Estimation and Use of the Potential GDP for Monetary Policy for the SEACEN Countries

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The South East Asian Central Banks (SEACEN)
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PREFACE

The output gap measured by the deviation of actual output from potential output plays a crucial role in policy formulation, especially in inflation targeting countries. As such, this paper on potential output estimation in the SEACEN countries intends to provide a comprehensive literature review on the methodologies of output gap estimation, to survey the methodologies used by the SEACN member countries and to highlight the pros and cons of the various methodologies to estimate potential output.

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However, the views as expressed in this paper are those of the author's and do not necessarily reflect those of the SEACEN Centre nor its constituent member central banks and monetary authorities.

Dr. A.G. Karunasena
Executive Director
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May 2007

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Executive Summary

The objective of this project is to review methodologies of computing the potential output gaps; to survey of international best practice with respect to the estimation and utilisation of potential output and output gap measures; and to identify weaknesses and strengths of the respective methodology. From the literature review, it is obvious that different approaches and estimation techniques can lead to different estimates as potential GDP is unobservable. It is difficult to know which technique performs better. The unobservable characteristic also implies that it is not possible to know precisely the statistical errors of these estimates. Furthermore three types of errors are possible - statistically uncertainty; inadequacy of the model and errors due to the revision to the real time estimates as a result of new data arrival. Noise introduced into the models as a result of supply shocks would also make the estimation of potential GDP difficult.

In addition to the available literature, the study has conducted a qualitative survey among SEACEN members on the use of potential GDP estimation in forecasting and policy analysis. From the country survey, it is clear that most SEACEN countries have used a variety of approaches. In some countries, potential GDP model forms part of the larger scale macroeconomic model. Although there are some country-specific issues in the estimation of the output gap, in general, the constraints faced by most SEACEN countries are similar. Firstly, the lack of availability of adequate data, especially on capital stock and labour statistics is problematic. Secondly, the accuracy of some data is a concern, making the estimation of potential GDP lack robustness and accuracy. For instance, it is difficult to assess the average non-inflationary degree of capacity utilisation which is an important input variable in the production function approach. Finally, another source of problem is the treatment of structural breaks. In this respect, it is clear that the estimation of potential output must be treated with caution given that empirical measures are unlikely to be sufficiently robust as to be useful for fine-tuning macroeconomic policy. A viable solution is to combine the estimates generated by different methods to arrive at a consensus figure.

ESTIMATION AND USE OF THE OUTPUT GAP AS A GUIDE FOR MONETARY POLICY FOR THE SEACEN COUNTRIES

1. Introduction

Theoretically, the output gap measured by the deviation of actual output from potential output is an extremely useful statistics as every central bank needs to know whether the economy is above or below its sustainable long-run capacity. In a way, potential output is the economy's maximum sustainable output without creating pressure on the rate of inflation. Hence it plays a crucial role in policy formulation, especially in inflation targeting countries.

Although the output gap has a well-established theoretical foundation, it is still an unobservable construct. Therefore, it has to be estimated and there are various methods for estimating it. These techniques range from methods to decompose output into its trend and cyclical components to more sophisticated approaches incorporating structural relationships within the economy. As these diverse approaches can provide estimates that may be significantly different from each other, substantial uncertainty surrounding these estimates could emerge. This may lead to unwarranted divergent views regarding macroeconomic policy recommendations. Furthermore, as there may be many variables involved in the estimation of potential output, country-specific circumstances may in one way or another influence the choice of methods of estimation the potential output. In this aspect, it may be desirable to ask whether the potential output estimation can prove to be reliable or useful for policy purposes.

Interest in the potential GDP was also spurred by the rapid acceleration in the productivity performance of the ICT sector in the second half of the 1990's. This development brings with it the possibility of permanent upturn in potential GDP growth (McMorrow and Roeger 2001).

1.1 Objectives

The objectives are:

1. To provide a comparative review of methodologies of output gap estimations;
2. To identify country-specific requirements in the estimation of potential GDP;
3. To highlight the pros and cons of various techniques to estimate potential output; and
4. To suggest alternative potential output measures for monetary policy formulation.

1.2 Issues to be Covered

The issues to be covered include the followings:

- Review of methodologies of computing the potential output gaps;
- Survey of international best practice with respect to the estimation and utilisation of potential output and output gap measures; and
- Identification of weaknesses and strengths of the respective methodology, and suggest more country-specific methodology.

2. Potential GDP Defined.[1]

In general, potential GDP is defined as the maximum output attained by the economy compatible with existing labour and capital without adding pressure on inflation (Conway and Hunt 1997, p.2).[2] The difference between the actual output and potential GDP is the potential output gap. If this gap is positive (actual output exceeds the potential GDP), it implies that there is excess demand in the economy and likewise, a negative gap implies that there is excess supply. Hence, the implication for monetary policy is obvious.[3] Central bankers would need to

1. Scacciavillani and Swagel (1999: 5–6 cited in Smith and Burrows, 2002, p.3) summarises the literature as follows: *"Broadly speaking the literature distinguishes between two definitions. In the first, more along the Keynesian tradition, the business cycle results primarily from movements in aggregate demand in relation to a slow moving level of aggregate supply. In business cycle downswings, there exist factors of production that are not fully employed... In the second approach – more along the neoclassical tradition – potential output is driven by exogenous productivity shocks to aggregate supply that determine both the long run growth trend and, to a large extent, short term fluctuations in output over the business cycle... Unlike the Keynesian framework where the economy might reach potential only after an extended period, potential output in the neoclassical framework is synonymous with the trend growth rate of actual output. The key measurement problem is thus to distinguish between permanent movements in potential output and transitory movements around potential."*

2. As noted by Smith and Burrows (2002, p.2), this definition was different from earlier definition where potential output is defined as the maximum possible output the economy can produce with no regards to sustainability.

3. Potential GDP and the estimation of its cyclical component are useful to gauge fiscal policy stance. This assessment of the structural fiscal balance is important for countries where the official act requires the government to be responsible to conduct fiscal policy in a prudent manner (Gibbs, 1995, p.76). There are other uses of potential GDP. Potential GDP can be used to assess structural trends or impact of supply shocks (e.g, the terrorist attacks in the US (Cotis, Elmeskov and Mourougane 2003, p.6). However a, theoretical argument against the use of potential GDP is that demand management is never a very useful tool for policy purposes because of possible lags, uncertainties and political pressure (US Congressional Budget Office, 2004, p.2). Furthermore, some argue that inflation is related to money supply, not business cycle.

know whether the economy is capable of more supply or that the change in output is caused by negative demand shock or by a negative supply shock. For instance, if demand is seen to increase when the potential gap is small, central banks may, in typical condition tighten monetary policy to prevent overheating. This proactive policy reaction may prevent the need to pursue tighter monetary policy later to control inflation (Bank of Canada, 1999). But if central banks mis-measure the level of potential output and compute a positive output gap where in fact the gap is negative, consequent monetary policy tightening will tend instead to amplify the business cycle (Gibbs 1995, p.75).

The definition of potential output can be complicated by taking into account the time frame when defining potential GDP (Dennis and et.al (2006, p5).

1. *In the short run (i.e. less than one year), the physical productive capacity of an economy may be regarded as being quasi fixed and its comparison with the effective/actual output developments (i.e. in output gap analysis) shows by how much total demand can develop during that short period without inducing supply constraints and inflationary pressures.*

2. *In the medium term (i.e. over the next five years), the expansion of domestic demand when it is supported by a strong upturn in the amount of productive investment may endogenously generate the productive output capacity needed for its own support. The latter is all the more likely to occur when profitability is high and either increased or supported by an adequate wage evolution with respect to labour productivity.*

3. *Finally, in the long run (i.e. 10 years and beyond) the notion of full employment potential output is linked more to the future evolution of technical progress (or total factor productivity) and to the likely growth rate of labour potential.*

Basically in the short-run, there is some degree of inflexibility over how the function of production can affect potential GDP. This distinction is important as a short-run output gap may indicate inflationary pressures but because of investment, potential GDP may increase in the long run. Thus in this case, it may not be desirable to stop pursing an expansionary monetary policy stance (Chagny and Döpke, 2001, p.3).

2.1 Theoretical Framework Linking Inflation Targeting to Potential GDP

In the inflation targeting (IT) framework, even though officially, the main objective of central bank is focused on inflation, potential GDP can be integrated into the framework.[4] In many cases of central banks pursuing the IT framework, it remains debatable whether in practice, price stability is the sole objective of the central bank. Central banks are known to simultaneously pursue multiple objectives such as economic growth and employment, albeit with different weights attached to these objectives. Thus, there is often a trade-off between monetary policy strategies such as issues relating to the variability of inflation, on one hand, and the variability of output, interest rate and exchange rate on the other. This issue is put forward by Svensson (1997) who argues that even 'strict' inflation targeters will respond to the best guess of the output gap as long as it helps to forecast future inflation.[5] By contrast, a "flexible" inflation targeter who are are concern about the intrinsically about fluctuations in the state of the economy, or output gap, will respond to its best guess of the output gap whether it helps forecast inflation or not. To the extent that SEACEN central banks view themselves as 'flexible' inflation targeters, they will likely want to have an estimate of the output gap 1) to help them forecast inflation, and 2) to lean against the business cycle, possibly dampening that cycle.

A typical loss function (L_t) of a central bank may look like (Favero, 2001, p.236):

$$L_t = \tfrac{1}{2} [(\pi_t - \pi^*)^2 + \lambda(y_t - y^*_t)^2] \qquad \text{eq (1)}$$

Where ð is inflation, π^* is an inflation target, y_t is real output, y^*_t is potential real output. In practice, when $\lambda > 0$, a central bank is a multiple targeter and if $\lambda = 0$, it is a strict inflation targeter. Obviously, if stabilising the real GDP

4. Traditionally central banks in the SEACEN region make use of intermediate targeting system such as broad monetary aggregate. However, in some SEACEN countries, rapid innovations have blurred the link between monetary aggregates and other macroeconomic variables. Four SEACEN countries, Indonesia (2000), Korea (2000), the Philippines (2002) and Thailand (2000) have since followed inflation targeting (IT) with price stability as the overriding objective.

5. This point was pointed out by Dr. Plantier in his comments on the draft. Dr. Plantier also points out that fact that optimal control theory says an inflation targeting central bank should respond to any economic statistic if it helps forecast inflation. The output gap is one such statistic, but it may or may not be the most appropriate measure of the business cycle and future inflationary pressure. For example, a central bank could just respond to capacity utilization since it is usually highly correlated with the output gap, either by construction or coincident.

is an important concern, then $\lambda > 0$. Using nominal interest rate as a policy measure, Walsh (2002) presents an elegant model linking potential output to inflation targeting.

Inflation targeting regime is different from other conventional framework because the *explicit* behaviour of central bank is made known and modelled. Assuming inflation can be modelled by the expectations-Augmented Phillips curve where inflation (π) is related to inflation expectation (π^e) and the ouput gap (y^{gap}), then

$$\pi = \pi^e + ay^{gap} + e, \text{ where e is the inflation shock.} \qquad \text{eq (2)}$$

In the IT framework, the monetary authorities will act to minimise fluctuations around the inflation targets and to some extend also minimising fluctuation of the output gap (multiple targeter). In this respect, the monetary authorities would consider the cost and benefits of its policy measures. It is reasonable to assume that the marginal cost to central bank of fluctuations to either output gap or inflation is proportional to the deviations from their respective targets.

Let the marginal costs of output fluctuations be λy^{gap} and the marginal costs of inflation fluctuations be $k(\pi - \pi^T)$, where π^T is the targeted inflation rate. Assuming there is a negative gap and when central bank attempts to increase output to its target level by increasing y^{gap} by Δy^{gap}, the gain would be $-\lambda y^{gap}\Delta y^{gap}$. Meanwhile, the marginal cost of this action would be the increase in inflation of $a\Delta y^{gap}$ (from eq 2)

Equating marginal cost equals marginal benefits, we have

$$-\lambda y^{gap}\Delta y^{gap} = ak(\pi - \pi^T)\Delta y^{gap}, \text{ or}$$
$$y^{gap} = -(ak/\lambda)(\pi - \pi^T), \qquad \text{eq (3)}$$

Outgap(y^{gap}) is related to deviation of inflation (π) from the target (π^T) which is consistent with central bank's policy to minimize inflation variability and cost of output. Since central bank may have other objectives (μ), consistent with optimal policy, equation (eq3) becomes

$$y^{gap} = -(ak/\lambda)(\pi - \pi^T) + \mu \qquad \text{eq (4)}$$

And some with manipulation of eq (4) becomes

$$\pi = \pi^T - \alpha(y^{gap} - \mu) \qquad \text{eq (5)}$$

where α is the slope and $\alpha = \lambda/ak$ and $\pi^T + \alpha$ and μ is the intercept.

