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GRADUATE INSTITUTE OF INTERNATIONAL
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Graduate Institute of
International and Development Studies Working Paper
No: 05/2014

Estimating the Output Gap to Support the Management of Interest Rates in Vietnam

Giang Huong Nguyen
The State Bank of Vietnam

Completed under the Bilateral Assistance and
Capacity Building for Central Banks - Graduate
Institute and SECO

Abstract

In this paper, I apply three methods to estimate the output gap for Vietnam to support the conduct of monetary policy of the State Bank: the Hodrick-Prescott Filter, the production function approach and Bayesian estimation. I then compare the results obtained from these approaches and discuss their advantages and disadvantages to choose the optimal method for the estimation of the output gap for the State Bank of Vietnam. For the Bayesian approach, my paper closedly relies on the paper of Tim Willems (2011) with some modifications to fit the situation of Vietnam. The output gap estimated by Bayesian method appears to be the most consistent with the economic developments of Vietnam.

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INSTITUT DE HAUTES ÉTUDES INTERNATIONALES ET DU DÉVELOPPEMENT

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BCC RESEARCH PROJECT

(FOR VISITING PROGRAM)

2013

"ESTIMATING THE OUTPUT GAP TO SUPPORT THE MANAGEMENT OF INTEREST RATES IN VIETNAM"

By GIANG HUONG NGUYEN

The State Bank of Vietnam

BCC Bilateral Assistance & Capacity Building for Central Banks

This research project was completed under the BCC programme, which is funded by the Swiss State Secretariat for Economic Affairs (SECO) and implemented by The Graduate Institute, Geneva.

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Abstract[1]

In this paper, I apply three methods to estimate the output gap for Vietnam to support the conduct of monetary policy of the State Bank: the Hodrick-Prescott Filter, the production function approach and Bayesian estimation. I then compare the results obtained from these approaches and discuss their advantages and disadvantages to choose the optimal method for the estimation of the output gap for the State Bank of Vietnam. For the Bayesian approach, my paper closedly relies on the paper of Tim Willems (2011) with some modifications to fit the situation of Vietnam. The output gap estimated by Bayesian method appears to be the most consistent with the economic developments of Vietnam.

1. INTRODUCTION

The main objective of this paper is to compare three different econometric methods – the Hodrick-Prescott Filter, the production function approach and Bayesian methods -- to estimate the output gap and to choose the appropriate estimation method for Vietnam based on its economic characteristics and the availability of data. The underlying motivation of this exerise is to support the management of interest rates of the State Bank of Vietnam in the near future since it will adopt a more flexible inflation targetting regime.

The output gap is the difference between actual output and potential output. Potential output is considered the output or the total gross domestic product (GDP) that could be produced by an economy if all its resources were fully employed. From a policy perspective, the output gap plays a prominent role in both monetary and fiscal policy. For monetary policy, the analysis of output gaps would be more useful considering the setup of monetary policy decision making.

Especially, for countries currently operating monetary policy under the framework of inflation targeting, the central banks tend to rely on the output gap to make their decisions on interest rates based on their inflation target. Since estimates of the output gap provide information on future inflation trends, monetary policy should respond to developments in the output gap independently of whether output stabilization is a first order objective or not. This role of the output gap has been encapsulated most prominently in the various versions of the Taylor rule for setting policy controlled interest rates. To determine appropriate policy interest rates, policy-makers often use the estimated output gap and their inflation target via Taylor's rule which is a function of real interest rates, inflation and output gap.

In Vietnam, the operating mechanism of interest rate has changed over the past. The interest rate has become an important economic indicator on financial and monetary markets. Households, firms, and investors in and out of the country as well as commercial banks are much interested in

[1] The author would like to thank Professor Rahul Mukherjee (Graduate Institute of Geneva), Professor Tim Willems (University of Amsterdam), PhD. candidate Carlotta Schuster and PhD. candidate Joao Rafael Cunha (Graduate Institute of Geneva), PhD. Long Pham and Toan Nguyen (State Bank of Vietnam) for helpful comments. All remaining errors are mine.

the developments of interest rates to respond quickly and optimally to adjust their investment, savings and consumption activities. This is a very important development because it has heightened the role and positive impacts of monetary policy on inflation control and macro-economic management.

