Parametric Estimation of Thailand’s Potential Output

By

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Abstract

This study estimates the difference between Potential Output and Actual Output during 1983-2000. The methods used are Non-accelerating Inflation Rate of Unemployment (NAIRU), Stochastic Frontier Production Function, Hodrick and Prescott Multivariate filter and Structural Vector Autoregressive Regression (SVAR). The study concludes that potential output calculated from NAIRU is more suitable for Thailand than other methods. Potential output in year 2000 grows 4.3 percent and output gap is around 7 percent of actual output. The findings do not fully accommodate changes in technology. Structural shift in 1997 makes measurement of TFP very difficult.

Keyword : Potential Output, Output Gap, Non-accelerating Inflation Rate of Unemployment (NAIRU), Stochastic Frontier Production Function, Hodrick and Prescott Multivariate filter, Structural Vector Autoregression(SVAR)

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1. Introduction

The Bank of Thailand has abandoned monetary aggregate targeting and adopted inflation targeting in May 2000 aiming at attaining sustained growth as well as price stability. The target is set to maintain core inflation within 0-3.5 percent. An econometric model is constructed to assist in assessing policy makers. The decision rule, for simplicity, is represented by a symmetric loss function,

\[ \min_r L = \sum_{i=1}^{8} \left[ a (\pi_i - \pi^*_i)^2 + \beta (y_i - y^*_i)^2 \right] \]  

(1)

where  
\( \pi_i \) observed inflation  
\( y_i \) forecast GDP  
\( \pi^*_i \) targeted inflation rate  
\( y^*_i \) potential output

In equation (1), \( r \) is the operating interest rate, 14 days repurchase rate, which is used to minimize loss over the next 8 quarters. Traditionally, when the output gap -difference between potential and actual output- narrows, demand for labor increases and has upward pressure on wages and inflation.

Currently, the Bank of Thailand model does not produce estimates of potential output. The model uses HP trend as a proxy of potential output; consequently, potential output can be said to be imposed on the model. The effect of output gap on core inflation is nearly negligible. Coe and Mcdemott (1996) also find that HP trend was insignificant for Thailand and China. The Bank of Thailand postulates that potential output grew by 5.5 percent annually through year 2002. This growth rate is also suggested by Barro and Xavier Sala-Martin (1995). We calculate potential GDP by various methods in order to be used in the loss function.


Potential output can be defined in several ways. Scacciavallini and Swagel (1999) classify potential output estimation into two groups.

a. Production function approach.

Potential output is defined as the maximum attainable output level. In other words, it is the level output received from fully utilize all production inputs. Chantanahom (1994) estimates potential output along this definition by stochastic frontier production function. Currently, potential output relies more on non-accelerating inflation rate of output (Nairu) approach which uses the natural rate of unemployment to determine potential output.
The quality of potential output estimations that are based on production functions are dependent on the quality of data. For Thailand, data on gross capital stocks and labor are inadequate. Therefore, we proxy labor series from the quarterly survey result by trend estimation and use quarterly investment data to construct gross capital stock.

b. Long-term growth trend.

This approach follows business cycle by decomposing series into long term trend and cyclical component. Estimations that follow this approach are latent variables and Structural Var (Svar). Potential output is determined by level of innovations, learning curves and the underlying economic structure. However, their non-linear estimation techniques makes it very difficult to implement them into an economic macro model.

2.1 Production Function

Consider an aggregate production function

\[ Y_t = F(K_t, L_t) \]  \hspace{1cm} \cdots (2)

where \( K_t \) = capital stock

\( L_t \) = labor used.

The capital stock in equation (2) should be utilized capital stock; amount of stock multiplied by utilization rate. Labor used should be expressed in labor-hour.

2.1.1 Maximum attainable output

Using a Cobb Douglas production function, equation (2) can be rewritten as,

\[ \ln Y_t = A + \beta_1 \ln K_t + \beta_2 \ln L_t + \nu_t \]  \hspace{1cm} \cdots (3)

where \( Y_t \) = output at constant price

\( K_t \) = net capital stock at constant price

\( L_t \) = employed persons in millions.

Equation (3) uses GDP at constant price for output. Usually, capital is not utilized at its maximum level or even at a constant rate. Rate of utilization tends to vary with output growth and new investment. Therefore, estimation equation (3) using net capital stock without adjusting for rate of utilization will make the residuals capture unobserved utilization rate.
The capital stocks of Thailand is only available in annual series. Consequently, we have to interpolate into quarterly data for data before 1999. For data after 1999, we use quarterly investment data to construct quarterly capital stocks.

We use number of employed persons as labor input as the data on hour work for Thailand is rather stable and only availed for formal market. Formal labor market work hour average is approximately constant during 1993 to 2000, ranging between 48 hours to 52 hours per week. When the GDP of Thailand declines by 10.8 percent in 1998, the minimum work hour is 48.4 per week in February survey. We also interpolate the labor data into quarterly because prior to 1998, employment survey is not conducted quarterly.

