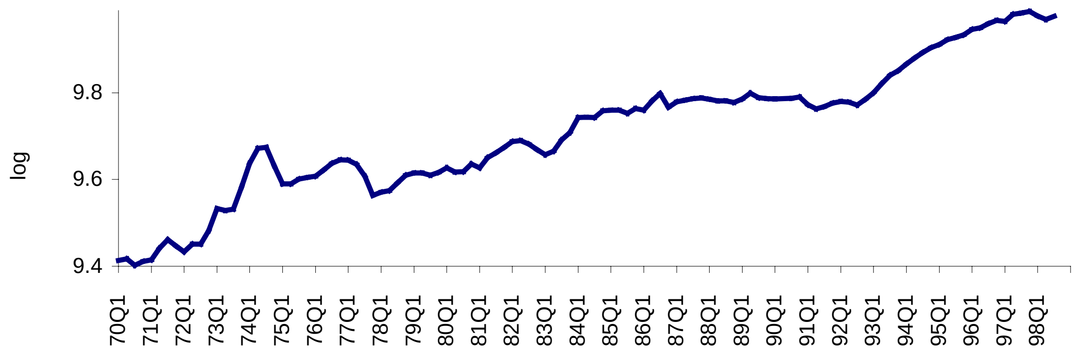
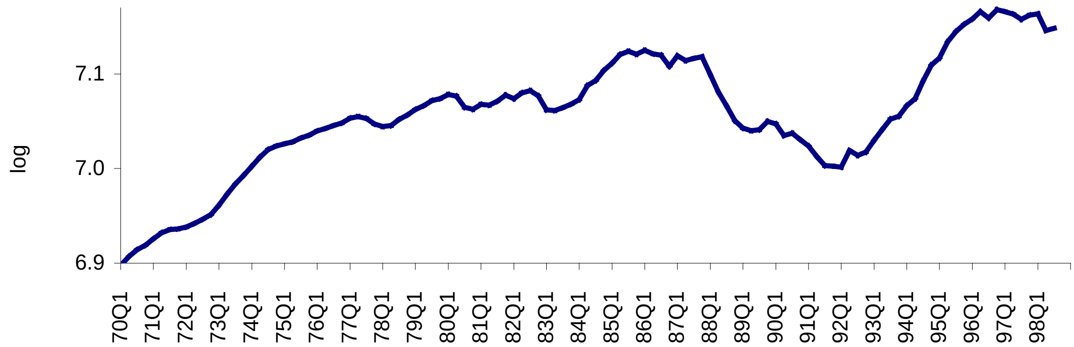
## Appendix 1: Data description

| | |
|---|---|
| Output | Real production gross domestic product. New Zealand 1991/92 dollar millions. Source: Statistics New Zealand and Reserve Bank of New Zealand. |
| Employment | Full-time employed. Thousands of workers. Source: Statistics New Zealand. |
| Capacity utilisation | Economy-wide. Index. Source: Quarterly Survey of Business Opinion. |
| Consumer price inflation | Consumer prices ex credit services. Whole index numbers. Source: Statistics New Zealand and Reserve Bank of New Zealand. |

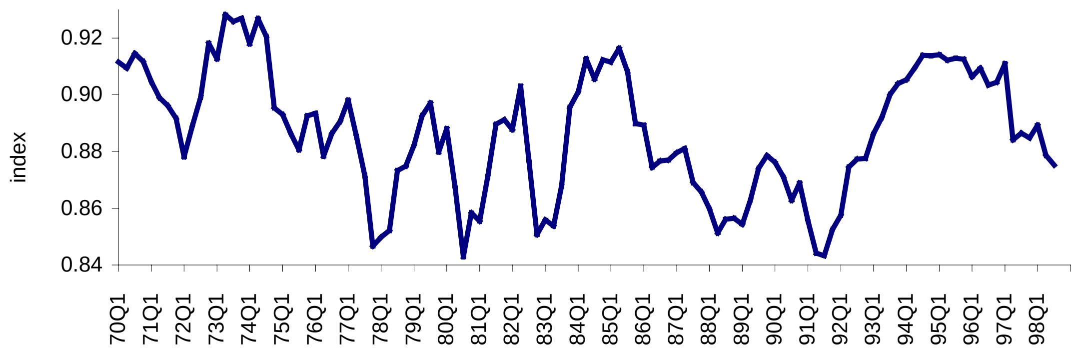
**Output**




**Employment**




**Capacity utilisation**



## Appendix 2: Tests for integration[a]

| | augmented Dickey-Fuller test (data dependent lag)[b] | | Phillips-Perron $Z_{\alpha}$ test[c] | |
|---|---|---|---|---|
| | no trend | trend | no trend | trend |
| output | -0.04122 (12) | -4.11712 (11) *** | -0.51879 | -9.99068 |
| Δ output | -2.64726 (11) * | -2.60102 (11) * | -62.12793 *** | -62.10730 *** |
| employment | -2.50483 (12) | -3.12679 (12) * | -4.03592 | -5.92737 |
| capacity utilisation | -3.06521 (11) ** | -3.05646 (11) | -18.23840 ** | -18.58496 * |