Potential output can thus be featured consistently with an inflation targeting framework and the tradeoff between inflation and potential output depends on the slope ($\alpha = f(\lambda/k)$), which are the weights the central banks put on the relative importance of output and inflation objectives.[6]

3. Challenges of Estimating Potential GDP

In theory, as discussed above, potential GDP can be featured neatly in the monetary policy decision-making process. However, having said that, the estimation of potential GDP in many developing countries can pose several overwhelming challenges. There are at least six challenges in estimating potential GDP. They are:

1. There are various methods of estimating potential GDP and obviously, the different methods can lead to significant differences in the estimates. Literature reviews on the empirical evidence suggest that there could be 'large divergences' on the output gap estimates by various methods. Potential GDP is generally unobservable (defined by Billmeier (2004 (a), p.3) as a *'ghost'* in the equation) and hence it is difficult to know which technique performs better. The unobservable characteristics also imply that it is not possible to know precisely the statistical errors of these estimates (Gaiduch and Hunt (2000, p.7). This 'imperfection' of modelling potential GDP estimates and the difficulties in discriminating among the different measures of output gap for specific point in time (Dupasquier, Guay and St-Amant, 1997, p.15) have great implications for optimal. Thus economic policy based on different approaches can result in 'divergent macroeconomic designs and policy recommendation' (EU Economic Policy Committee, 2001). monetary policy.

2. As noted above, one way to assess the estimates of various methods is to see how well each method forecasts inflation. This is done by ranking the various measures to examine how well they can help to explain price and wage inflation (Brouwer 1998, p.23). However, even if the relationship is significant, it may be difficult to isolate the effect of the cyclical changes

6. Other possible objective in the objective function may include interest rate smoothing (Woodford 2003).

and change in the trend component of the potential output on inflation. Further, the ranking criteria may be subject to the criticism of the *Lucas Critique*.[7]

3. The estimation of Potential GDP contains element of forecasting uncertainty. Three types of errors are possible in the estimation of potential GDP (Cayen and Van Norden, 2004, p.27); (i) statistically uncertainty, (ii) inadequacy of the model and (ii) revision to the real time estimates as a result of new data arrival. Errors as a result of uncertainty, even if they are small can accumulate over time and it has been argued that the great inflation of the 1970s in the US was a result of misguided monetary policy that failed to recognize shifts in potential output since 1965 (Yap, 2003, p.3). Also, the very act of using the output gap to forecast inflation and then responding to one's forecast of inflation can destroy the relationship between the output gap and inflation if the central bank responds aggressively enough to its view of the output gap (Plantier, 2007).

4. Output data is often subject to revision and hence using real-time data can be problematic as the estimation of potential GDP can be unreliable and distorted (Graff, 2004 and Koichiro, 2004). Furthermore, Orphanides and Van Norden (2002) note that even if the data were not revised, with the arrival of new data, the view the prevailing business cycle may be informed by new information. In addition, when data is revised, often in the case of GDP figures of developing countries, the output estimation would be different using the revised data. In addition, in potential GDP estimation, one of the basic premises of isolating demand shocks from supply shocks estimating potential GDP can prove to be a challenging task as in many case, demand and supply shocks are not independent from each other.

5. Structural breaks often experienced by developing countries can pose problems in the estimation of potential GDP. Orphanides and et.al.(1999)[8] note that in times when the economy is experiencing large structural breaks, real-time estimates can be seriously flawed and as a result, there is unnecessary variation in output and inflation due to the policy responses of

7. Lucas critique implies because of changing expectation, it is difficult to predict accuraccy the effect of one variable affecting another variable by just using the aggregated historical data.

8. Studies have shown that in the case of Hodrick Prescott estimates, the arrival of new data has a greater influence over published data revisions (Orphanides, 1999, cited in Yap 2003, p.5).

the money authorities to the misestimates of excess demand and supply. For instance, when there is a deceleration or acceleration of trend GDP growth, it can cause significant problems as the case of the 1997 Asian financial crisis.

6. Temporary supply shocks associated with droughts and floods can introduce noise to any output gap estimate, and may destroy of any positive relationship between output gap and inflation since these shocks could lead to a negative relationship in the short run. On the other hand, it could enhance positive relationship between output gap and inflation if the impact on farmers' income from weather shocks is the more dominate effect.

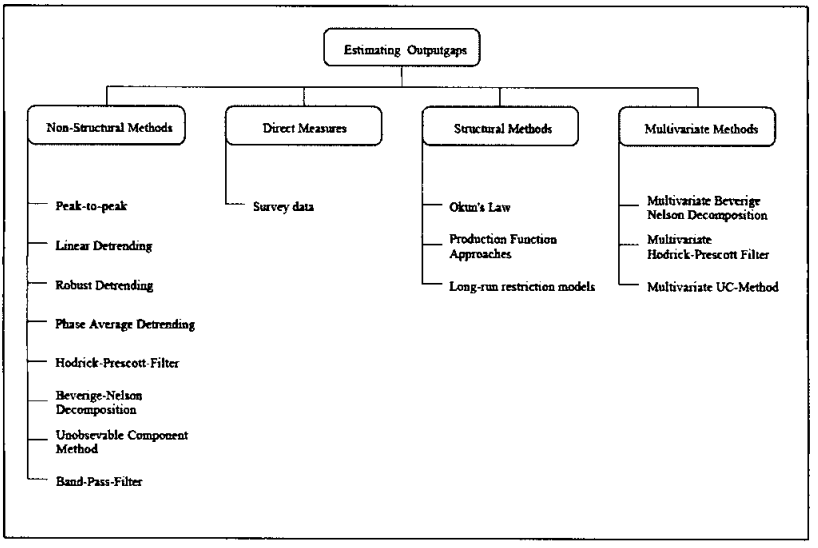
4. Selected Potential GDP Model Estimation Techniques

As noted above, there are various methodologies used by national and international institutions as well as policymakers to estimate potential GDP. In general, these methodologies could be classified into three main techniques. Basically, the first method depends purely on statistical computation (non-structural model such as trend and univariate analysis). The second method, the structural and multivariate methodologies contain some elements of economic theories built into them (see Chart 1). The third method is to conduct a field survey related to potential GDP.

Statistically, univariate and trend analyses use only information from the output (GDP) series itself while the structural and multivariate approaches make use of other related variables in the estimation of the potential GDP output. The structural and multivariate methods are preferred by many institutions because they can contain some measure of the aggregate supply capacity of the economy. For instance, the EU Economic Policy Committee (2001) is of the opinion that structural model, normally associated with the Philips curve and the NAIRU concept is 'the true and genuine way as it is potential GDP associated with stable inflation'. Multivariate methods are also some times preferred as they solve the problem of the-sided filters at the beginning-and end- of-sample problems (Dupasquier, Guay & St-Amant, 1997, p.1). Furthermore, univariate estimation cannot account or cope with large supply shocks (Cotis, Elmeskov and Mourougane, 2003). However, simple unvariate filter is more cost-effective for historical analysis while the more sophisticated methods are more suited for forward-looking, long term structural analysis (Cotis, Elmeskov and Mourougane 2003, p.2).

Chart 1

Various Methodologies to Estimate Potential GDP



Source: Chagny and Döpke (2001, p.5)

Below we discuss some selected models which are popularly used to estimate potential GDP.[9]

4.1 Direct Measure: Survey Methodology

As discussed above, given the scenario of a short-run, there is no technological change. Thus, the assumption that production is constraint by the factor of production is appropriate. In such a case, based on the industrial production capacity, the output gap can be measured from a survey (Menashe and Yakhin, 2004).

Potential GDP can be measured (Chagny and Döpke, 2001, p.6) by:

$$Y^p = (CAP^*/CAP_t)*Y_t, \qquad \text{eq (6)}$$

9. Based on De Brouwer (1998) unless otherwise stated.

where Y^p is potential output, Y_t is actual output, CAP is the utilisation rate and CAP^* denote the degree of capacity utilisation coherent with the absence of tensions on the goods market. However, two problems exist in this methodology. Firstly, there is much difficulty in designing the construct to measure production capacity in a questionnaire survey. Secondly, normally in industrial survey, the survey sample is relatively small and normally targets only the manufacturing sector. Chagny and Döpke (2001, p.6) also note that survey data by definition is subjective and it is difficult to measure accurately the variable CAP^*. As the data collected during a survey reflects a short-term time horizon, it will not take investment into account. Therefore, it would appear that the survey method is more appropriate to measure the *evolution* rather than the actual level of potential output. But Chagny and Döpke (2001, p.6) note that survey data are the only non-estimated direct obtained data to measure business cycle turning points.

4.2 Non –Structural Methods

4.2.1 Linear Time Trend Model

Another extremely simple method of estimating potential GDP is the using the linear trend method. The obvious advantage of this method is that it is easy to estimate the potential GDP as one has to just run a simple regression of GDP with a time trend. This model was a respond to the weaknesses of the trends through peak approach where a linear line is used to connect between each major peak (Gibbs, 1995, p.77). However, this method generally suffers two basic weaknesses. Firstly, the starting point of the sample matters in the estimation. Apart from ensuring that the 'outlier' periods are not included in the estimation sample, there is no objective way to access whether the estimation using a specific sample is better than the other. Secondly, the time trend model assumes that potential GDP is growing at a constant rate. This is a concern because if the GDP is non-stationary, the usual assumption that the output gap is stationary is violated.

4.2.2 Unobservable Component Method (UCM)

This model is also known as the dynamic factor and state-space model (Cayen and Van Norden, 2004) and the assumption is based on the fact that an observed variable can be broken down into two or more components that are not observable (Bjørnland, Brubakk, and Jore 2006). There are a few versions to this model, namely, Watson (1986), Clark (1987) and Harvey-Jaeger (1993).

Basically, two equations are involved. The measurement equation (eq (7)) and the transition equation (eq (8)) are as follows.

$$Y_t = Z\alpha_t + \beta X_t + \varepsilon_t \qquad \text{eq (7)}$$

$$\alpha_t = T\,\alpha_{t-1} + \delta W_t + \mu_t \qquad \text{eq (8)}$$

where α is a vector of unobservable state variables (for instance potential output), Y is a vector of observed variables, X, W are vectors of observable exogenous variables and Z and T are matrix of coefficients. What distinguishes the variation of the models is how the transition equation (eq (8)) is modeled. This changes the characteristics of the potential GDP estimation.

The relationship between potential output (Y^p_t), actual output (Y_t) and output gap (Y^{gap}), in logs form can de defined as[10]

$$Y_t = Y^p_t + Y^{gap} \qquad \text{eq (9)}$$

That is the actual output decomposed into two unobserved components, the potential output and the output gap. Assume potential output follows a random walk, we have:

$$Y^p_t = \mu_{t-1} + Y^p_{t-1} + \varepsilon^y_t \qquad \text{eq (10)}$$

where ε^y_t are the temporary shocks and are normally distributed with mean zero and a constant standard deviation (σ_y). μ_{t-1} is the more persistent growth factor. We may allow μ_t to behave in the following manner:

$$\mu_t = \mu_{t-1} + \varepsilon^\mu_t \qquad \text{eq (11)}$$

where ε^μ_t represents the permanent shock to potential GDP, with mean zero and constant standard deviation (σ_μ). Allow the output gap (Y^{gap}) to follow an AR(2) process, we have:

10. This section is extracted from Gerlach and Peng (2006, p.6).

$$Y^{gap} = \beta_1 Y^{gap}_{t-1} + \beta_2 Y^{gap}_{t-2} + \sigma_g \qquad \text{eq (12)}$$

Equation 9-12 can be combined to give the observation equation as well as the transition equation (see Gerlach and Yiu 2004) and σ_y, $\sigma_{\tilde{a}}$, σ_g, β_1 and β_2 can be estimated by sequentially evaluating the likelihood function using the Kalman filtering methodology.

A major disadvantage of the ULC procedure is that it is 'highly complex' and is difficult to 'operationalise' within the framework of macroeconomic policy models (Bolt and van Els 1998).

4.4.3 Hodrick –Prescott (HP) Method[11]

The HP filter is perhaps one of the most popular methods.[12] It estimates an unobserved time trend for time series variables using the smoothing method. The whole concept is to minimise the equation below (eq (13)) to compute the smoothed series y^T (In this context, if Y_t is output, then Y^T is the estimated of potential GDP) of the series y by minimising the variance of y around y^T, subject to the penalty of the second difference of Y^T (Eviews, p.344).

$$L = \sum_{t=1}^{s} (y_t - y_t^T)^2 + \lambda \sum_{t=2}^{s-1} (\Delta y_{t+1}^T - \Delta y_t^T)^2 \qquad \text{eq (13)}$$

The HP (i) minimises the distance between the actual and the trend value of the time series and (ii) minimises the change of the trend value (Chagny and Döpke, 2001, p.10). The parameter λ controls the smoothness of the series.[13]

11. As pointed out by Dr. Plantier, band-pass filters may have an advantage over the HP filters as they are flexible and capable of taking out some of this high frequency noise that may distort or enhance relationship between the measure of the output gap and inflation.