Estimating equation (3) using ordinary least squares (Ols), we have

\[
\ln(Y_t) = 2.906^{**} + 0.318^{**} \ln(K_t) + 0.238\ln(L_t) \\
\text{period: 1993-2000}
\]

\[
R^2 \text{ adjusted} = 0.4033 \quad D.W. = 0.5579 \quad F\text{-statistic} = 11.48
\]

In equation (4), we assume that capital is either fully utilized or is utilized at a constant rate. This can be acceptable when an economy is expanding at a constant rate. When there is structural break in the growth pattern, such an assumption will not hold. Klein(1999) states two problems in measuring fixed capital. First, capital stock data do not reflect utilization and they do not account for change in technology which improves the quality of capital as well as lowers the price. Second, capital is not always fully utilized. Potential output should be treated as maximum output level when all resources are used at their potential — fully utilized capital and full employment.


We impose a utilization rate to equation (2) in order to reflect changes in utilization of capital which is a very important factor particularly during recession,

\[
Y_t = A(F(K_t, L_t)) \cdot U_t \\
\text{where} \quad A \text{ is a scale factor} \\
U_t \text{ is the overall utilization.}
\]
If all inputs are fully utilized, $U_i$ is equal to 1. However, $U_i$ is not observed and must be estimated. Utilization rate also performs as a transmission from production which is defined in unit of output into value added measure or GDP. Traditionally, the variables that are used to link output into value added are energy consumption and imports of raw material.

Equation (5) can be written in Cobb Douglas production function as,

$$\ln Y_i = A + \beta_1 \ln K_{i1} + \beta_2 \ln L_{i1} + \beta_3 \ln U_i + \epsilon_i \quad \cdots (6)$$

Nevertheless, equation (5) does not account for changes in technology.

We discover that the number of employed persons in equation (4) is in appropriate. During recession, 1998 – 1999, underemployed persons who worked less than 35 hours per week and willing to work more, increases significantly. Thailand underemployed normally fluctuates around 2 percent of total labor. The ratio averages 3-4 percent during recession and peaks at 5 percent in the 4th quarter of 1998. Underemployment also has strong season pattern due to the dominant of agricultural sector. Consequently, we redefined employed labor as employed persons minus under employment to reflect labor that does not have strong constraint in their work hour (LF, fully employed labor).

We specify equation (6) under homogeneous function and let LF adjust to utilization rate in capital stocks,

$$\ln Y_i = \alpha_1 + \alpha_2 \ln(K_{i1} \times KU_i) + \alpha_3 \ln LF_i + \epsilon_i \quad \cdots (7)$$

where $KU_i$ is capital utilization and $LF_i$ fully employed labor.

Capital utilization rate, $KU_i$ is non directly observable. We use manufacturing capacity utilization rate (CU) which is constructed by the Bank of Thailand to replace $KU_i$. The proportion of manufacturing capital stocks to total capital stocks for the past decade is between 15-17 percent.

We assume that $KU_i$ is proportional to $CU_i$, that is

$$KU_i = \gamma CU_i \quad \cdots (8)$$

Substitute equation (8) into equation (7), we get

$$\ln Y_i = A + \alpha_2 \ln(K_{i1} \times CU_i) + \alpha_3 \ln LF_i + \epsilon_i \quad \cdots (9)$$

where $A = \alpha_1 + \alpha_2 \ln \gamma$ and $CU_i$ is manufacturing utilization rate.
The result is,

\[
\ln Y_t = 1.333 + 0.694^{**} \ln (K_t \times CU_t) - 0.207 \ln LF_t
\]

\[
(1.78) \quad (8.06) \quad (-0.99)
\]

** significant at 1 percent

\[
R^2 \text{ adjusted} = 0.7011 \quad D.W. = 0.774 \quad F- \text{Statistics} = 37.36
\]

The adjusted $R^2$ is higher than that of equation (4). However, the coefficient of LF has a negative sign which might have been caused by multicollinearity. That is, LF is determined by the capacity adjusted capital stocks ($K^*CU$). Kilen (1999) suggests constant return to scale production function to reduce multicollinearity among regressors.

Based on Chow’s test, there is a significant structural shift of the production function in 1997. Furthermore, LF has a strong seasonal pattern in the second and third quarter when new graduates enter the market as well as being harvesting season. Therefore, two dummy variables are added.

\[
\ln Y_t = 0.016 + 0.612^{**} \ln (K_t \times CU_t) + (1 - 0.612)^{**} \ln LF_t + 0.040^{**} \cdot D97
\]

\[
- 0.047^{**} \cdot DQ23
\]

\[
(0.04) \quad (7.83) \quad (7.83) \quad (-3.35)
\]

* significant at 10 % ** significant at 1 %

\[
R^2 \text{ adjusted} = 0.7621 \quad D.W. = 1.148 \quad F-\text{Statistics} = 34.10
\]

Equation (11) produces better result than equation (10). The intercept or technology coefficient is insignificant.