Moreover, in recent years, the multi-objective mechanism of monetary policy (with the expectation of accelerating growth, containing inflation, stabilizing monetary as well as using monetary policy as a supplementary tool for budget stability, poverty reduction, and national security) has been obviously demonstrating its limitations. The experience of many countries shows that inflation targeting may be a reasonable option for monetary policy in Vietnam in the future. In addition, recent studies have pointed out that operating monetary policy under the inflation targeting framework is consistent with the strategy to develop the Vietnamese banking system. It is also the general guideline of the Vietnamese Government recently.

According to the experience of developing countries with similar conditions to Vietnam such as Thailand, Philippines, and Indonesia, in the current situation, Vietnam should think about applying flexible inflation targeting (FIT), in which the emphasis is on establishing an inflation targeting framework for the medium and long term in order to achieve the optimal balance between price stability and other macroeconomic objectives. FIT does not only aim at stabilizing inflation around the inflation target but also puts some weight on stabilizing the real economy via the output gap. Thus, the ‘target variables’ of the central bank include not only inflation but other variables as well, such as the output gap. This is compatible with the objective selection of developing countries like Vietnam.

Thus, in view of the fact that (i) the management of monetary policy through the interest rate channel has become increasingly important; and (ii) Vietnam is planning to run monetary policy through an inflation targeting framework, it is essential to estimate the output gap to create a scientific basis for the management of interest rates. However, so far, due to the shortage of data and the difference in the structure of the economy as well as the financial markets, Vietnam has not had any formal research on estimation of the output gap in order to support the management of interest rates of the central bank.

In addition, estimating potential output and the output gap is notoriously difficult, particularly for transition economies undertaking large structural changes. So far, the academics have introduced a number of methods for estimation of potential GDP to get the output gap. Since the most suitable method for estimating the output gap depends on a number of factors, and due to the problems inherent in estimating the output gap for transition economies outlines above, this paper compares the three most popular methods which may be used by the SBV. This is not only consistent with international practices, but also creates a sound quantitative basis for the management of interest rates of the SBV.

This research is not only theoretical but also highly practical, in the medium and long term. It will be a useful reference for operating the SBV's monetary policy in the future, especially when building the framework of inflation targeting. At the same time, it is also the starting point for more extensive and comprehensive research to develop a framework of management of interest rates through the output gap and inflation targeting as many countries have been conducting.

The paper is structured as follows. Section II provides an overview of Vietnam's economic growth and developments. Section III reviews the literature on output gap measures. Section IV describes the methodology and data used for estimation of the output gap. Section V compares the results of the output gap estimated by the three methods and provides an empirical evaluation. Section VI concludes.

2. OVERVIEW OF VIETNAM ECONOMIC GROWTH AND DEVELOPMENTS

Vietnam is a small open transition economy. Along with high economic growth rates, Vietnam often faces with high inflation.