12. Some exceptions are for instance, in the Bank of Japan, where the HP filters play only a small role in the formulation of monetary policy (Koichiro, 2004, p.8).

13. But interestingly, the parameter λ has an economic interpretation (Laxton and Tetlow cited in Gibbs, p.87). As mentioned above, if λ is relatively large, a linear trend is expected and this implies that the supply shock is deterministic but demand shocks are the cause of variation of output. This is consistent with an extreme Keynesian model. On the other hand, if λ is relatively small, potential GDP would be driven by supply shocks and this would be consistent with an extreme real-business-cycle model where the variation in output contributes significantly to variation in potential output.

One of the major disadvantages of the HP methodology at the estimation stage is that one has to make a judgment on the value of the λ. A larger λ (as $\lambda = \infty$) implies a smoother trend, making potential GDP more of a linear trend growth rate while a relatively smaller λ means the loss function is mimimised by making potential GDP as close as possible to actual output.

Ravin and Uhlig 2002 (cited in Eviews 5.1 manual, p.345) recommend using the frequency power rule as the number of periods per year divided by 4, raised to a power and multiplied by 1600. The smoothing parameters of 1600 for quarterly data and 100 for annual were also suggested by Kydland and Prescott 1990 (cited in Coe and Mcdermott, 1996, p.5). Based on a study of the US economy, Coe and Mcdermott (1996) note that the values of ë have become standard even though it may not be appropriate for countries that have very different business cycle compared to the US. Thus, economic theories and statistical criteria are hardly used to justify the choice of parameter ë (Norden, 1995, p.4 and Coe and Mcdermott, 1996 p.5).

The HP methodology has several other disadvantages. First, the HP filters work by decomposing an observed shock into demand and supply shocks. However, there are problems associated with such methodology (Gibbs 1994, p.86). By the typical HP methodology assumption, supply shocks have lasting long term effects while the effect of demand shocks is only temporary. The HP methodology would encounter problems if demand shock is persistent, making it difficult to isolate it from supply shocks, particularly at the end of the sample. Furthermore, demand and supply shocks may not be independent from each other. For instance, one type of shock may be a function of another or they may even be simultaneously determined. In addition, the assumption that supply shock has long lasting effect may not be realistic. For instance, some supply shocks due to droughts and floods are only temporary.

Secondly, a major disadvantage of HP is that the estimation technique suffers from what is known as the 'end-of-sample' problem. The HP is based on a symmetric approach in the middle of the sample, but gradually become one sided as one approaches the end of the sample (Norden 1995). Therefore, if the beginning and end of the series do not exhibit similar cyclical pattern, then the output trend for the first few and last few observations can depart significantly

towards the path of actual output.[14] For instance, for countries which are slower to recover from a recession, potential output will be underestimated for the current period (Giorno and et.al., 1995, p.9).[15] However, the end point problem of HP can be minimised by adding forecast values at the end of the sample but this is an obvious tradeoff. One particular way is to conduct a sensitivity analysis using different set of forecasts under different scenarios (Billmeir, 2004(b), p.12). Thirdly, the HP method can also exhibit spurious cyclicality when the data is integrated or nearly integrated (Cogley and Nason, 1995 cited in Dupasquier, Guay and St-Amant, 1997).

The HP also allows for structural breaks at any point (Gibbs 1995, p.87) but depending on the value of λ, structural break is spread and smoothed over several periods. However, the HP can encounter difficulties dealing with a one off structural break, as in the case of a large discrete change in output levels (Giorno and et.al., 1995, p.9). In this case, the HP may report 'nonsense results' (Chagny and Döpke, 2001, p.11).[16] That is, the HP method, being statistical filters, will only perform well for relatively stable economies in the absence of large shocks (McMorrow and Roeger, 2001). HP is more appropriate when the potential output is likely to follow a smooth trend, an uncommon feature in developing economies where excessive boom-bust cycle is common with macroeconomic dynamics constantly changing rapidly (Ozbek and Ozlale, 2005).

14. A one-sided method uses current and past information to compute the potential GDP, up to time t(y^*_{tr}, where $0 \leq t \leq T$) while a two sided method uses the entire sample, including 'future' values to compute current potential GDP (y^*_{tr} , where $0 \leq t \leq T$, where T is the total sample size (Gerlach and Yiu, 2004, p.123). The end-of-sample problem implies that as the estimation reaches the end of the same, less information is available.

15. As trends normally consist of averaging the past and future values (trend computed as average of current and future trends, after a fixed date), trends at the end of the sample may be difficult to identity as future data becomes increasingly less in the average. However, it is this current trend that policymakers are most interested in (Congressional Budget Office (CBO, (2004, p.6), CBO (2004, p.5)) argues that HP methodology may just measure *trends* and not *potential* in the estimation of potential GDP.

16. One way to eliminate this problem is by applying the HP filter separately as in the case of Thailand.

4.3 Multivariate and Structural Models

4.3.1 Multivariate Hodrick-Prescott Filter

Further extension of the HP is the Multivariate HP. In this methodology, the aim is to add economic information to the HP filters. This information can come from known economic relationships (Chagny and Döpke, 2001, p.20). For instance, a Multivariate HP can incorporate well-known economic relationships and economic indicators such as the Philips curve (π) and Okun Law (μ) and capacity utilisation (cu) which contains information on the supply side of the economy and business cycle.

$$L = \sum_{t=1}^{s} (y_t - y^T)^2 + \lambda \sum_{t=2}^{s-1} (\Delta y^T_{t+1} - \Delta y^T_t)^2 + \sum_{t=1}^{s} \mu_t \varepsilon^2_{\pi,t} + \sum_{t=1}^{s} \beta_t \varepsilon^2_{u,t} + \sum_{t=1}^{s} \psi_t \varepsilon^2_{cu,t} \qquad \text{eq (14)}$$

$$\pi_t = \pi^e_t + A(L)\ (y_t - y^T_t) + \varepsilon_{\pi,t} \qquad \text{(Philips Curve)}$$

$$u_t = nairu_t - B(L)\ (y_t - y^T_t) + \varepsilon_{u,t} \qquad \text{(Okun's Law)}$$

$$cu_t = cu^T_t + C(L)\ (y_t - y^T_t) + \varepsilon_{cu,t} \qquad \text{(Capacity Utilisation)}$$

Obviously the advantage of Multivariate HP is that a more precise estimate of potential output can be obtained given it contains more information (Brower 1998, p.10). The disadvantage is that it is rather disturbing with respect to its ontological status (Graff, 2004, p.54) and the additional information needed in the estimation, such as the concept of NAIRU itself is highly uncertain (Congressional Budget Office 2004, p.5 and Staiger, Stock and Watson, 1996).

4.3.2 Structural Vector Auto-Regression (SVAR): Long Run Restriction Model

Structural VAR to estimate potential GDP is based on Blanchard and Quah (1989) to decompose a variable into its contemporary and permanent component. SVAR has been used by many (Cerra and Saxena, 2000, and St. Amant and van Norden, 1997) to estimate potential GDP although the variables of inclusion into the VAR system differ.

Consider a bivariate SVAR model of output and prices,[17] the moving average representations of output (y) and price (p), ignoring the incept term can be modeled as

$$\Delta y_t = \mu_y + \sum_{K=0}^{\infty} C_{11}(K)\varepsilon_{1t-k} + \sum_{K=0}^{\infty} C_{12}(K)\varepsilon_{2t-k}$$

$$\Delta p_t = \mu_p + \sum_{K=0}^{\infty} C_{21}(K)\varepsilon_{1t-k} + \sum_{K=0}^{\infty} C_{22}(K)\varepsilon_{2t-k}$$

$$\text{Or} \begin{bmatrix} \Delta y_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} \mu_y \\ \mu_p \end{bmatrix} + \begin{bmatrix} C_{11}(L) & C_{12}(L) \\ C_{12}(l) & C_{22}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \qquad \text{eq (15)}$$

where μ=deterministic trend, A(l) is the lag operator and is determined by using the information criteria, $E(\varepsilon_t \varepsilon_t)=I$, the identity matrix. Since the shocks $\begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$ are not observable, a VAR system of the form is estimated:

$$\begin{bmatrix} \Delta y_t \\ \Delta p_t \end{bmatrix} = \begin{bmatrix} \mu_y \\ \mu_p \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) \\ A_{21}(l) & A_{22}(L) \end{bmatrix} \begin{bmatrix} \Delta y_t \\ \Delta p_t \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \qquad \text{eq (16)}$$

or in compact form:

$\Delta y_t = [I-A(L)L]^{-1} e_t$, Therefore $C(L) = [I-A(L)L]^{-1}$. It can be shown that the VAR residuals can be written as

$$\begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} = \begin{bmatrix} \mu_y \\ \mu_p \end{bmatrix} + \begin{bmatrix} C_{11}(0) & C_{12}(0) \\ C_{21}(0) & C_{22}(0) \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \qquad \text{eq (17)}$$

where c(0) is the matrix of the contemporaneous effects of the structural innovations. Together with the VAR estimates of the variances $Var(e_1)$, $Var(e_2)$ and covariance $Cov(e_1, e_2)$ and the long run restriction (for instance, setting $\sum_{K=0}^{\infty} C_{11}(K)\varepsilon_{1t-k} = 0$, implying that the cumulative effect of the shock is equal to zero, i.e. transitory shocks), the structural innovations can be recovered. It can be shown that potential GDP (y^*_t) is the sum of the projected deterministic trend in output and the cumulative effects of past permanent supply shocks i.e.,[18]

17. See Morling (2002) and Enders (1995).

18. Since potential output corresponds to the permanent component of the output (Cerra and Saxwna, 2000).

$$y^*_t = \mu_y + c(L)\varepsilon_{2t} \qquad \text{eq (18)}$$

Thus the part of output due to the transitory shocks is the output gap.[19] The advantage of the structural VAR is that even though it uses minimum theoretical consideration, an economic interpretation can be attached to the potential output as being caused by certain types of shocks (Morling 2002, DeSerres, Guay and St-Amant, 1995). The SVAR methodology also allows for the dynamics of the system to be fully explored and accounted for (Morling, 2002). Another major advantage of the SVAR model is that a minimum of two variables can be employed to estimate potential GDP, for example, as shown above, using just output and price data (Keating and Nye 1998, Morling, 2002). This is useful for practical purposes where data is limited, especially in developing countries (Srinvasan, cited in Morling, 2002).[20]

One disadvantage is that by virtual of its estimation technique, the SVAR is non-linear. Therefore, it may be difficult to incorporate the SVAR methodology into an existing macroeconomic model that emphasises linearity (Chantanahom, 2003).[21] Owing to the lag structure, the SVAR approach is rather data-intensive and requires long data series. For instance, if only annual data is available, using SVAR may in a way, limit the possible dynamic effects of these shocks (Rosana and Seater, 1995, cited in Morling 2002).

The long-run restriction of the SVAR assumes that the effects of demand shocks on output are often considered temporary while the aggregate supply shock permanent. These assumptions may not be appropriate for developing countries where temporary supply shocks due to oil prices and shocks due to adverse weather conditions are common (Morling 2002). In addition, SVAR is sensitive to the long-run restrictions and these restrictions cannot be tested statistically (Cooley and Dwyer (1998) cited in Cotis, Elmeskov and Mourougane 2003, p.27)

19. An intuitive explanation is that since output gap equals output minus potential output, the component determined by the transistory shock can be interpreted as the output gap

20. However, a lower dimension SVAR may not be able to isolate the different shocks that may affect a system.

4.3.3 Production Function Model

In the production approach, the estimation of potential GDP is based on the assumption that the country resources, including labour and capital are operating at full capacity. For instance, the supply side is modeled by the production function using either the specification of the Cobb-Douglas or the Constant Elasticity of Substitution (CES) while technology and the input factors of labour and capital determine the output.

Typically, the Cobb-Douglas production function is used

$$Y_t = A_t * K^{\beta}_t * L_t^{(1-\beta)} \qquad \text{eq (19)}$$

and the above equation can be specified in log form as follows:

$$Y_t = A_t + \beta K_t + (1-\beta)L_t \qquad \text{eq (20)}$$

where Y_t is real output, where A_t is total factor productivity (TFPt), L_t is effective labour, K_t is capital stock and â is the labour share of income. As total factor productivity (TFP) is not directly observable, it is usually derived from the so-called Solow's residual from a growth accounting framework.[22] A typical production function approach is illustrated in Chart 2.