If we estimate $CU$ independently from $K$, equation (9) becomes

\[
\ln Y_t = \alpha_1 + \alpha_2 \ln K_t + (1 - \alpha_2) \ln LF_t + \alpha_3 \ln CU_t + \alpha_4 D97 + \alpha_5 DQ23 + e_t
\]

and the estimation result is

\[
\ln Y_t = -0.851^{**} + 0.759^{**} \ln K_t + (1 - 0.759)^{**} \ln LF_t + 0.369^{**} \ln CU_t
\]

\[
- 0.059^{*} \cdot D97 - 0.046^{**} \cdot DQ23
\]

\[
(-2.49) \quad (11.88) \quad (11.88) \quad (4.95) \quad (-2.68) \quad (-4.50)
\]

* significant at 10 % ** significant at 1 %

\[
R^2 \text{ adjusted} = 0.8736 \quad D.W. = 1.208 \quad F-\text{Statistics} = 54.53
\]
Equation (13) improves on equation (11). We suggest that capacity utilization rate should be treated as the average utilization rate of all inputs not of a particular input. We obtain maximum attainable level of output by using \( CU \) equals to one. For Thailand, however, some industries temporarily have utilization rate more than one; pulp, paper products, construction material, petroleum, beverages and integrated circuits. The result is presented in Figure(1). Producers keep excess capacity to meet positive shocks in demand.

![Figure(1) Maximum output from Production Function Approach](image)

Potential output defined as maximum output grows around 0.6 percent during 1997-98. Before the crisis, the average growth is 8.6 percent. The difference comes from slowdown in stock accumulation. Our conclusion is contingent on the suitability of capacity utilization of manufacturing sector (CU) as an approximation to the overall utilization rate (KU).

2.1.2 Non accelerating inflation rate of unemployment (Nairu).

In order to find Nairu, we have to establish a Phillips curve - inflation and unemployment are related in the short run. When unemployment is too low, wages will adjust upward to clear the labor market and raise inflation. Lipsey(1960), Phillips(1985), Coe(1985,1988) and Grubb(1986) find the trade off between inflation and unemployment can be non linear. Nickell(1987), Layard, Nickell and Jackman(1991) and Clark and Laxton(1997) find non linear relationship between inflation, real wage and unemployment.
Following Clark and Laxton(1997) and Gruen, Pagan and Thompson(1999), we specify a Phillips curve as

\[ \pi_t = \pi_t^e + F(\text{NAIRU}_t - u_t) \]  \hspace{1cm} \text{...(14)}

Where \( \pi_t \) is inflation rate and \( \pi_t^e \) is expected inflation. \( F(\text{NAIRU}_t - u_t) \) is a function representing imbalances in output measures as difference of Nairu and actual unemployment. Figure(2) we plot unemployment against inflation during 1973 to 2000. Roughly, we can classify the relationship into two periods pre and post 1981. Post 1981 is influenced by series of shocks in oil prices.

![Figure(2) Unemployment and Inflation](image)

Figure (3) shows the relationship between inflation and LF (fully employed labor) to conform with our estimation functions. There is strong evidence of a structural shift of the pattern between 1997:q4 to 1999:q1, the early part of the crisis.

Inflation expectation in equation(14) is formed by a distributed lags function with lag length equal 2 (Akaike criteria). Therefore, the expectation process is backward looking. Equation(14) can be written as,

\[ \pi_t = \alpha \pi_{t-1} + (1-\alpha)\pi_{t-2} + \gamma(\text{NAIRU}_t - u_t) \]  \hspace{1cm} \text{...(15)}
Suppose that Nairu is fixed which conforms with the concept of natural rate of unemployment, equation(15) becomes, where u_t is total labor force minus LF,

$$\pi_t = \gamma A + \alpha \pi_{t-1} + (1 - \alpha) \pi_{t-2} - \gamma u_t$$  \hspace{1cm} \text{(16)}$

The estimation result is,

$$\pi_t = (0.121)_{(3.74)} + 1.537_{(10.54)}^{**} \pi_{t-1} + (0 - 1.537)^{**} \pi_{t-2} - 0.121 u_{t1}$$  \hspace{1cm} \text{(17)}$

* significant at 10%  ** significant at 1%

$R^2$ adjusted = 0.8548  D.W. = 1.55  F-stat = 92.27

The coefficient $\gamma$ is insignificant. This is can be caused by omitting key variables affecting inflation. Therefore, we include price of imports into equation(16),

$$\pi_t = \gamma A + \alpha \pi_{t-1} + (1 - \alpha) \pi_{t-2} - \gamma u_t + \beta p_m$$  \hspace{1cm} \text{(18)}$

where $p_m$ is the changes in price of imports express in local currency.
The estimation result is,  
\[
\pi_t = (0.147)^* (3.45)^* + 1.192 ?>< (1 - 1.192) \pi_{t-1} + 0.147^* \pi_{t-2} - 0.147^* u_{lt} + 0.033^* \pi_{lt} \quad \cdots (19)
\]

* significant at 10 %  ** significant at 1 %

$R^2$ adjusted = 0.877  DW = 1.25  F-stat = 73.78

All the coefficients are statistically significant. From equation(15), constant Nairu is simply $\gamma A$.