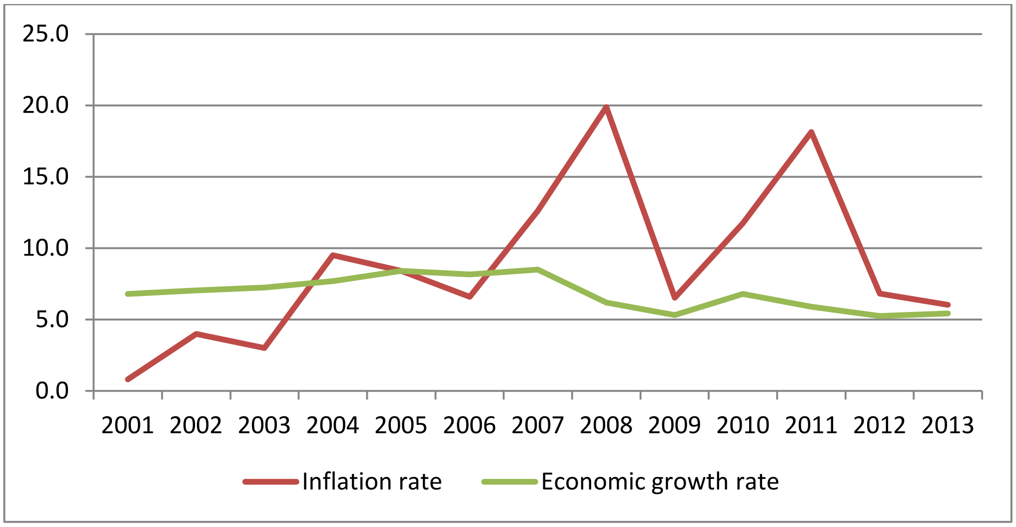
Vietnam experienced a bout of hyperinflation in the second half of the 1980s (with rates of above 300 percent) and in the early 1990s (with rates of above 50 percent) due to unfavorable weather conditions, under-developed agricultural and industrial sectors and a weak financial system during the 1980s. These difficulties were followed by the liberalization of prices and a variety of economic structural reforms. However, Vietnam underwent major stabilization efforts with the restrictive monetary and fiscal policy as a key role that brought inflation under control. Inflation was brought down from the annual rate of above 300 percent in 1986-88 to below 20 percent in 1992 and close to 10 percent in 1995 (Maliszewski, 2010). The stabilization led to a strong growth performance in the early 1990s which was really an achievement in the process of international integration of Vietnam.

The economic growth slowed and inflation remained subdued in the late 1990s and early 2000s due to the impact of the Asian financial crisis in 1997-1998 as well as the increasingly unsustainable composition of growth in the past. This period was marked by very low inflation, and even by the first mild deflation in 2000 with the inflation rate of -0.5 percent.

The economy began to rebound in late 1999, largely due to a revival of domestic investment. Real GDP picked up and inflation rose sharply between 2004 and 2007. After declining slightly in 2006, inflation rose sharply to 12.6 % in 2007 and up to 20 % in 2008. Increased demand along with higher nominal wages in the public sector and the FDI sector in 2003 further spured inflation. In addition, the strong growth was fuelled by buoyant consumption and export growth, notwithstanding a number of supply shocks. Inflation was rising sharply on the back of the sustained strength of international commodity prices and the growing excess demand.

In 2008, growth declined to the slowest pace since 1999 at 6.25 percent. The slowdown was driven by subdued activity in the construction and service sector, following a steep downturn in the property market. Price reduction along with overall international demand helped Vietnam reverse ominous trends of increasing inflation in 2008. In addition, the global financial crisis 2008-2009 has contributed to reducing inflation in Vietnam since the late of 2009. However, inflation rebounded strongly from September 2010 due to the devaluation of Vietnamese Dong in August 2010 and the recent volatility of the gold prices. Owning to the sound and timely monetary and fiscal policy operation, inflation was contained and fell down to 6.8 and 5.4 percent in 2012 and 2013 respectively (see Figure 1).

Figure 1. Inflation and Economic Growth in the period 2001-2013



Source: Vietnam General Statistics Office (GSO)

3. LITERATURE REVIEW

General research on the output gap probably started with Okun in 1962 and has been abundant ever since. Hodrick and Prescott (1997), as well as Corbae and Ouliaris (2002) define potential output as the underlying trend of actual output. While Hodrick and Prescott estimate the output gap by separating longer-run changes in the trend from short-term temporary movements around potential, the latter authors use frequency domain methods to extract information on the business cycle (and underlying trend) properties of GDP.