*** $H_0$ of a unit root is rejected at the 1 percent level.
** $H_0$ of a unit root is rejected at the 5 percent level.
* $H_0$ of a unit root is rejected at the 10 percent level.

a. All test regressions include a constant.
b. A lag-length selection is used that tests the included lagged terms for significance at the 10 percent level. The initial number of lags is set equal to three times the seasonal frequency, ie twelve. Critical values are obtained from table 1 in MacKinnon (1990).
c. The spectral density is estimated with an AR(4) spectral estimator. Critical values are obtained from table B.5 in Hamilton (1994).

## Appendix 3: Estimation of the confidence interval around the output gap using bootstrapped resampling with random shocks drawn from the estimated structural shocks

This appendix describes the process used to generate the confidence bands in figure 4.

Step 1: Obtain an estimate of the moving average representation (equation 2), that is, $S(0)^{(0)}$ and the structural shocks, $\upsilon_t^{(0)}$, and calculate the output, $gap_t^{(0)}$.

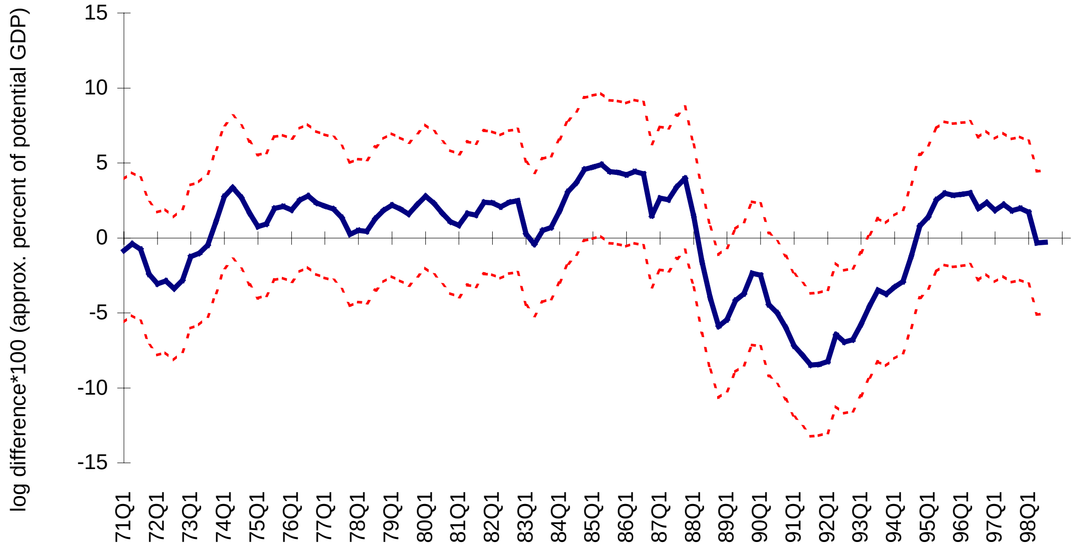
Step 2: Bootstrap random shocks, $\upsilon_t^{(r)}$, drawn from the estimated structural shocks, $\upsilon_t^{(0)}$ with 1,000 replications. Using $S(0)^{(0)}$ and $\upsilon_t^{(r)}$ re-calculate the output gap, $gap_t^{(r)}$.

Step 3: Use $S(0)^{(0)}$ and $\upsilon_t^{(r)}$ to generate artificial data, re-estimate the VAR for each set of artificial variables and obtain an estimate $\hat{S}(0)^{(r)}$ and $\hat{\upsilon}_t^{(r)}$ for each set of re-constructed data. Using $\hat{S}(0)^{(r)}$ and $\hat{\upsilon}_t^{(r)}$ re-calculate the output gap, $g\hat{a}p_t^{(r)}$.

Step 4: Calculate $gap_t^{(r)} - g\hat{a}p_t^{(r)}$ as a measure of the parameter uncertainty of the moving average representation.

Step 5: Calculate $gap_t^{(0)} + gap_t^{(r)} - g\hat{a}p_t^{(r)}$ and sort in ascending order, with the 50$^{th}$ and 950$^{th}$ elements forming the 90 percent confidence interval.

**Appendix 4: SVAR output gap with 90 percent confidence interval using normal approximation with random shocks to the unrestricted, reduced-form VAR**



**Appendix 5: Output response to a transitory shock with 95 percent confidence interval**