For the period 1993 to 2000, Nairu is 3.4 percent. If we split the sample into 1993-1996 and 1997-2000, Nairus are 4.9 and 4.4 percent, respectively. Consequently, we conclude that the concept of constant Nairu is not applicable for Thailand. The obvious reason is changes in employment pattern and need further micro level analysis which is not the scope of this study.

As a consequence, we use a time varying parameter model via Kalman filter to find Nairu. From equation(14), we specify a relationship of unemployment as,

\[
F(\text{NAIRU}_t - u_t) = \gamma (\text{NAIRU}_t - u_t) / (u_{lt} - \phi) \quad \cdots (20)
\]

$\gamma$ is the parameter measuring the degree of convexity and $\phi$ is the absolute minimum unemployment. However, estimating $\phi$ is not straight forward and is unobservable as policy makers avoid arriving at $\phi$. Given $\phi = 0$, a non linear Phillips curve is

\[
\pi_t = A(L)\pi_t + \gamma (\text{NAIRU}_t - u_{lt}) / u_{lt} + \varepsilon_t^2 \quad \cdots (21)
\]

Let $Z_t = \gamma \text{NAIRU}$, then equation(21) can be rewritten in a time varying constant term as,

\[
\pi_t = -\gamma + A(L)\pi_t + Z_t^{*} u_{lt}^{-1} + \varepsilon_t^2 \quad \cdots (22)
\]

and $Z^{*}_t$ is a random walk with error term $\nu_t \sim N(0, \sigma^2)$.

\[
Z^{*}_t = Z^{*}_{t-1} + \nu_t \quad \cdots (23)
\]

It is very unlikely that $Z^{*}_t$ is a random walk. However, other form of distribution will give too strong a priori condition.
We estimate the residuals of equation (21) by assuming that expected inflation takes a form of polynomial lag. Thus,

\[ \hat{\varepsilon}_t = \pi_t - \Lambda(L)\pi_t \]
\[ = \hat{\varepsilon}_t^\pi + Z_t^\pi / u_t - \gamma \]

\[ \cdots (24) \]

Using polynomial lag order 3 and 4 lags with far end constraint, we obtain the result

\[ \pi_t = 1.434^{*}\pi_{t-1} - 0.225^{*}\pi_{t-2} - 0.490^{*}\pi_{t-3} - 0.069^{*}\pi_{t-4} + 0.33^{*}\pi_{t-5}, \cdots (25) \]

* significant at 10 %  ** significant at 1 %

\[ R^2 = 0.9038 \quad \text{Adjusted } R^2 = 0.8972 \]

Substituting the residuals of equation (24) into equation (23), and use Kalman filter with noise to signal ratio equal to 0.3, we get

\[ \hat{\varepsilon}_t = -0.714^{*} + Z_t^\pi / u_t + \hat{\varepsilon}_t^\pi \]
\[ Z_t^\pi = Z_{t-1}^\pi + \nu_t \]

\[ \cdots (26) \]

The variance of \( \hat{\varepsilon}_t \) equals 0.584.

* significant at 10 %  ** significant at 1 %

From equation (26), \( \text{Nairu} = Z_t^{\hat{\gamma}} \)

Figure (4) Nairu, Unemployment and Inflation

Unemployment (dashed) Nairu (solid) Inflation (solid & symbols)
In figure(4), during 1993 to 1998, the unemployment is below the appropriate level (Nairu) and causes inflationary pressure. During 1993 and 1994, Nairu is high averaging 7-11 percent of total labor force which is caused by tight labor market condition.

Using equation(7). we estimate potential output by obtaining employed person \( (LF^*) \) from calculated Nairu. \( LF^* \) is defined as

\[
LF^*_i = L_i - Unemp^*_i
\]  

\[\text{...(27)}\]

where \( LF^*_i \) is employed person corresponding to Nairu  
\( L_i \) is total labor force  
\( Unemp^*_i \) is unemployed person.

We then approximate capital stocks adjusted for utilization rate that corresponds with Nairu \( (KU^*_i) \) by

\[
KU^*_i = (100 - NAIRU_i)/(100 - u_{11})
\]

\[\text{...(28)}\]

\( KU \) is obtained by using equation(8) by estimating the relation \( CU_i \). Consequently, \( KF^*_i \) is

\[
KF^*_i = K_i * KU^*_i
\]

\[\text{...(29)}\]

To obtain potential output we substitute \( KF^*_i \) and \( LF^*_i \) in equation(13) and excluding the dummy variables for structural changes and seasonal pattern as they are reflected by the Nairu series. The result is presented in figure(5).

Figure(5) Potential Output from Nairu
2.2 Frontier Production Function

Maximum output of any production unit is defined as
\[ y_t = \max( f( k_t, l_t) ) \]  \hspace{1cm} (30)

Aggregating the production function(30) of all production unit, we will have

\[ Y_t = \max( F(K_t, L_t) ) \]  \hspace{1cm} (31)

Assuming that the functions are summable.