The second approach estimates output gap on the basis of an economic model. This method views business cycle swings and the gap between actual and potential output as the outcome of demand-determined actual output fluctuating around a slowly-moving level of aggregate supply. The model-based approaches are developed by Blanchard and Quah (1989), Artus (1977) and, more recently, De Masi (1997). The application of the production function approach follows closely the latent variable approach developed in Kuttner (1994), and further refined by the

European Commission.[2]

The use of the output gap in policymaking and related research are manifold. In the field of monetary policy, much of the discussion over the last decade or so has focused on the advantages of rules versus discretion, and the conduct of monetary policy under major regimes relies on some form of the output gap. In a seminal paper, Taylor (1993) proposed a simple instrument rule that tracks US monetary policy surprisingly well during the 1980s and early 1990s. In the simplest form of the rule, interest rates are adjusted according to deviations of inflation from a target level and of output from its trend, the output gap. Since then, uncountable papers have investigated similar issues. It has also been recognized that, notwithstanding the terminology, the output gap plays an important role in inflation targeting, at least in its “flexible” form (see Svensson, 1999). For the Euro Area, Gerlach and Svensson (2003) attribute greater importance to the output gap than to money growth as a predictor of future inflation.

Moreover, several researchers have used multivariate models to estimate output gaps. Benes and N'Diaye (2004) applied a similar model with calibrated parameters to construct output gap series for the Czech Republic.

While technically more challenging than classical methods, estimation of even fairly complex Bayesian models is nowadays straightforward due to great strides in econometric theory and increasing computing power. Applications of Bayesian methods to estimate the output gap have been scarce.

Kuttner (1994) estimated a simpler model relating the output gap to inflation through the Phillips curve using the classical (frequentist) methodology. The same model was replicated by Kichian (1999) for the G7 countries, and popularized by Gerlach and Smets (1999) who also augmented the standard unobserved component model for output with a backward-looking Phillips curve. Basistha and Nelson (2007) added the micro-founded, forward-looking New Keynesian Phillips curve to the UC model. Apel and Jansson (1999a, 1999b) extended the model to include unemployment. The European Commission used it to estimate structural unemployment (Planas et al., 2003), and the OECD applied a closely related version for estimating the non-accelerating inflation rate of unemployment (NAIRU) (OECD, 2000).[3]

Üngör (2012) estimated an output gap measure for Turkey using a production function approach relying on a simplistic representation of the production technology. Output gap estimates in this note and the ones obtained in Alp, Öğünç, and Sarıkaya (2012) using Bayesian estimation of a New Keynesian model exhibit a similar pattern qualitatively, whereas there are some differences in quantitative terms.

Berg et al. (2006) in the paper “Practical model-based Monetary Policy Analysis: A How-To

[2] Andreas Billmeier, 2004, Ghostbusting: Which Output Gap Measure Really Matters?
[3] Wojciech S. Maliszewski (2010), Vietnam: Bayesian Estimation of Output Gap

guide" provides a how-to guide to model-based forecasting and monetary policy analysis. It describes a simple structural model, along the lines of those in use in a number of central banks. This workhorse model consists of an aggregate demand (or IS) curve, a price-setting (or Phillips) curve, a version of the uncovered interest parity condition, and a monetary policy reaction function. The paper discusses how to parameterize the model and use it for forecasting and policy analysis, illustrating with an application to Canada. It also introduces a set of useful software tools for conducting a model-consistent forecast.

However, none of the aforementioned papers included the New Keynesian dynamic IS-equation in the analysis (they all specified a backward-looking AR-process for the output gap), nor did they consider rational expectations. Tim Willems (2011) took further steps by applying Bayesian estimation of a complete New Keynesian model, augmented with an unobserved components model for output.

In Vietnam, so far, there is very little research on the estimation of the output gap. Maliszewski (2010) constructed a new output gap measure for Vietnam by applying Bayesian methods to a two-equation aggregate supply – aggregate demand model, while treating the output gap as an unobservable series to be estimated together with other parameters. However, this study just only stops at the application of Bayesian methods to estimate the output gap that has a lack of specific analysis and comparison with other methods to come to a conclusion on the optimal method of estimation of output gap in line with the economic development and data availability of Vietnam. Moreover, the structural model developed in this paper is simple and seems to exclude some information of the economy.

Nguyen et al. (2013) introduced three mothods to estimate the potential output of Vietnam, including time trend, HP filter and production function approach. However, the assumptions used in the last method are ambiguous.