Like all econometric models, this model has several advantages (Adam and et.al., 1987, cited in Gibbs, p.84). Firstly, the production approach is, theoretically, the most desirable as the model can account for the explicit relationships between the various factor markets (Gibbs, 1995, p.83). Secondly, it can account for growth in term of the contribution of total productivity factor. Thirdly, it allows one to analyse the impact of various shocks (e.g., oil price increase) and finally, the production function model can be effectively used for forecasting to account for changes in the various factor, such as NAIRU.[23]

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21 However, one can, by using the appropriate restriction use the SVAR model to simultaneously estimate the NAIRU, output gap and structural budget balance (Hjelm (2003).

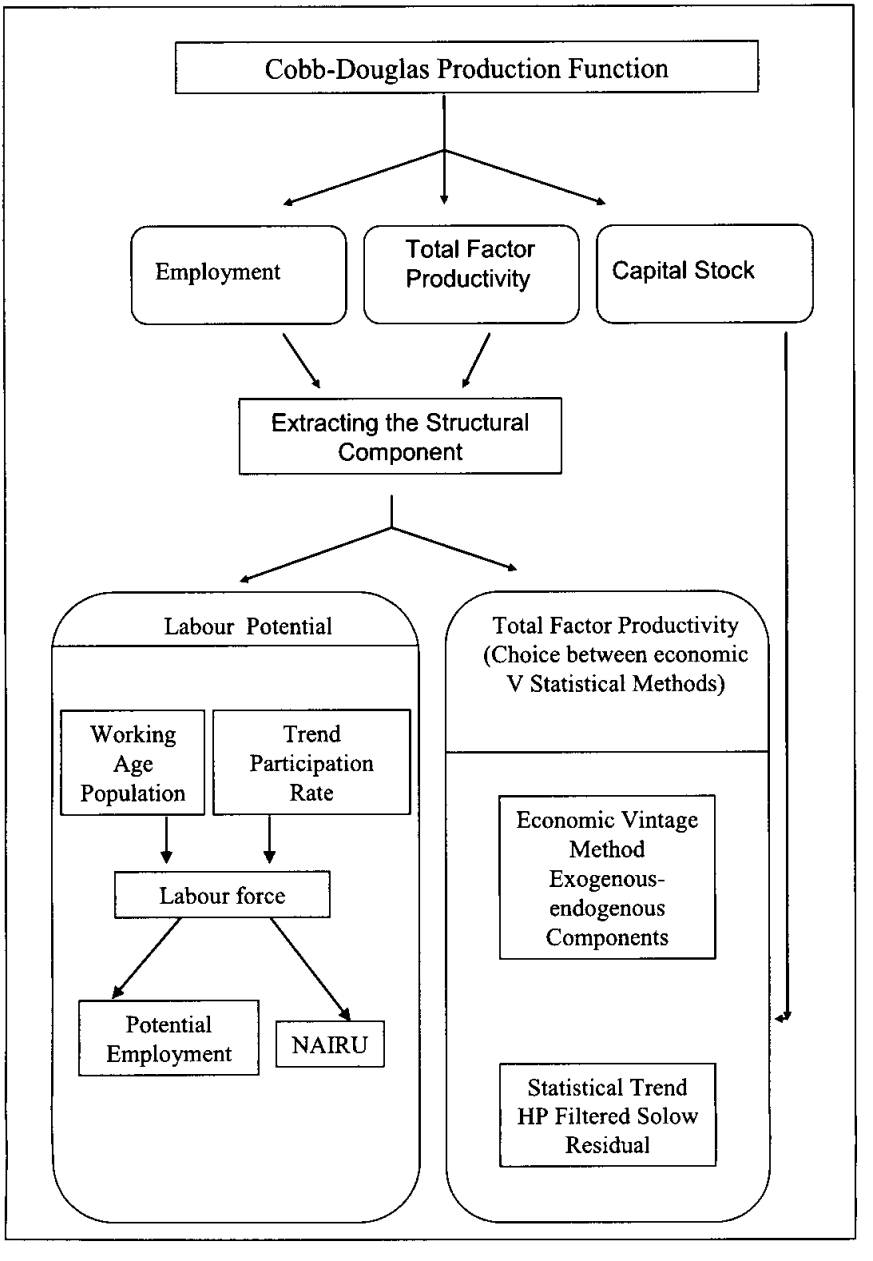
22 Alternatively, using the equation $Y_t = a_0 + \delta L_t + (1-\delta)K_t + e_t$ where a_0 is constant, and all the variables are in natural log, total productivity is estimated as the residual e_t. See Bjørnland, Brubakk, and Jore 2006). The normal practice is to model the long run 'trend' of capital stock and labour with capital utilisation and NAIRU respectively.

23. NAIRU is defined by Claus (2000) as 'the rate that prevails when expectations are fully realised and incorporated into all wages and prices, and inflation is neither accelerating nor decelerating'.

Obviously, the use of production functions approach to determine potential GDP and the output gap requires one to make explicit assumptions on the production technology, the equilibrium employment, the level of capital stock and the total factor productivity (Chagny and Döpke, 2001, p.15). That is to estimate the "unobservable" potential output, a range of other "unobservables" have to be referred to (Graff 2004, p.5). These variables such as NAIRU is what Graff (2004, p.5) terms as "second order" "unobservables".

One major disadvantage of the production function approach is that even if these second-order "unobservables" are available through various estimation techniques, the data for the inputs (typically capital, labour, a measure of productivity, and sometimes intermediate inputs) is often of poor quality or is infrequently measured (Claus, 2000). For instance, Yap (2003) notes that the data on NAIRU and capacity utilisation are not available in the Philippines and Chantanahom and et.al., (2002) finds inadequacy of gross capital stock data in Thailand as it is only available in annual series. Even in developed country like Japan, there is no direct data on capital utilisation in the non-manufacturing sector (Koichiro 2004). In addition, the estimations obtained from the production function approach are often very sensitive to minor specification changes (Chagny and Döpke, 2001, p.16).

Chart 2
The Production Function Approach



Source: McMorrow and Roeger (2001, p.22)

The OECD, EU and the IMF had used some versions of the production function to estimate potential GDP (Cotis, Elmeskov and Mourougane, 2003, p.5). The OECD use the hybrid approach as it estimates potential output based on the Cobb-Douglas production and also uses various univariate filters such as the HP to calculate other variables such as trend hour worked and trend total factor productivity. However, neither the IMF nor OECD has an 'official method' and they rely on each country desk to choose the method that fits the situation best.

5. Requirements for Estimating Potential GDP

One way to assess the appropriate use of the various methodologies of estimating potential GDP is to examine the requirements for potential GDP methodologies. According to Cotis, Elmeskov and Mourougane (2003), the requirements can be divided into two criteria, namely,

(1) The core requirements; and,
(2) User-specific requirement.

The core requirements can be further broken down into:
(1) Consistency between priors and underlying assumptions of the methods, i.e., one chooses a particular method to suit the underlying assumptions;
(2) Transparency; and,
(3) Size of the revisions between real time and ex-post estimates.

The user specific requirements can be further divided into:
1) Information needed;
2) Ability to detect persistent structural changes at the end of the sample; and,
3) Reliability of the estimates at the end of the sample.

Based on Cotis, Elmeskov and Mourougane (2003), a summary of the core and specific requirements and how they are related to specific model is presented in Table 1. Basically, they argue that there may be a trade-off between the various requirements. For instance, structural models may satisfy many of the criteria in the user-specific requirements but they may conflict with the core requirement of transparency as the estimation needs a hybrid of various methods.

Table 1

Requirements for Estimating Potential GDP[1]

	Core Requirements
Consistency between priors and underlying assumptions	1. As regards to the assumption that output gap is stationary, linear trend model is not suitable as it is incapable of extracting stochastic trend component. 2. Liner trend assumes supply shock is deterministic and it is difficult to reconcile with the fact that potential GDP may be technological driven. 3. Linear trend model implies a linear trend and thus are implausible under the assumptions that potential GDP growth is expected to vary over time. 4. Hodrick-Prescott filter implicitly assumes output is white noise and thus will be inconsistent with data that shows a high degree of persistence of the output gap. 5. Multivariate Kalman filter can encounter difficulties in assessing sudden breaks of trends. 6. Multivariate HP may contain OKUN lags, Phillips curve and NAIRU but NAIRU is highly uncertain. 7. Potential GDP estimation based on the production approach may be highly cyclical due to the usage of the series of actual capital stock. 8. The length of cycles in output estimated depends on the chosen methods and may conflicts with some priors.
Transparency	1. Statistical method in general are more transparent than economic (For instance, the smoothen parameter of both HP and multivariate HP). 2. Production function approach is transparent and economic explanation can be used in conjunction with the methodology. However, in practice the production function approach is a hybrid as it also makes use of HP or multivariate HP in some stages of estimation of the model. 3. Specification of the production function is also open to debate.

24. Based on Cotis, Elmeskov and Mourougane (2003)

Size of revisions between real time and ex-post estimates	1. The size of the revision should not be too large for credibility purposes; significant revisions imply uncertainty of the model parameters. 2. Linear and mechanistic filter are sensitive to the estimation periods. 3. Production function approach is less likely to experience significant end of the sample problems; 4. It is easy to justify update in production function approach as explanation on information on contribution to potential growth is available.
	User Specific Requirements
Information Needed	1. There is a need to restrict the quantity of data to keep estimation process manageable and transparent, especially for countries that lack reliable data. 2. The use of two-side filters needs both past and future observations compared to the methodology based on production function, the Beveridge-Nelson decomposition or structural VAR which uses historical data.
Ability to Detect Persistent Structural Changes at the End of the Sample	1. The chosen methods should be able to detect permanent structural changes. 2. The property of estimates at end of sample is crucial for policy makers who are interested in recent and future potential GDP estimates. Baxter-King methodology provides no estimates at end of sample. 3. Most univariate techniques and also some multivariate technique assume symmetric gap; to ensure the actual and trend GDP move closely but if inflation response is asymmetric, on average the economy will not be at potential, if inflation is to be stabilised.

Reliability of the Estimates at the End of the Sample	1. Two-sided filter needs future data to estimate current potential GDP output. Backward methods such as the structural VARS and Beveridge-Nelson decomposition do not need future data. Linear trend method is also a problem if the sample at the beginning and at the end has very dissimilar cycles. 2. HP filter is a two-sided filter estimation technique. 3. The problem of two-sided filters can be 'solved' by using more forecast values but this is forecast values may be based on judgmental assumptions or the fact that most forecast is close to the average historical values.

6. Review of Empirical Evidence

There are studies which conclude that a particular method of estimating potential GDP is better in terms of the estimates having larger predictive power over inflation. However, despite extant empirical evidence, there is generally, no consensus on the superiority of one method over another (Chagny and Lemoine, 2004, p.4, see Table 2 for a summary of various empirical studies). Billmeier (2004a) using five European countries, namely, Finland, France, Greece, Italy and UK, observe that the output gap rarely provides useful information in terms of simulated out-of-sample inflation forecasting and he concludes that is no single best output measure across countries. However, Billmeir (2004b) in another paper, also notes that in terms of inflation-forecast exercises, none of the methodologies outperform the simple univariate model for the Finnish inflation. Gounder and Morling (2000) also observe that all the various methods give imprecise estimations and thus the output gap is not a good predictor of inflation in Fiji. However, they find that the SVAR performs relatively better.

Varelas (2006) using data from Greece finds that the Hodrick-Prescott perform better in terms of reducing the ex post prediction error in modeling inflation. On the other hand, according to Araujo, Areosa and Guillén (2004), the Beveridge-Nelson methodology outperforms all the other models at all forecast horizons. Meanwhile, Dupasquier, Guay and St-Amant (1997) using US data, recommend the structural VAR while Slevin (2001) notes that the Cobb Douglas production function estimation of potential output is the only measure that has a significant relationship with inflation in Ireland. On the other hand, Conway and Hunt (1997) and Gibbs (1995), using New Zealand data, find that the multivariate filter estimates of potential output provide a better measure of inflationary pressure.

The study of Gerlach and Yiu (2004) is particularly interesting as it compares five different methodologies using quarterly data series ranging for about 20 years ending 2001 for six SEACEN countries, namely, Indonesia, Korea, Malaysia, the Philippines, Singapore, and Taiwan. They observe that similar results were obtained using the various approaches but they recommend using the HP since it is implemented and available in a number of software packages. Meanwhile, the study of Chantanahom and et.al. (2002) on Thailand, notes that the output gap from NAIRU best fits the inflation relationship compared to SVAR and multivariate HP.