Equation(31) represents the maximum output level attainable. If there is no measurement error and all variables are accounted for, production cannot be more than what is specified by the production function. Chantanahom(1994) use the production function

\[ \ln Y_t = \alpha_1 + \alpha_2 \ln K_t + \alpha_3 \ln L_t + v_t - w_t \]  \hspace{1cm} (32)

where \( v \) is a random variable of statistical error and has the distribution \( v \sim (0, \sigma_v^2) \) and \( w \) is a random variable of outside factors that prevent production to reach its maximum as specified in equation(30) and \( w \) has a truncated normal distribution \( \sim (\mu_w, \sigma_w^2, \Omega_w) \).

In order to account for utilization rate of capital, equation(32) is rewritten as,

\[ \ln Y_t = \alpha_1 + \alpha_2 \ln K_t \cdot CU + \alpha_3 \ln L_t + v_t - w_t \]  \hspace{1cm} (33)

Let \( e \) equal to \( v-w \). Therefore, the probability density function of \( e \) is

\[ f(e_t) = (2/\sigma) \cdot f^* (e_t / \sigma) \cdot [1-F^* (e_t, \lambda, / \sigma)] \]  \hspace{1cm} (34)

where \( \sigma^2 = \sigma_v^2 + \sigma_w^2 \) and \( \lambda = \sigma_v / \sigma_w \) and \( f^* \) and \( F^* \) are normal Pdf and normal Cdf, respectively. Its log likelihood function gives,

\[ E(u_t | e_t) = \sigma \left[ \frac{f^* (.)}{(1-F^* (.) - (.)} \right] \]  \hspace{1cm} (35)

where \( (.) = \sigma (e_t, \lambda, / \sigma) \) and \( \sigma^2 = \sigma_v^2 / \sigma^2 \)

We estimate stochastic frontier production from equation(33) with and without imposing homogeneity of degree 1 constraint. In addition, we also test the validity of using CU in the equation by restricting it to zero. Ordinary least squares estimates are used as the starting values then we use Davidon, Fletcher and Powell and Newton Raphson with half step length. The result is
Table 1: Stochastic frontier estimation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Homogenous</th>
<th>Homogenous-CU</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-0.647*</td>
<td>0.705*</td>
</tr>
<tr>
<td>K</td>
<td>0.726*</td>
<td>0.462*</td>
</tr>
<tr>
<td>L</td>
<td>0.274*</td>
<td>0.538*</td>
</tr>
<tr>
<td>CU</td>
<td>0.349*</td>
<td></td>
</tr>
<tr>
<td>D97</td>
<td>-0.061*</td>
<td>-0.075*</td>
</tr>
<tr>
<td>D23</td>
<td>-0.041*</td>
<td>-0.047*</td>
</tr>
<tr>
<td>\lambda</td>
<td>3.846*</td>
<td>3.103*</td>
</tr>
</tbody>
</table>

*significant 10%

In Figure (6), we compare the estimated output gap from the two equations. Both specifications give very similar results. However, restricting CU to be zero gives output gap with smaller variation. We select the estimation excluding as CU (capacity utilization rate of manufacturing sector) may not fully reflect the overall capacity.

Figure (6) Output gap of Stochastic Frontier Production Function

With CU (dashed) Without CU (solid)
2.3 Hodrick-Prescott (HP) multivariate filter

HP filter is a mathematical solution to find the least fluctuate long term growth path. The IMF extensively uses HP filter to obtain potential output or medium term growth. HP filter has certain limitations. First, the trend has no linkage with economic theory. Second, the trend towards the end changes when new observations are added. This is because HP filter is symmetric.

Let \( Y^* \) be the HP trend of output. The idea is to find a trend that minimizes the growth pattern. In other words,

\[
\min_Y \left\{ \sum_{t=1}^{T} (\ln Y_t - \ln Y_t^*)^2 + \lambda \sum_{t=2}^{T-1} \left[ (\ln Y_{t+1}^* - \ln Y_t^*) - (\ln Y_t^* - \ln Y_{t-1}^*) \right]^2 \right\} \quad \cdots (36)
\]

The parameter \( \lambda \) determines the degree of similarity between the trend and actual values. Laxton and Tetlow (1992) modify HP trend by including inflation into the minimization problem. Output trend, or potential output, will also be determined by inflation and other exogenous variables.

\[
\pi_t = A(L)\pi_{t-1} + B(L)Z_t + C(L)(Y_{t-1} - Y_{t-1}^*) + \varepsilon_t \quad \cdots (37)
\]

where \( \pi \) is inflation and

\( Z \) is a matrix of exogenous variables.

The minimize problem becomes,

\[
\min_Y \left\{ \sum_{t=1}^{T} \alpha_t (\ln Y_t - \ln Y_t^*)^2 + \sum_{t=1}^{T} \beta_t \varepsilon_t^2 + \lambda \sum_{t=2}^{T-1} \left[ (\ln Y_{t+1}^* - \ln Y_t^*) - (\ln Y_t^* - \ln Y_{t-1}^*) \right]^2 \right\} \quad \cdots (38)
\]

where \( \alpha \) and \( \beta \) are relative weights for inflation and output, respectively.