This paper aims at designing an optimal estimation approach for the output gap using three methods in accordance with its socio-economic conditions and the availability of data in Vietnam.

4. METHODOLOGY AND DATA

4.1. Methodology

According to Cotis et al. (2004) there are a number of methods to estimate potential output and output gap that are devided into four groups including: (i) Trend (Linear trend, Split trend); (ii) Univariate filters (Hodrick Prescott (HP), Baxter-King filter, Beveridge Nelson Decomposition, Kalman filter); (iii) Multivariate filter (HPMV), Beveridge Nelson Decomposition, Kalman filter; and (iv) production function approaches (Full structural model, Production function with exogeneous trends, Structual VAR).

Respectively, the research will focus on the three methods of estimation of the output gap including (i) HP filter which is the most commonly used frequentist approach, (ii) Production function approach which is a method combining frequentist approach and model-based approach, and (iii) Bayesian method which is a model-based one. The first two methods are popular while the last one which is well suited for countries having scarcity of data is different from the standards methods and challanging in terms of econometrics techniques.

A. HP Filter

The HP filter was popularized in the field of economics in the 1990s by economists Robert J. Hodrick and Edward C. Prescott. It is a mathematical tool used in macroeconomics, especially in real business cycle theory to separate the cyclical component of a time series from its underlying trend. It is used to obtain a smoothed-curve representation of a time series, reflecting long-term rather than short-term fluctuations. The adjustment of the sensitivity of the trend to short-term fluctuations is achieved by modifying a multiplier λ.

The methodology uses ideas related to the decomposition of time series. It is supposed that the original series y_t is composed of a trend component denoted by τ and a cyclical component, denoted by:

$$y_t = \tau_t + c_t$$

Given an adequately chosen, positive value of λ, the HP filter isolates the cyclical component by following minimization problem:

$$\min_{\tau}\left(\sum_{t=1}^{T}(y_t-\tau_t)^2+\lambda\sum_{t=2}^{T-1}[(\tau_{t+1}-\tau_t)-(\tau_t-\tau_{t-1})]^2\right)$$

The first term of the equation is the sum of the squared deviations $d_t = y_t - \tau_t$ which is a measure of the fitness of the time series (penalizing the cyclical component). The second term is a multiple λ of the sum of the squares of the trend component's second differences which is a measure of the smoothness (penalizing variations in the growth rate of the trend component). There is a conflict between "goodness of fit" and "smoothness". To keep track of this problem, there is a "trade-off" parameter λ.

The larger the value of λ, the higher is the penalty. HP filter also requires choosing values of the smoothing parameter λ in the above minimization problem. The Smoothing parameter determines the degree of smoothing of smoothed trend series τ_t. With a small value of λ, the estimated trend series τ_t fluctuates closely to the actual observed time series y_t, and therefore is a more volatile. Meanwhile, with a large value of λ, the elasticity of the trend series τ_t with respect to short-term fluctuations of the actual series y_t will decrease, the estimated trend series, thus, will be smoother and close to a linear trend line. In other words, the larger the value of λ the smoother the estimated trend τ_t. This also reflects the choice between a relatively smooth trend series and a trend series which is close to the actual observed series.Note that, if λ =0, the trend component becomes equivalent to the original series, while λ diverges to infinity, the trend component approaches a linear trend.

The size of the smoothing parameter is dependend on the frequency of the data, the higher the frequency the larger the smoothening parameter. Hodrick and Prescott (1997), as well as other literature suggest 1600 as a value for λ for quarterly data. For the monthly and annually data, there is no consensus the value for λ. Ravn and Uhlig (2002) state that λ should vary by the fourth power of the frequency observation ratio; thus, λ should equal 6.25 for annual data and 129,600 for monthly data. Meanwhile, some other literature suggested a range from 10-100 for λ for annually data and 14400 for λ regarding monthly data.