Empirical evidence also suggests that the estimation of potential GDP is highly uncertain. Chagny and Döpke (2001) using data from Euroland find that no two methods produce the same business cycles. Similar uncertainty is also pointed out by De Brouwer (1998, Australian data), DeSerres, Guay, and St-Amant (1995, Mexican data) and Claus (1999, New Zealand Data). Coe and Mcdermott (1996) using data from 13 Asian countries, found that the estimation of the output gap can be uncertain for the most recent periods. On the production function approach, empirical evidence also suggests uncertainty is due mainly to the estimation of NAIRU (Cerra and Saxena, 2000 and Willman, 2002) and the measurement of the capital stock variable (Conway and Hunt, 1997).

Table 2

Findings of Selected Papers on Potential GDP Estimation

Authors/Data Sources	**Methodology**	**Major Findings**
Araujo, Areosa and de Carvalho Guillén (2004) Brazil	Deterministic Trends,. Moving Average, Hodrick-Prescott Filter, Beveridge-Nelson Decomposition,. Unobserved Component Models and. Hodrick-Prescott constrained to a Production Function	Potential output estimates by the deterministic trend, moving average, Hodrick-Prescott, Beveridge-Nelson and production function models possess strong short-term co-movements, with the series moving upward and downward at roughly the same time. However, Beveridge-Nelson methodology outperforms all the other models at all forecast horizons.
Billmeier (2004) Five European countries: Finland, France, Greece, Italy and UK	Hodrick-Prescott Filter, Frequency Domain Approach, Structural VAR (BQ Decomposition) and Production function approach	Output gap rarely provides useful information in terms of simulated out-of-sample inflation forecasting. There is no single best output measure across countries.
Billmeir (2004) Finland	Various measures, including production function approach emphasises the derivation of the NAWRU—non-accelerating wage inflation rate of unemployment—as a latent variable.	The volatility of the Finland output makes the estimation of potential output difficult with large uncertainty. In terms of inflation-forecast exercises, none of them outperform the simple univariate model for Finnish inflation. This could be due to the high volatility of the output itself and also the fact that the data used is annual.

Bjørnland, Brubakk, and Jore (2006) Norway	Both unvariate and multivariate approach	The multivariate methods also display the highest correlation with real time estimates such as the unemployment gap, making them more reliable with regard to assessing the current economic situation. However, some of the alternative indicators like the employment gap do as well or in some cases even better, than the multivariate methods in predicting inflation.
Cerra and Saxena (2000) Sweden	Hodrick-Prescott, Beveridge-Nelson, Unobserved Component, both univariate and bivariate, Common Permanent and Transitory Components, Structural VAR, Production Function and System Unobserved Components	Production function approach may be the preferred methodology because of the confidence in the potential levels of the underlying inputs. But there is much uncertainty due to difficulties in estimating NAIRU.
Chagny and Döpke (2001) Euroland	Linear de-trending, segmented trend model, robust trend estimation, HP-filter, BP-filter, survey data SVAR estimation and multivariate unobserved component model	Correlation of output gaps calculated with different methods is generally low. No two methods produce the same business cycles. The difference in the gap using various approaches can be as large as 3 percent. Some of the methods are sensitive to the time span used in the analysis. They conclude that all in all, the actual output gap is far from exactly known.

Chagny and Lemoine (2004) France	The production-function approach is implemented within the Hodrick-Prescott framework, assuming a Cobb-Douglas functional form for the production function.	The multivariate HP production-function approach provides output gap estimates that can differ quite substantially from the univariate HP estimates. For instance, excess supply and excess demand periods are more pronounced. However, the accuracy of the output gap estimates, the confidence bands is generally larger with the production-function approach However, the forecasting performance of the production-function approach can be considered as broadly satisfactory.
Chantanahom and et.al. (2002) Thailand	Non-accelerating Inflation Rate of Unemployment (NAIRU), Stochastic Frontier Production Function (SFP), Hodrick-Prescott Multivariate filter and Structural Vector Autoregressive Regression (SVAR)	Output gap from NAIRU best fit the inflation relationship
Claus (2000) New Zealand	Hodrick-Prescott filter, the Reserve Bank of New Zealand's multivariate filter, a structural vector autoregression and an unobserved components model	Two models tested. The change in inflation is related to (i) the *level* of the output gap and (ii) the change in the level of output gap. The results suggest that the output gap does provide a useful signal to the monetary authority.

Claus (1999) New Zealand	Alternative estimations technique are used to obtain a measure of the output gap.	The output gap associated with both the Hodrick- Prescott and the multivariate filters, is more negative than the output gap derived from the vector auto regression estimation Therefore, there is substantial uncertainty surrounding the estimate of the output gap.
Coe and Mcdermott (1996) 13 Asian countries	Modified Hodrick-Precott with the degree of smoothing determined on statistical ground by the data itself.	Out of the 13 countries, estimation of the potential GDP of 11 counties were found to be a significant determinant of inflation, implying that the output gap can be a useful tool for policy analysis. However, they also found that the estimation of the output gap can be uncertain for the most recent periods.
Conway and Hunt (1997) New Zealand	Multivariate HP, Hodrick-Prescott filter is augmented with information from a Phillips curve relationship, an Okun's Law relationship and a survey measure of capacity utilisation	The output gap obtained using the MV filter estimate of potential output provides a better measure of inflationary pressure in the New Zealand economy, relative to an output gap estimated using the HP filter. Using rolling estimates, the authors claims that revisions to the MV filter estimate of the current output gap in response to new data are much smaller than those of the straight HP filter.
De Brouwer (1998) Australia	Linear Time Trends, Hodrick-Prescott, Multivariate HP filter trends, Unobservable Components model and Production Function model.	Estimation of the gap is sensitive to changes in model specification. However, the gap is similar across the range of methods used but the gap estimation at any point in time is imprecise. The output gap however, improves the fit of the inflation equation and substantially reduces ex-post prediction error.

DeSerres, Guay, and St-Amant (1995) Mexico	The three-variable VAR representation model approach comprises of industrial production, monetary base and oil price	There is considerable uncertainty surrounding the estimation of the output gap as there are few periods of statistically significant excess demand (actual output above potential) or excess supply (negative gaps) when the conventional 90 per cent confidence interval is used.
Dupasquier, Guay & St-Amant (1997) US	Multivariate Methodologies,Beveridge-Nelson, Cochrane's methodology and Structural VAR.	Recommend SVAR as it allows for estimated transitional dynamics following permanent shocks. Although the correlation between the different output gaps appears to be relatively small, it may still be relatively difficult to discriminate among the different measures of the output gap for specific points in time. However, there is a substantial amount of uncertainty surrounding the estimation of the output gap.
Funke (1997) West Germany	Structural VAR and other univariate methods	The output gap obtained from the structural VAR appears to be smaller when compared to the traditional Hodrick-Prescott procedure. Funke suggests combining different output gap measures to enhance the predictability range of inflation. This suggests that using alternative gap measures should become part of the mainstream modelling practice.
Gerlach and Yiu (2004) Asian countries including six SEACEN countries; Indonesia, Korea, Malaysia, the Philippines, Singapore, and Taiwan	Hodrick–Prescott (HP) filter, a band-pass (BP) filter, the Beveridge–Nelson (BN) filter and unobservable-components (UC) techniques	The output gaps generated using the HP and BP filters and the UC approach appear quite similar, suggesting that they contain much the same information for inflation and other variables that policy makers are interested in. Since the HP filter is implemented in a number of software packages, it seems likely that it will remain the preferred method for constructing output gaps in applied econometric research.

Gibbs (1995) Data for New Zealand	Simple and structural multivariate estimates, production function approach, HP filters and Multivariate HP	Wide range of estimates of potential output appears to be consistent with data. Estimation must be treated with caution. Empirical measures unlikely to be sufficiently robust as to be useful for fine-tuning macroeconomic policy.
Gounder and Morling (2000) Fiji	Use 4 methods, namely the linear tend method, the HP method, the Aggregrate production function and SVAR to estimate potential GDP of Fiji	Overall, they note that the four methods all give imprecise estimation of the output gap. They also note that the output gap is not a good predictor of inflation even though the SVAR performs relatively better. They caution against the use of these gap for policy analysis.
Scott A (2000) New Zealand	Reserve Bank's MV filter Structural VAR, a multivariate unobserved components approach. These are benchmarking to linear and segmented trends, a fourth difference filter, the band pass filter of Baxter and King , the Hodrick-Prescott filter, an optimal filter of Agénor, McDermott and Prasad (2000)), and the non-parametric estimate of trend used in Coe and McDermott (1997).	The analysis leads to the conclusion that while different filters result in estimates of the output gap with quite different properties, the three models are generally in agreement on the historical profile of the output gap, if not exactly precise. The average durations of cycles tend to co-move but there are significant differences and disagreements on the severity of swings in the cycles. They note that 'this uncertainty implies that the gap is best treated as an indicator of the state of the world rather than an exact measure of the precise level of the output gap'.

Slevin (2001) Ireland	Various methods were employed, in particular, the Cobb Douglas function with technology as a linear trend and one with varying trend	Some degree of consistency were reported among the various output gap estimation but the Cobb Douglas production function output gap with technology as a linear time trend is the only measure that has a significant relationship with inflation.
Varelas (2006) Greece	linear time trend, quadratic time trend and the Hodrick-Prescott	The output gap calculated using the Hodrick-Prescott approach appears to be superior in reducing the ex post prediction error in modeling inflation.
Willman (2002) Euro area	A three equation supply-side model based on aggregation across sectors with sector specific mark-ups and the technology parameters of the production function. The underlying production function is either Constant Elasticity of Substitution (CES) or Cobb-Douglas	Output gap estimates are quite insensitive with respect to alternative parameterisations and functional forms of the underlying production function. Hence, the principal source of the measurement error of the output gap, when the production function approach is applied, is the estimate of the NAIRU.

7. A Survey of Potential GDP Estimation in the SEACEN Countries

From the questionnaire survey of SEACEN member banks and monetary authorities, the central banks and monetary authorities of Papua New Guinea, Malaysia, Mongolia, Nepal, Singapore Taiwan and Thailand use the univariate method to estimate potential GDP. However, Malaysia, Singapore, Taiwan and Thailand also use multiple approaches (see Table 3). Out of all the fourteen member countries[25], Indonesia, Korea, Malaysia, Singapore and Taiwan use different forms of the production function approach, with capital stock, labour supply and technological changes being the key input variables. As with most cases, the estimation is done using the hybrid approach where the main production function is structurally estimated while the natural/non-inflationary levels of factors input components are derived using a combination of univariate and multivariate statistical filtering.

The multiple approaches enable the SEACEN countries to carry out cross-check comparisons with different models. For Bank Indonesia, comparisons are made between the estimates from Cobb-Douglas production function model (a part of the quarterly scale macroeconomic model (SSM-X), the short-term forecast model for Indonesian economy (SOFIE) and also with survey data on capacity utilisation. It is interesting to note that these two models differ in their fundamental assumptions. In the SSM-X model, capital stock is exogenous while labour is endogenous but it is the opposite for the SOFIE model.[26] Korea also incorporates the Cobb-Douglas production function into The Bank of Korea's official macro-econometric model (BOK04). However, The Bank of Korea does not formally compare the estimates from the Cobb-Douglas estimation with other methods although from time to time, a comparison is made to ascertain the precision of the estimated series to see how well the estimates fit into recent economic conditions. On the other hand, Thailand uses the Hodrick-Prescott de-trending procedure and the estimates are also incorporated into the Bank's macro-econometric model. Thailand has also explored other methods of estimating

25. Due to lack of adequate data, Myanmar and Vietnam are excluded.

26. It is interesting to note that SSM-X potential GDP data often moves in line with the survey and other observed macro variables.

potential GDP which include NAIRU, Stochastic frontier production function multivariate HP and the SVAR but the central bank notes that the preferred choice of the HP de-trending procedure method is adopted because the other methods require data that is difficult to obtain, unreliable or difficult to project.[27] Besides, the HP methodology is both easy to use and interpret. Singapore, on the other hand, has a different approach. The output estimates from three methods, namely the multivariate Hodrick-Prescott approach estimated with Kalman filters, the Friedman's (1984) variable span smoother and the simple univariate HP are subsequently weighted based on the explanatory power on inflation represented by the standard errors in the simple linear regression on the three output gap measures.

27. The HP de-trending procedure takes into account the structural shift during the crisis as real GDP is broken into two group, pre-and post-crisis. The HP procedure is then applied to both groups separately. The connecting points of the two groups are then made equal and smoothed out using the exponential smoothing method.

Table 3 Potential GDP estimation in the SEACEN Countries.