Estimation procedure starts with coming up with error terms of inflation and potential output estimates. We use ordinary HP trend and substitute it into equation(37). The residuals is then use in minimization of equation(38). We then obtain an initial estimate of multivariate HP filter. We repeat the procedure by using multivariate HP filter instead of ordinary HP.
The estimation result of equation (37) for the period 1984 – 2000, as some observations are lost in the estimation procedure, is

\[
\pi_t = 0.782_{(10.49)} \pi_{t-1} + 0.028(\hat{Y}_{t-1} - \hat{Y}_{t-1}^*) + 0.145_{(0.56)} (\hat{Y}_{t-2} - \hat{Y}_{t-2}^*) + 0.145_{(2.81)} (\hat{Y}_{t-2} - \hat{Y}_{t-2}^*) \quad \cdots(39)
\]

**1% significant level

\[R^2 = 0.932, \quad R^2 \text{ adj.} = 0.920, \quad DW = 1.732, \quad F\text{-stat} = 81.72, \quad Q\text{-stat}(1) = 0.362\]

where \(\pi\) is inflation

\(\hat{Y}_{t}^*\) is HP multivariate potential output

and \(\hat{Y}_t\) is GDP; output is expressed in log term.

Apart from determining the parameter \(\lambda\), as in ordinary HP trend, we have to determine the weights assigned to output and inflation, \(\alpha\) and \(\beta\), respectively. The greater the value of \(\alpha\) relative to \(\beta\), the more HP multivariate filter will resemble ordinary HP trend, and vice versa. We set both parameters to one.

The result is presented in figure (7).

![Figure(7) Potential Output from HP Multivariate](image-url)
There are several choices of measuring price effects in HP multivariate. We use inflation rate (INF), percentage change of CPI from the same period last year, and percentage change of CPI from last quarter (CPI). HP multivariate using INF, GDP-INF, is below actual output since the third quarter of 1999 showing a deterioration of production. The output gap usually is positive. When quarterly growth of CPI is used, the output gap GDP-CPI diverges from the previous method starting from the 4th quarter of 1998. The second method produces smaller output gap than the first one. We use GDP-INF as an estimate of potential output since the Bank of Thailand uses year on year growth rate of CPI as its policy variable.

2.4 Structural VAR (SVAR)

We also use SVAR in our estimation of potential output. In brief, VAR (vector autoregression) has been criticized that being a system of reduced form equations, its interpretation is dependent on the researcher which may not be necessary based on economic foundations. Amisano and Gianni(1997) suggest that by imposing valid restrictions to VAR, we can establish meaningful relationships between the residuals and other observable variables. Without the ability to recover structural forms from reduced form equations, the direct interpretations of the innovations from the model is not possible.

Our study is developed along the line of Blanchard and Quah(1989). Output is affected by both demand and supply disturbances. Output is unaffected in the long run by demand disturbances based on natural rate of unemployment hypothesis. On the contrary, supply disturbances are regarded as productivity shocks and will affect output in the long run. We follow Blanchard and Quah’s argument and define potential output as GDP that excludes the affect of demand disturbances.

We apply an autoregressive system with two variables in order to identify the source of output variation. Assuming that $\Delta Y$ and $u$ are stochastic stationary processes where $Y$ is output and $u$ is unemployment, normal unemployment plus under employment. They are affected by supply disturbances, $e_s$, and demand disturbances, $e_d$ which are both assumed to be independent.

$$\Delta Y = e_d(t) - e_d(t - 1) + \alpha(e_s(t) - e_s(t - 1)) + e_s(t) \quad \cdots(41)$$

$$u = -e_d(t) - \alpha e_s(t) \quad \cdots(42)$$

Demand disturbances affect output and unemployment only temporarily until prices are adjusted. Supply disturbances such as production innovations affect output in the long run. However, long run or natural rate of unemployment is unaffected by both demand and supply disturbances.

We follow Blanchard and Quah(1989) but using the specification stated in Amisano and Giannini(1997).
The model of Blanchard and Quah(1989) is presented as an A-B model. Let A and B be n x n matrices,

\[ AA(L)^{\gamma} = Ae_t \]  
\[ A(e_t) = Be_t \]  \hspace{1cm} (43) \hspace{1cm} (44)

where \( e_t \) is a vector of white noise \( \sim (\mathbb{0}, \Sigma^2) \) and \( e_t \sim (\mathbb{0}, I_r) \).

We determine the appropriate lag length by Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The lag used is 5 quarters.

![Figure 8 Structural VAR Potential Output](image)

3. Comparison of various measures of output gap

In this study, we have constructed output gap based on 4 approaches; namely, ordinary least squares, frontier production function, HP multivariate filter and structural Var. Each approach can be summarized as follows:

1. Ordinary least squares. Estimation is contingent upon the characteristics of residuals. Results can be improved by linking the appropriate level of output to macro variables like capacity utilization and Nairu.
2. Stochastic frontier production function (Sfp). Based on a production function, this approach takes a non linear approach to explaining the residuals. Output is then imposed not to exceed what is obtained from production function.