Application of HP filter in estimating output gap

HP filter is one of the simple and popular methods that are commonly used to estimate the potential value of the time series. Specifically, the HP filter will decompose time series of real GDP (or output) Y_t into two components: (i) the trend or growth component (which can be considered as potential output Y_t^*, and (ii) the cyclical component (or the difference between actual output and potential output that could be seen as the output gap Y_t^{gap}):

$$Y_t = Y_t^* + Y_t^{gap}$$

This method is based on the assumption that the cyclical component fluctuates around the growth component with time diminishing amplitudes. Therefore, the average deviation of Y_t from Y_t^* for the whole period is assumed to be equal to 0. Also, the HP filter will remove cyclical component from the GDP series to obtain the trend component as potential GDP by solving the similar minimization problem:

$$\min_{Y^*}\left(\sum_{t=1}^{T}(Y_t - Y_t^*)^2 + \lambda\sum_{t=2}^{T-1}[(Y_{t+1}^* - Y_t^*) - (Y_t^* - Y_{t-1}^*)]^2\right)$$

The output gap can be obtained based on the formula below:

$$Y_t^{gap} = Y_t - Y_t^*$$

It is noted that the output gap Y_t^{gap} is the cyclical component of the real GDP series Y_t.

Advantages and disadvantages of HP filter

HP filter is integrated in some econometrics softwares like Eviews, Stata and easy to apply. The HP filter provides rather good results for stable economies without significant shocks. Moreover, this method has the advantage of ensuring that the estimated output gap (cyclical component) is stationary. The HP filter, however, has some serious limitations.

Firstly, it is well known that the Hodrick-Prescott (HP) filter suffers from an end-point bias due to the size of the revisions in preliminary estimators: the last point of the series has an exaggerated impact on the trend at the end of the series. If one is only interested in the properties of the cycle, this is not that bad, one simply has to omit the trend values at the end of the series (Bruchez, 2003), but this is problematic when the filter is used recursively for economic policy because in this case the end-point is the point of interest.

Second, another limitation of the HP filter deals with the treatment of structural breaks which tend to be smoothed by the filter. As a result, the effect of a structural break tends to be distributed over several periods, instead of being felt in one period alone that hashappendwith the linear trend for instance, once the break period is identified (Botas et al., 1998).

Third, the HP filter tends to create spurious or artificial cycles i.e., it generates cycles even when these are not present in the original data.

Fourth, as mentioned before, HP filter is simply a statistical procedure that lacks economic context or theoretical foundations. It imposes a standard degree of smoothness on the estimated potential output series, while the potential output volatility may be much larger in transition countries (Maliszewski, 2010).

In addition, the amount of noise in the cyclical signal seriously disturbs its interpretation.

B. Production Function Approach

The previously presented method is a statistical procedure aimed at identifying the trend of a time series. The major drawback of this approach is that it is simply statistical procedure that disregards any information on eventual structural constraints binding the economy, namely the greater or smaller availability of production factors. Therefore, some economists argue that the potential output extrapolated by HP filter may be inconsistent with the behaviour of the capital stock, employment and productivity. The so-called production function approach intends to overcome these drawbacks.

According to this approach, potential output is the maximum output level consistent with stable inflation. Consequently, this concept should not be identified with maximum output level — in the technical sense — which corresponds to the full utilisation of productive factors.

Potential employment is given by the expression: $L^* = LF(1\text{-}NAIRU)$ where *LF* stands for the labour force.

The expression above shows the role that different production factors play in determining potential output. First, the greater the capital stock, the higher is potential output. This means that high investment rates, especially if investment is channeled to expand productive capacity, yields higher growth rates of potential output. Second, the higher potential employment — i.e., the lower the NAIRU - the higher is potential output. Finally, potential output is also higher the greater the trend technical progress is (Botas et al.,1998).

The production function-based method estimates potential output based on the Cobb-Douglas (1928) production function. The research paper closely follows the modeling and estimation strategy employed in Üngör (2012), and Epstein and Macchiarelli (2010).