Country	Potential GDP model	Role of potential GDP in accessing policy	Reconciliate with other estimates	Constraint factors in developing existing potential GDP model	Model/Data disclosured to Public	Future development
Brunei	No					Computable general equilibrium model
Cambodia	No					No plan by the Central bank as the Ministry of Planning is responsible for national statisics.
Fiji	No formal model	At present, potential GDP does not play any role.		Expertise		Econometric modellling
Indonesia	Fully integrated into the quarterly small scale macroconomic model (SSM-X)	Complement other information	Yes, BI has other models such as SOFIE(Short-term Forecast Model) with different assumption about endogenity of capital stocks and labour. Also obtain surveys on capacity utilisation	Data accuracy and availability of certain variables. E.g., annual data must be extrapolated into quarterly data. Substantial lags in labour data	(No/-)	
Korea	Cobb_douglas Production Function; integrated into the BOK04, the official macroeconometric model	Yes, very important, the estimates are incorporated into the BOK official macroeconometric models	Does not perform direct comparison	Accuracy in estimating capital stock etc	(Yes/No)	
Malaysia	Production Function apporach	Potential GDP is used for forecasting and monetary assessment exercises	Yes, assess the consistency of the estimates by competing models	Capital stock data	(Yes/Yes), though not on regular basis	Refining current model
Mongolia	Hodrick-Prescott filter	Very little, mostly for research purposes only	No	Data shortages, Extensive shadow economy	(Yes/Yes)	
Nepal	De-Trending methods;	Yes, very crucial	Compare with value and subjective judgment	Capital stock data difficult to obtain		Developing macro econometric model
PNG	Hodrick-Prescott	Yes, in infllation equation		GDP yearly data; interpolate into quarterly data		To develop more advanced method when quartely data becomes available
Philippines	None	Potential GDP does not play any role.				SVAR, Production function and dynamic stochastic general Equilibrium (DSGE)

Singapore	Three main methods:Multivariate Hodrick Prescott, using kalman filter; non-parametric Freidman's variable span smoother; Simple Hodrick Rescott Filter	Forms a broader information set on inflationary pressure	Output gap estimates are weighted based on their explanatory power in inflation	Do not systemtically collect data from all industries.	(Yes/upon request)	To take into account globalisation; implementation of regular surveys on resource utilisation
Sri Lanka	None			Accuracy in estimating capital stock etc		Modified production function approach
Taiwan	Several approaches, including unvariate approach, HP, Band-pass and Production function of Cobb-Douglas	Yes, it plays some role	Yes, professional judgement is used	Difficulties in assessing non-inflationary degree of utilisation;data on capital stock n may not be robust	(No/No)	Semi-structural approach combined with structural approach, Philips Curve with filtering appraoch
Thailand	Hodrick-Prescott de-trending procedure to diffferent samples to account for pre-post crisis. Also use NAIRU, MVHP, SVAR, Stochastic frontier production function.	Yes, especially for medium-term projections; within the Bank's macroeconometric model	Yes, cross-check to ensure consistency with variables such as capacity utilisation and inflation data	Modelling structural breaks	(Yes/No)	BOT is actively considering other methods

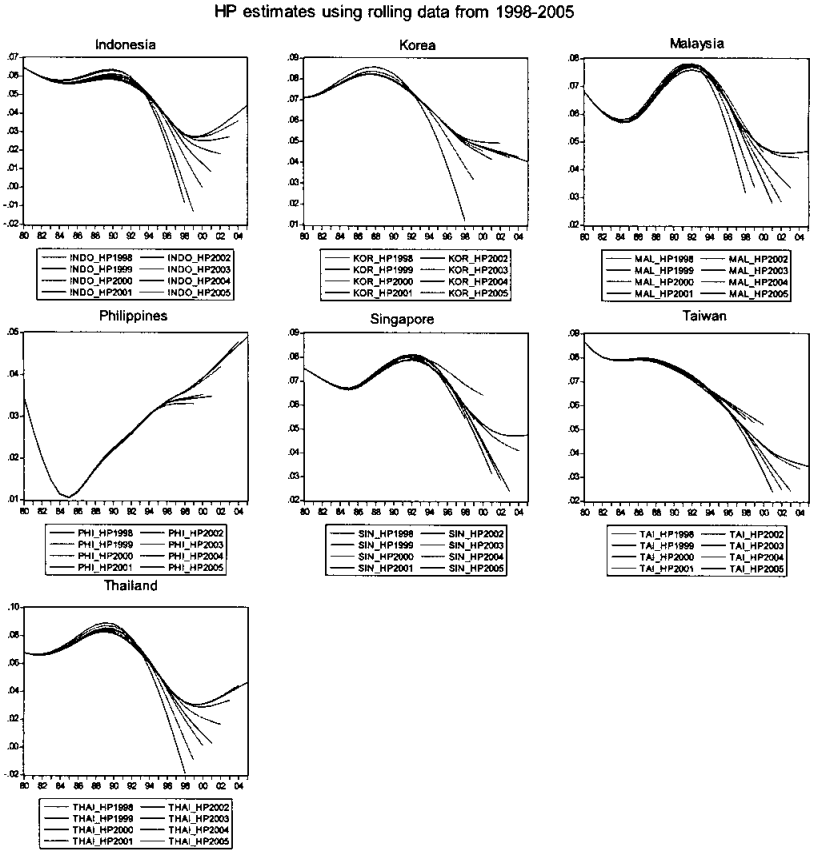
7.1 Empirical Investigation into Estimation of Potential Output

It is clear from the above survey that in the SEACEN countries, various approaches are adopted. Obviously, the complexity of estimation of potential GDP increases from univariate to the production function approach with the structural SVAR somewhere in between. Because of simplicity and the availability of computer software, most univariate methods such as HP can be easily estimated. On the other hand, the production function requires data sets which in many cases are not available, even for developed countries. In this section, we investigate both the HP and SVAR methodologies.

In the HP methodology, the rolling estimates of potential GDP are estimated using data with initial sample starting from 1975 to 1998 and subsequently, an extra data point is added one at a time to the sample until the year 2005. The results in Chart 3 clearly show that the rolling estimates of similar periods (but using different samples) are significantly different from each other. For the seven selected countries, this clearly indicates that the HP provides much uncertainty about the potential output as new data becomes available. This is an important consideration given that there is often a lag in the availability of current data on GDP.

In real-time, as output growth slowed after Asian crisis, the HP filter would gradually lower its estimate of trend GDP growth as new data becomes available. This slow revision to what turns out to be a permanent reduction in trend GDP growth would cause the real-time (or one-sided) output gap estimate to be lower than what the ex-post (or two-sided) output gap estimate. From a policymaker's perspective, this could be problematic if interest rates were lowered too much in an attempt to lean against the recession since the recession will appear bigger in real-time than ex-post.[28]

28. This was pointed out by Dr. Plantier.



In the SVAR methodology, the SVAR is examined to see whether it is consistent with priors and the underlying assumptions. We can then examine whether potential GDP derived using the SVAR can be a good guide for monetary policy. In the SVAR methodology, the long run restriction as discussed above (in Section 4.3.2) is imposed such that the aggregate supply shock is assumed to have a permanent effect while aggregate demand shock to have only temporary effects on output. Following Morling (2002), by examining the impulse response functions of a SVAR system, we can investigate whether temporary fluctuations in output around the potential output in the SEACEN countries are primarily caused by demand shocks or temporary aggregate supply shocks. [29]

29. Morling (2002) uses the analysis for a group of developing countries. We extend Morling's (2002) analysis to each individual SEACEN country.

The SVAR is estimated using annual data with two variables, output and prices.[30] The usual caveats regarding the limitation of using SVAR applies. As annual data is used, only one lag across all countries is deemed sufficient. The effects of the various shocks to output is interpreted as: (a) permanent supply shocks will cause output to increase and price to decline permanently but (2) temporary shocks (demand) should cause output and prices to move together. The above is applicable at least for a significant portion of time after the shock occurs (Keating 2006). However, a temporary supply shock may cause output and prices to move in different direction. For instance, a temporary supply shocks due to weather conditions which disrupt supply can cause output to decrease and prices to fall.

Table 4

Possible Impact of Various Shocks on Output and Prices

Positive permanent shock	→	Permanent Increase in Output; Permanent Fall in Prices.
Positive Transitory (demand) shock	→	Temporary Increase in Output; Temporary Increase in Prices; In the long run, Output remains unchanged, only results in change in Prices.
Temporary supply shock[31]	→	Output and Prices moves in opposite direction.

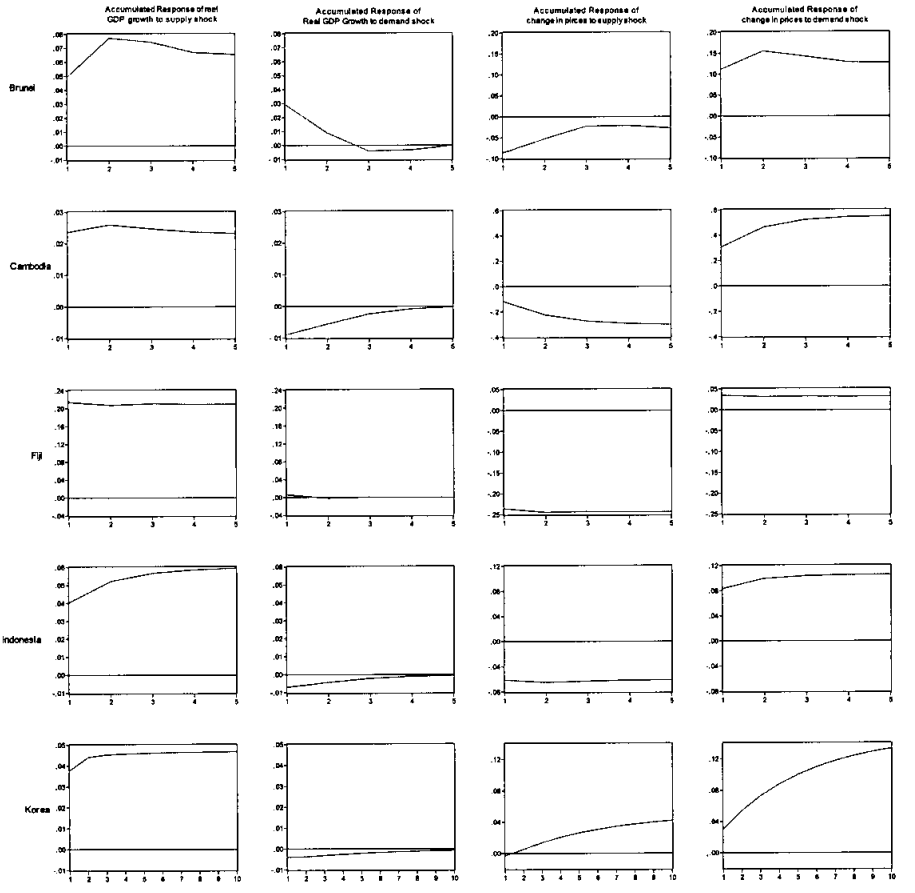
30. The sample size is for Brunei, Myanmar, Nepal and Papua New Guinea :75-04, Fiji :75-2001, Cambodia :87-04, Mongolia: 80-05, Vietnam: 91-05 and Indonesia, Korea, Malaysia, Philippines, Singapore, Sri Lanka, Taiwan and Thailand: 75-2005. The data is obtained from the IMF FS CD-Rom. First differencing of the variables is used to avoid the issue of non-stationarity.