3. Multivariate filter (HPM). A long term trend that takes inflation variation into account is calculated. One advantage is that only output and price data are needed. Therefore, it tends to have limited link to economic theory.

4. SVAR. Disturbances of the system are being labeled demand and supply driven. Only supply disturbances have long run effects on output. SVAR can be related to business cycles. However, if the data series are limited or have possible structural breaks, conclusions may changed as data points are increased.

We compare these four findings by 1) their ability to explain inflation and 2) their loss functions.

3.1 Inflation Equation.

We postulate that output gap should reasonable explain inflation. In figure(9), we compare the output gaps obtained from the methods considered in our study.

Figure(9) Comparison of Output Gap
From figure(9), we can rule out the output gap from HP multivariate filter which indicates negative output gap in year 2000. Towards the end of 2000, Thailand still faces high unemployment and manufacturing capacity utilization is low.

In table(3), we fit an ordinary least squares and a polynomial lag relationship to inflation and output gap.

Table 3 Inflation and output gap relationship

\[ \pi = a_0 + a_1 \pi(-1) + a_2 \pi(-2) + b((y^* - y) / y) \]

<table>
<thead>
<tr>
<th>variable</th>
<th>y-NAIRU</th>
<th>y-SFP</th>
<th>y-HPM</th>
<th>y-SVAR</th>
</tr>
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<tbody>
<tr>
<td>( \pi (-1) )</td>
<td>1.183**</td>
<td>0.931*</td>
<td>0.288</td>
<td>0.859**</td>
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<tr>
<td>( \pi (-2) )</td>
<td>1.443**</td>
<td>1.520**</td>
<td>1.519*</td>
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<tr>
<td>y-gap</td>
<td>-0.047*</td>
<td>-0.030*</td>
<td>-0.066*</td>
<td>-0.066</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.9075</td>
<td>0.8969</td>
<td>0.9190</td>
<td>0.9176</td>
</tr>
</tbody>
</table>

\[ \pi = A(\pi) + b((y^* - y) / y) \]  
A(\pi) is polynomial lags  lags=4 order=3 and end point restriction

<table>
<thead>
<tr>
<th>variable</th>
<th>y-NAIRU</th>
<th>y-SFP</th>
<th>y-HPM</th>
<th>y-SVAR</th>
</tr>
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<tbody>
<tr>
<td>( \pi (-1) )</td>
<td>1.435**</td>
<td>1.428**</td>
<td>1.350**</td>
<td>1.439*</td>
</tr>
<tr>
<td>( \pi (-2) )</td>
<td>-0.247*</td>
<td>-0.222*</td>
<td>-0.165*</td>
<td>-0.233**</td>
</tr>
<tr>
<td>( \pi (-3) )</td>
<td>-0.489**</td>
<td>-0.485**</td>
<td>-0.440*</td>
<td>-0.498**</td>
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<tr>
<td>( \pi (-4) )</td>
<td>-0.034*</td>
<td>-0.066*</td>
<td>-0.092**</td>
<td>-0.072**</td>
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<td>( \pi (-5) )</td>
<td>0.376*</td>
<td>0.331**</td>
<td>0.261**</td>
<td>-0.332**</td>
</tr>
<tr>
<td>y-GAP</td>
<td>-0.057*</td>
<td>-0.024</td>
<td>-0.060*</td>
<td>-0.064</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.9256</td>
<td>0.9100</td>
<td>0.9301</td>
<td>0.9311</td>
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<tr>
<td>Sum ( \pi )</td>
<td>1.042</td>
<td>0.986**</td>
<td>0.914**</td>
<td>0.967**</td>
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</table>

* significant at 10%
** significant at 1%

From table(3), ordinary least squares gives the best result for HP multivariate, judging on its \( R^2 \).
The coefficients on inflation are similar for every definitions while those of output gap ranges between -0.047 to -0.066. Consequently, we conclude that only SVAR does not adequately explain the inflation and output gap relationship.

Polynomials gives the best result for SVAR. However, its coefficient on output gap is insignificant. Only HP multivariate and Nairu have coefficients on output gap that are significant with values between -0.057 to -0.06. Output gap from Sfp gives low coefficient for output gap for Ols and polynomials. Therefore, we conclude that output gap from Nairu specification best fit inflation relationship. This is not surprising as by construction inflation is included in Nairu. However, other
methods also provide good comparisons. Output gap from Svar and Sfp can be used to confirm the results.

Figure(10), compares the growth rate of potential output from Nairu and actual output. If potential output calculated from Nairu is used as potential output, we find negative potential growth for the later half of year 2000 and expanding −4.3 percent for the whole year. For an economy that has a positive growth of labor this is very controversial even when there is no growth in capital or tfp. All of the potential output presented in this study are medium term ones not a long term growth which rely on resource accumulation and tfp. Potential means “the level of output that is appropriate to the economic conditions”.