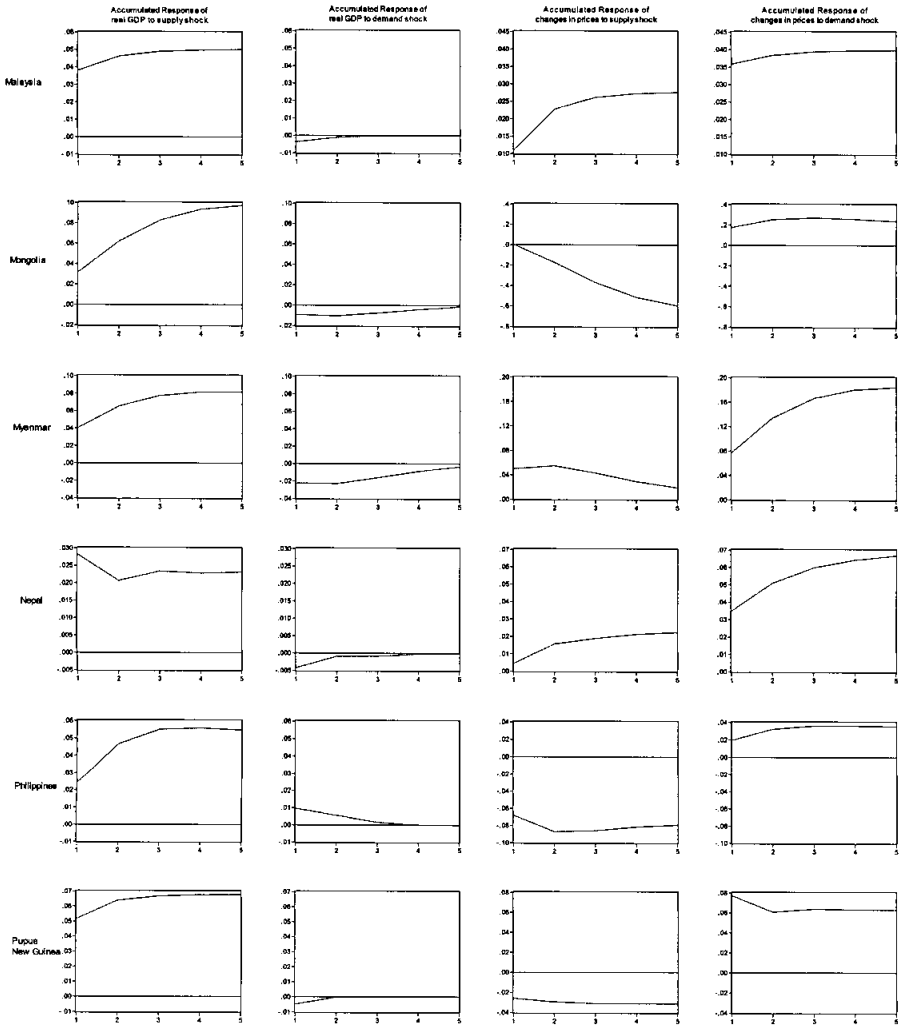
31. In developing countries, as mentioned earlier, temporary supply shocks such as oil prices can influence short-term fluctuations in output around potential GDP.

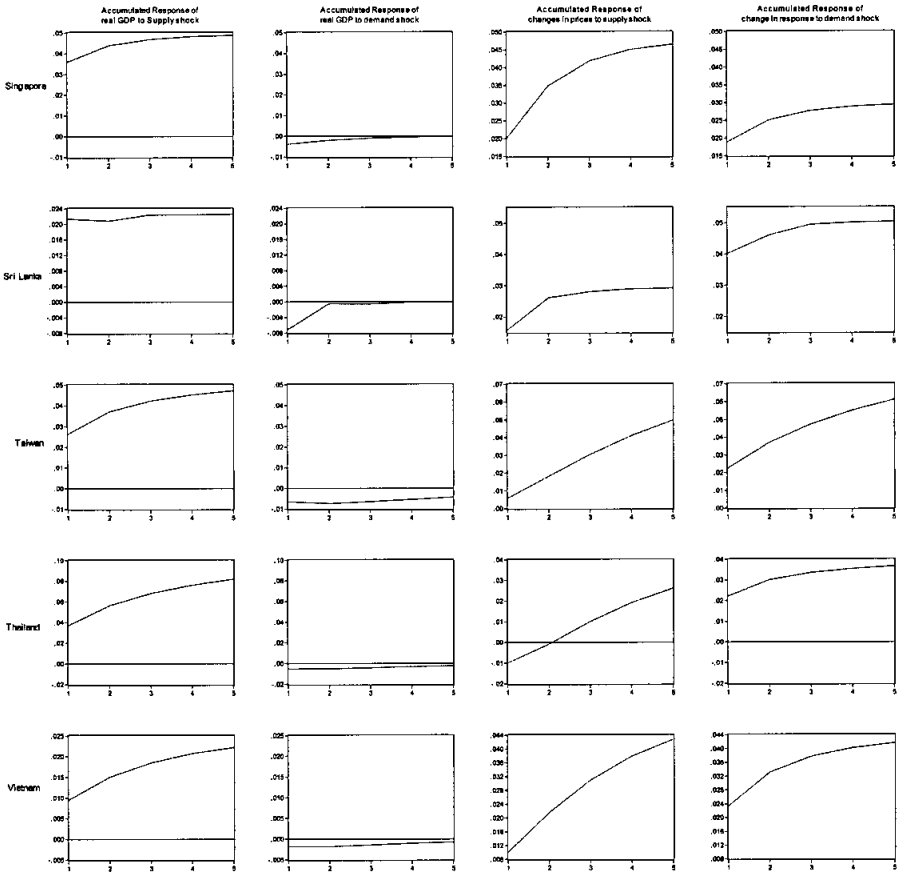
Looking at the accumulated impulse response functions (Chart 4), permanent shocks to output increases output in all cases, suggesting that supply shocks are indeed the *dominant force* in determining permanent movement in output in the SEACEN countries. However, in over half of the SEACEN countries, the permanent shocks lead to an *increase* in prices. This perhaps suggests that in general, monetary policy in these countries may be relatively relaxed during this period. It is interesting to note that in all SEACEN countries except Brunei and the Philippines, temporary shocks cause output to fall but prices to rise.[32] It thus, appears that the temporary shocks do not behave like 'traditional demand-side shocks' but are dominated by *temporary* supply shocks (as defined by Morling 2002).

32. However, for the case of the Philippines, the effects dissipate within a period of two to three years.

Chart 4
Accumulated Impulse function Responses




Accumulated Response of real GDP to supply shock
Accumulated Response of real GDP to demand shock
Accumulated Response of changes in prices to supply shock
Accumulated Response of changes in prices to demand shock
Malaysia
Mongolia
Myanmar
Nepal
Philippines
Pupua New Guinea


Accumulated Response of real GDP to Supply shock
Accumulated Response of real GDP to demand shock
Accumulated Response of changes in prices to supply shock
Accumulated Response of change in response to demand shock
Singapore
Sri Lanka
Taiwan
Thailand
Vietnam

According to the SVAR methodology, the output gap is the accumulation of transitory shocks. Thus in the empirical results, the gap is likely to be influenced by temporary supply shocks. Hence, output gap measures may not be a *useful* guide to assess inflationary pressure. The original analysis of Quah and Blanchard uses real GDP and unemployment.[33] Others such as Bayoumi and Eichengreen (1994) and Keating and Nye (1998) have replaced unemployment with price data (cited in Keating 2006). Obviously, our results are limited in the sense that only output and price data sets are used. However, the advantage is the availability and currency of the price data. The other advantage of using the price data according to Keating (2006) is that the variable price can be analysed to have effect on each of the variable in the SVAR.

8. Conclusion and Overview

The measurement of potential output is far from straightforward and so is its usefulness. McMorrow and Roeger (2001, p.5) have strongly indicated that the estimation of potential GDP "requires a number of arbitrary choices, either at the level of parameters (in statistical methods) or in the theoretical approach and choice of specifications, data and techniques of estimation (in econometric work)". No one single method is unequivocally declared better than the alternatives in all cases (Dennis and et.al. (2006, p6).

With regard to potential GDP modelling in the SEACEN countries, several practical issues are observed.

1. According to the questionnaire survey, potential GDP estimates in assessing monetary policy play a relatively important role in Indonesia. Korea, Nepal, Papua New Guinea, Singapore, Taiwan and Thailand. Conversely, the central banks or monetary authorities of Brunei, Cambodia, Fiji, Mongolia, the Philippines and Sri Lanka have yet to use potential GDP to formulate monetary policy.[34] Some of the reasons cited for not using potential GDP estimation are the lack of human resources and expertise (in the case of Fiji) and data limitations and difficulties encountered due to an extensive

33. Time series unemployment statistics are difficult to obtain in many SEACEN countries, although in practice, the employment gap can be estimated.

34. On a technical level, the reserve bank of Fiji is working closely with the Bank of Thailand to build a in-house econometric model for the estimation of potential GDP.

shadow economy (in the case of Mongolia). However, many of these SEACEN countries have plans to use potential GDP estimation in the near future.

2. As reported by the survey, most SEACEN members currently using the univariate methods have the intention to migrate to more complicated models, such the production function and the dynamic stochastic general equilibrium model (DSGE).[35] In this respect, there are two issues that needed to be resolved. Firstly, the lack of data and secondly, the accuracy associated with the data. These limitations have somewhat reduced the choice of methods. In many SEACEN countries, the data needed to estimate GDP using multivariate and the production function approaches is not easily available since these methodologies require specific data that is either difficult to obtain or lack robustness and accuracy. A major common problem experienced by the SEACEN countries is the lack of capital stock data as well as information on capacity utilisation (see Table 3). In other instances, real GDP and labour data is only available on a yearly basis. This has somewhat undermined the usefulness of the potential GDP models. Furthermore, labour data is only available following a substantial lag.

3. As far as structural modelling is concerned, various kind of economic and financial reforms could create problems for the estimation process Gibbs (1995, p.86). This scenario is likely in many SEACEN countries. For instance, the Bank of Thailand reports that the 1997 financial crisis has created some econometric issues regarding the estimation of potential GDP with respect to structural breaks. Furthermore, SEACEN countries have in the past experienced long period of economic growth due to periods of long-run growth rate of productivity. In this respect, the measurement of potential GDP may be become unreliable because it is difficult to isolate for example, the factors that affect its long run behaviour such technological changes and those that do not, including monetary policy (Nelson and Nikolov 2003). Furthermore many SEACEN countries are converging towards advanced economies, and that this convergence process is unlikely to be done at a constant growth rate since different types of policy reforms may impact the

35. For instance, Philippines is evaluating the DSGE model in which potential output derived from DSGE is assumed to have no price stickiness and rigidity. The output gap is the difference between the results of a DSGE model with rigidities and the fully flexible model.

pace of convergence. In theory, the rate of convergence should slow over time, so past history would not necessarily be a good indication of future economic growth performance (Plantier, 2007).

4. One must also bear in mind that potential output is also of extreme importance to the private sector (Gibbs, p.76). This is especially applicable for long–term private investment where the economy sustainable growth rate can provide a useful gauge for the viability of private investment projects. For a few SEACEN countries, official potential GDP estimates remain confidential. Thus, this brings us to the issue of transparency - of whether official estimates should be made available to the general public. However, if the potential GDP figures are released to the public, the authority must ensure and justify the methodology used.

5. Globalisation is another issue that needs to be examined in the context of the how potential GDP may affect prices (IMF 2006). For instance, while Singapore has always been closely integrated with the global economy, the rapid pace of globalisation in recent years could have fundamentally changed the above relationship somewhat (Survey Reply, Monetary Authority of Singapore). The structural increase in global capacity, largely due to the emergence of China and India, could have engendered a downward trend in import prices, thus reducing the sensitivity of inflation to domestic capacity constraints. Similarly, such effects could have also manifested as a result of the highly competitive environment, which holds down wage demand of domestic workers amidst productivity gains, even as the economy is operating at full capacity. On the other hand, strong global growth and diminishing economic slack coupled with demand-pull commodity price increases, could trigger a synchronised wave of price increases, thus offsetting the deflationary impact of globalisation. Thus, there is an urgent need to address this issue, especially for small open SEACEN economies.

6. A further area of research in the SEACEN countries is on real time data as this is what policy decisions are based on (Cayen and Norden (2004, p.3). For instance, the well-known Taylor-Rule recommendation is to set the interest rate using current output gap and inflation rate. The practical use of potential GDP is limited by what Graff (2004, p.8) terms as 'the inherent difficulty to know with sufficient reliability the magnitude of the output gap at the time *when the policy maker needs to know* it, i.e., in *real time'*. As policy makers do not have the luxury of waiting for lagged information, this informational problem can make the comparison of alternative

policy rules difficult in the assessment of feasible policy outcome in terms of the degree which these policies can stabilise economic fluctuations.

Finally, it is clear that the estimation of potential output using data and different techniques must be treated with caution given that empirical measures are unlikely to be sufficiently robust as to be useful for fine-tuning macroeconomic policy (Gibbs, 1995). Policy makers must be made aware of the consequences and be fully aware of the implications of using potential GDP as a policy guide. However, we can derive some benefit from estimates/forecasts of various alternative indicators. For instance, efforts should be intensified, for instance, for the conduct of regular surveys on resource capacity across all industries to serve as a useful cross-check. This idea of using various alternative indicators simultaneously was noted by Giorno and et.al.(1995, p.6, cited in Gibbs (1995, p.114) as far back as 1995. They argue that:

> *'The OECD has revised its estimation methods to provide a single measure of potential output. . . . Nonetheless, it is clear from this work and the wide range of analytic and survey based indicators which are available that significant margins of error are involved in their estimation and use. Reliance therefore cannot wholly be placed on a single measure of potential or trend output, and related indicators must therefore be treated with due caution'.*

One way as suggested by Ehrmann and Smets (2003) and also Camba-Mendez and Rodriguez-Palenzuela (2003) is by using three criteria to evaluate and assess potential GDP estimation. Firstly, the estimates must be able to significantly forecast inflation, secondly, ex-post statistical revisions must not change significantly from previously computed measures and thirdly, it must be positively correlated with standard measure of capacity utilization. But a viable solution proposed by Funke (1997), which is employed by the Monetary Authority of Singapore, is to combine the estimates generated by different methods to arrive at a consensus figure.

References

Araujo, CHV, Areosa, MBM and de Carvalho, Guillén, (2004), "Estimating Potential Output and the Output, Gap for Brazil", Central do Brasil, July 2004 <Http://www.anpec.org.br/encontro2004/artigos/A04A041.pdf.

Bank of Canada, the Output Gap, Backgrounder, September 1999 <Http://dsp-psd.pwgsc.gc.ca/Collection/FB12-7-1999-15E.pdf#search=%22output%20gap%22>.

Billmeier, A., (2004), "Ghostbusting: Which Output Gap Measures Really Matters?", *IMF Working Paper*, WP/04/146, August 2004 (a).

Billmeier, A., (2004), "Measuring a Roller Coaster: Evidence on the Finnish Output Gap", *IMF Working Paper*, WP 4/57, April 2004 (b).

Bjørnland, H.C,, Brubakk, L. and Jore, A.S., (2006), Forecasting Inflation with an Uncertain Output Gap", *Working Paper*, ANO 2006/2, Norges Bank, 8 March.

Bolt, W., and Van Els, P.J.A., (1998), "Output Gap and Inflation in the EU", *De Nederlandsche Bank Working Paper Series,* 550.

Camba-Mendez, G. and Rodriguez-Palenzuela, D., (2003), "Assessment Criteria for Output Gap Estimates", *Economic Modelling*, Vol.20.

Cayen, J.P. and Van Norden, S., (2004), The Reliability of Canadian Gap Estimates, Studies of the Economic Research Centre, Deutsche Bundesbank, *Discussion Paper Series 1* ,No 29.

Cerra, V. and Saxena, S.W., (2000), "Alternative Methods of Estimating Potential Output and the Output Gap: An Application to Sweden", *IMF Working Paper*, WP/00/59, March 2000.

Chagny, O, and Döpke, J., (2001), "Measures of the Output Gap in the Euro-Zone: An Empirical Assessment of Selected Methods", *Kiel Working Paper*, 1053, June 2001.

Chagny, O, and Lemoine, A., (2004), "An Estimation of the Euro Area Potential Output with a Semi-Structural HPMV Filter", *Document de travail*, Observatoire Francais des Conjonctures Économiques (OFCE), no. 2004-14, December 2004.

Chagny, O., (2004), "An Estimation of the Euro Area Potential Output with a Semi-Structural Multivariate Hodrick-Prescott Filter", No. 2004-12, December 2004, Observatore Francais des Conjonctures Economiques, http:wwww.ofce.scirnces.po.fr>.

Chagny, O. and Döpke, J. (2001), "Measures of the Output Gap in the Euro-Zone: An Empirical Assessment of Selected Methods", *Kiel Working Paper,* No.1053, June 2001.

Chantanahom, P., (2003), "A Differential Equation Approach to Thailand's Potential Output An Application to Bank of Thailand's Macro Economic Model", Monetary Policy Group, Bank of Thailand, May 16, 2003 <www.bot.or.th>.

Chantanahom, P., Buranathanang, N., Imudon, W., Rattakul, Y. and Kiatkomol, P., (2002), "Parametric Estimation of Thailand's Potential Output", Bank of Thailand, *Discussion Paper,* November 2002.

Claus, I.,(1999) 'Estimating Potential Output for New Zealand: A Structural VAR Approach', *Discussion paper Series*, No. DP2000/03, Reserve Bank of New Zealand.

Claus, I., (2000) 'Is the Output Gap a Useful Indicator of Inflation?', *Discussion paper Series*, No. DP2000/05, Reserve Bank of New Zealand.

Coe, D.T. and Mcdermott, C.J., (1996), "Does the Gap Model Work in Asia", *IMF Working Paper,* No.69, February 1996.

Congressional Budget Office, U.S., (2004), "A Summary of Alternative Methods of Estimating Potential GDP", a Background Paper, March 2004, < http:// www.cbo.gov/ftpdocs/51xx/doc5191/03-16-GDP.pdf>.

Conway, P. and Hunt, B., (1997), "Estimating Potential Output: A Semi-structural Approach", *Discussion Paper* No. G97/9, Reserve Bank of New Zealand December 1997.

Cotis, J.P., Elmeskov, J. and Mourougane, A., (2003), "Estimates of Potential Output: Benefits and Pitfalls from a Policy Perspective", Paper Presented at the CEPR Conference "Dating the Euro Area Business Cycle" on 21 January 2003. <www.oecd.org/dataoecd/60/12/23527966.pdf>.

Cukierman, A. and Lippi, F., (2005), "Endogenous Monetary Policy with Unobserved Potential Output", *Journal of Economic Dynamics & Control,* Vol.29.

Denis, C., Grenouilleau, D,, Mc Morrow, K. and Röger, W., (2006), "Calculating Potential Growth Rates and Output Gaps - A Revised Production Function Approach", *Economic Paper*, No. 247, European Commission, March 2006.

De Brouwer, G., (1998), "Estimating Output Gap", *Discussion Paper*, 9809, Economics Research Department, Reserve Bank of Australia, August 1998.

DeSerres, A,, Guay, A., and St-Amant, P., (1995), "Estimating and Projecting Potential Output Using Structural Var Methodology: The Case of the Mexican Economy", *Working Paper,* 95-2, Bank of Canada, March 1995.

Dupasquier, C., Guay, A. and St-Amant, P., (1997), "A Comparison of Alternative Methodologies for Estimating Potential Output and the Output Gap", *Working Paper*, 97-5, Bank of Canada, February 1997.

Ehrmann, M. and Smets, F., (2003), "Uncertain Potential Output: Implications for Monetary Policy", *Journal of Economic Dynamics & Control,* Vol.23.
EU Economic Policy Committee, (2001), "Report on Potential Output and Output Gap', Brussels. <http://ec.europa.eu/economy_finance/epc/documents/finaloutput_en.pdf#search=%22hp%20filter%20demand%20supply%20shock%22.

Enders, W., (1995), Applied Econometric Time Series, John Wiley & Sons. Inc.

Favero, C.A., (2001), Applied Macroeconometrics, Oxford University Press.
Federal Reserve Bank of San Francisco, "What is Taylor's Rule and what Does it say about Federal Reserve Monetary Policy?", 3/1998 <http://www.frbsf.org/education/activities/drecon/9803.html.>.

Federal Reserve Bank of San Francisco, (2000), "How Fast Can the New Economy Grow?", Economic Letter, 2000-05; February 25.

Friedman, J.H., (1984), "A Variable Span Smoother", Department of Statistics, Stanford University, Technical Report, LCSS.

Funke, M., (1997), "Supply Potential and Output Gaps in West German Manufacturing", International Journal of Forecasting, Vol.13.

Gaiduch, V. and Hunt, B., (2000), "Inflation Targeting under Potential Output Uncertainty", *IMF Working Paper* , 128, October 2000.

Gerlach, S. and Yiu, M.S., (2004), "Estimating Output Gaps in Asia: A Cross-Country Study", *Journal of the Japanese International Economies*, Vol. 18.

Gerlach, S. and Peng, W., (2006), "Output Gaps and Inflation in Mainland China", *BIS Working Papers*, No. 194, February 2006.

Gibbs, D., (1995), "Potential Output: Concepts and Measurement", *Labour Market Bulletin*, Vol.1.

Giorno, C., Richardson, P., Roseveare, D. and Van Den Noord, P. (1995), "Estimating Potential Output Gaps and Structural Budget Balances", *OECD Working Paper,* No.152.

Gounder, K. and Morling, S., (2000), "Measures of Potential Output in Fiji", Economics Department, Reserve Bank of Fiji, *Working Paper*, No.6.

Graff, M., (2004), "Estimates of the Output Gap in Real Time: How Well Have We Been Doing? *Discussion Paper Series*, DP2004/04, Reserve Bank of New Zealand, May 2004.

Harvey, A.C., Jaeger, A., (1993), "Detrending, Stylized Facts and the Business Cycle", *Journal of Applied Econometrics*, Vol.8.

Koichiro, K., (2004), "Real-Time Estimation of the Output Gap in Japan and its Usefulness for Inflation Forecasting and Policymaking", Bank of Japan, April 2004, <http://www.e.u-tokyo.ac.jp/cirje/research/workshops/macro/macropaper04/kamada.pdf>.

Keating, J.W., and Nye, J.V., (1998), "Permanent and Transitory Shocks in Real Output: Estimates from Nineteenth-Century and Postwar Economies", *Journal of Money, Credit and Banking*, Vol.30, No.2.

Laxton, D. and Tetlow, R., (1992), "A Simple Multivariate Filter for the Measurement of Potential Output", *Bank of Canada Working Paper*, Technical Report No.59.

Mayer, T., (2005), "The ECB's Monetary Policy Strategy: Trying to Go Beyond Inflation Targeting", Deutsche Bank AG, November 2005,

<http://www.econ.ku.dk/epru/EPRUConference2005/Papers/TomMayer.Beyond_inflation_targeting.doc>

McMorrow, K. and Roeger, W., (2001), "Potential Output: Measurement Methods, New Economy Influences and Scenarios for 2001-2010: A Comparison of the EU15 and the US", *Economic Papers*, No. 150, Directorate-General for Economic and Financial Affairs (ECFIN) of the European Commission. April 2001.

Menashe, Y. and Yakhin, Y., (2004), "Mind the Gap: Structural and Nonstructural Approaches to Estimating Israel's Output Gap", *Israel Economic Review*, Vol.2, No.2.

Mitchell, J., (2005), "Should We Be Surprised by the Unreliability of Real-Time Output Gap Estimates?", Density Estimates for the Euro Area, National Institute of Economic and Social Research, January 2005, <http://www.niesr.ac.uk/pubs/dpsdp225.pdf#search=%22loss%20function%20potential%20output%20gap%22>.

Morling, S., (2002), "Output Adjustment in Development Countries: A Structural Var Approach", *Discussion Paper,* No.307, School of Economics, The University of Queensland, May 2002.

Nelson, E. and Nikolov, K., (2003), "UK Inflation in the 1970s and 1980s: The Role of Output Gap Mismeasurement", *Journal of Economics and Business* Vol.55.

Orphanides, A., (2001), "Monetary Policy Rules Based on Real-Time Data", *American Economic Review,* Vol.91, No.4.

Orphanides, O. and Van Norden, S., (2002), "The Unreliability of Output-Gap Estimates in Real Time", *The Review of Economics and Statistics*, Vol. LXXXIV, No.4.

Ozbek, L. and Ozlale, U., (2005), "Employing the Extended Kalman Filter in Measuring the Output Gap", *Journal of Economic Dynamics & Control*, Vol. 29.

Scott, A., (2000), "Stylised Facts from Output Gap Measures", *Discussion Paper Series*, DP2000/07, Reserve Bank of New Zealand, January 2000.

Plantier, LC, (2007) 'Comments and Suggestion of this Draft Report '

Svensson L.E.O., ' Inflation Targeting in an open Economy: Strict or Flexible Inflation Targetinf, Insititute for International Economic Studies, Stockholm University, <http://www.princeton.edu/svensson/papers/NZLECT.PDF>

Slevin, G., (2001), "Potential Output and the Output Gap in Ireland", *Technical Paper*, /Rt/01, Central Bank of Ireland, September 2001.

Smith, B. and Burrows, L.R., (2002), "Estimating Potential Output And Output Gaps for the South African Economy", *Stellenbosch Economic Working Papers*, University of Stellenbosch, May 2002.

Staiger, D., Stock, J. and Watson, M.W., (1996), "How Precise are Estimates of the Natural Rate of Unemployment", *NBER Working Paper,* No.5477, March 1996.

Van Norden, S., (1995), "Why is it So Hard to Measure the Current Output Gap?" Presented to the Canadian Economics Association, The Bank of England, The Federal Reserve Bank of Kansas City, and McGill University, June 1995.

Varelas, E., (2006), "Output Gap - Inflation: The Case of Greece (1858-1938)", *International Research Journal of Finance and Economics*, no.4.

Walsh, C., (2002), "Teaching Inflation Targeting: An Analysis for Intermediate Macro", *Journal of Economic Education*, Fall 2002.

Willman, A., (2002), "Euro Area Production Function and Potential Output: A Supply Side System Approach", *Working Paper,* No.153, European Central Banks, June 2002.

Woodford, M.,(2003), "Optimal Interest-Rate Smoothing", Review of Economic Studies, Vol. 70, No.4.

Yap, J.T., (2003), "The Output Gap and its Role in Inflation-Targeting in the Philippines", *Discussion Paper,* No. 2003-10, The Philippine Institute for Development Studies.