Figure10  Actual GDP growth and Potential Output growth

3.2 Loss Function

Testing methodology by using inflation equation does not mean that output gap that can best explain inflation is the most appropriate one. As discussed in section(3.1), all approaches taken produce results that are basically similar. Furthermore, Nairu and HP Multivariate use inflation in their construction.
We use the following loss function,

$$L_t = \sum_{j=0}^{1} \rho^j \left[ \left( \frac{y^p - y}{y} \right)_{t+j} \right]^2 \cdot W + (p - \bar{p})_{t+j}^2 \right]$$

... (45)

where $W$ is the weight assigned to output gap.

The parameter $0 < \rho \leq 1$ is preference parameter assigning more preference to the current period more than the distant future. For $\rho=1$, the loss function will be unbounded. We use in sample observations of GDP and inflation in our loss function. However, in policy decisions, we ought to use forecasted values. We use the value of $W$ from 0.5 to 1 and $\rho$ from 0 to 1. We find that the loss of Nairu is similar to HP multivariate and that of Sfp is similar to SVAR.

Figure 11 Loss values from output gap obtained from Nairu.
We compare the loss from potential output of Nairu and Svar. The loss from Nairu potential output exceeds that of Svar for the range studied.


We have explored various methods in estimating potential output to use in monetary policy guidelines. Production function when correctly specified gives the maximum level of output attainable which can be estimated by including utilization rate or via stochastic frontier production function. Nevertheless, this definition of potential output is not appropriate to be use for policy makers. Therefore, we use another definition of potential output which is derived from Nairu which performs relatively better than its competitors including Svar and HP multivariate.

Potential output from Nairu has certain limitations. We apply Nairu in a macro framework; as a consequence, a common structure of labor market is imposed. Furthermore, the literature on Thailand labor market by sector in quantitative is and we do not discussed changes in total factor productivity.
Appendix

Productivity Estimation.

Effective management, increase in the quality of capital and labour can produce more output than that is expected from production function. Traditionally, productivity is measured from growth accounting approach, Tinakorn and Sussangkarn (1998) and Sithikul (2001), and from production function. We use a production function approach specified as,

\[ y_t = K_t^\alpha (L_t)^{1-\alpha} e^{Z_t} \]  \hspace{1cm} (A.1)

where \( Z_t \) is productivity shocks described as,

\[ Z_t = \rho Z_{t-1} + e_t \]  \hspace{1cm} (A.2)

where \( 0 < \rho \leq 1 \) and \( e_t \) has zero mean and variance \( \sigma_e^2 \).

From equation (13),

\[ \ln y_t = \alpha_1 + \alpha_2 \ln K_t + (1 - \alpha_2) \ln L_t + \alpha_3 \gamma \ln c_i + \alpha_4 D97 + \alpha_4 DQ23 + e_t \]  \hspace{1cm} (13)

We can write equation (A.1) as,

\[ \ln Y_t = \alpha_1 + \alpha_2 \ln K_t + (1 - \alpha_2) \ln L_t + \alpha_3 \gamma \ln c_i + \alpha_4 D97 + \alpha_4 DQ23Z_t + e_t \]  \hspace{1cm} (A.3.1)

\[ Z_t = \rho Z_{t-1} + e_t \]  \hspace{1cm} (A.3.2)

We estimate equations (A.3.1) - (2) by Kaiman’s filter with starting values of \( Z \) between 0 – 0.05 and \( \sigma_e^2 = 0.6 \sigma_e^2 \).

\[ \ln Y_t = -1.492 + 0.869 \ln K_t + (1 - 0.869) \ln L_t + 0.33 \ln c_i - 0.06 D97 - 0.04 DQ23 + Z_t \]  
\[ (60.7) \hspace{1cm} (109) \hspace{1cm} (6.1) \hspace{1cm} (5.3) \hspace{1cm} (9.2) \]

\[ Z_t = 0.843 Z_{t-1} \]  
\[ (27.7) \]

(A.4)

The value \( e_t^2 \) reflects the proportion of output that is unexpected from the production function which according to Walsh’s (1998, p. 69) terminology is productivity shock.
Figure A1 Productivity shocks

Figure A1 represents the case which productivity shocks cannot be assigned to a factor. Nevertheless, productivity can be associated to a factor of production (technical augmented). If we assume that productivity is attached to labor (labor augmented), increase in capital, for instance, leads to more labor output holding usage of labor constant. We rewrite the production function as,

$$ y_t = K_t^\alpha (Z_t L_t)^{1-\alpha} $$

(A.5)

$Z_t$ is defined earlier. The value $L_t Z_t$ is efficiency unit of labor. One benefit of using labor augmented is that it has strong tendency to approach steady state. Estimation results of equation(A5) is,

$$ \ln y_t = -0.929 + 0.771 \ln K_t + (1-0.771) \ln L_t + 0.349 \ln c_t - 0.062 \text{D}97 - 0.046 \text{D}23 + Z_t $$

(31.2) (87.6)  (5.7)  (4.3)  (5.4)

$$ Z_t = 0.773 Z_{t-1} $$

(1.9)  (A.6)
Figure A2 Labor Augmented Productivity
Table A.

Actual output and estimated potential output from various methods.

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>MOL</th>
<th>NAIRU</th>
<th>SPF+CU</th>
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References


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