According to this method, and with the *constant return to scale* assumption, the actual output is given by the Cobb-Douglas production function as below:

$$Y_t = A_t L_t^{\alpha} K_t^{1-\alpha} \qquad (1)$$

where Y_t represents real gross domestic product (GDP), A_t is the Total Factor Productivity (TFP), K_t is real physical capital stock (or net capital stock - NCS) and L_t is employment at date *t*; and (1-α) and α are the elasticities of output with respect to capital and labor, respectively.

The production function is linearized as follows:

$$ln(Y_t) = ln(A_t) + \alpha ln(L_t) + (1-\alpha) ln(K_t) \qquad (2)$$

The idea of this approach is that if we got the potential values of the capital, employment and total factor productivity (TFP), then we can obtain the potential output. Owning to that, we can estimate the output gap. The potential output is given by:

$$ln(Y_t^*) = ln(A_t^*) + \alpha ln(K_t^*) + (1-\alpha) ln(L_t^*) \qquad (3)$$

where Y_t^* represents potential GDP, A_t^* is potential TFP, K_t^* is potential physical capital stock and L_t^* is potential employment at time *t*.

The HP filter will be applied, using the standard value of 1600 for the smoothing parameter λ, to actual capital, labour, and TFP series separately. Then, the trend underlying each series will be used as its potential value. Finally, potential output will be estimated from the equation (3).

However, in order to do that, first, I have to calculate the physical capital stock K_t. Until now, Vietnam has had no statistics on the real physical capital stock K_t. Therefore, I use related statistics and assumptions in prior literature. The physical capital stock is constructed using the Perpetual Inventory Method (PIM) following Hall and Jones (1999) and Berlemann Wessel-Hoft (2012). In the case of Vietnam, where there is no data on the capital stock but on gross fixed capital formation (GFCF), applying the PIM I construct the physical capital stock series based on the following assumptions: (i) the initial value of the capital stock is given as: $K_0 = \frac{GFCF_0}{\delta + g_{GFCF}}$, where $GFCF_0$ is the initial value of gross fixed capital formation (1st year of the considered period), δ is the depreciation rate , and g_{GFCF} is calculated as the average geometric growth rate for the whole considered period of the investment series, and (ii) the physical capital stock is constructed using the PIM, i.e. $K_t = K_{t-1} - \delta K_{t-1} + I_{t-1}$, where δ is the depreciation rate, I is the total investment (Gross fixed capital formation - GFCF). I assume a depreciation rate of 6 percent following Hall and Jones (1999), as well as, Nguyen et al. (2013). I consider the period from 1998Q1-2012Q4.

Second, I have to define the production function for Vietnam by (i) estimating the elasticities α and (1-α) of labour and capital; and (ii) calculating the TFP (A_t).

The paper uses the assumption of elasticity of labour α=0.67, which is broadly consistent with the literature in many developing as well as developed countries where α is approximatedly 2/3, and with results of the Input-Output analysis for Vietnam referred by Nguyen et al. (2013) where α=0.642.

Then from (1), TFP can be derived from the Cobb Douglas function: $A_t = Y_t / L_t^{\alpha} K_t^{1-\alpha}$

Y_t^* is given by: $Y_t^* = A_t^* L_t^{*\alpha} K_t^{*1-\alpha}$

Finally, I can get the output gap in percent: Output gap (%) = 100*($\frac{Y_t - Y_t^*}{Y_t^*}$)

Advantages and disadvantages of Production Function Approach

The PF approach is also relatively simple in terms of econometric technique. It overcomes the drawbacks of HP filter relating theoretical foundations by taking the greater or lower availability of the productive factors into account. However, the production function approach is not free of limitations. First, potential output depends on the type of production function assumed, on the method of calculation of NAIRU (which encompasses a certain level of uncertainty), on the method of calculation of capital stock (in case of no statistics information), and on the method of calculation of trend productivity (or potential value of total factor productivity). In the case of Vietnam, since there is no information about NAIRU, the HP filter is used to compute the potential value of employment, capital stock and TFP. Therefore, all kinds of limitations associated to this method are brought into this approach (Botas et al, 1998).

C. Bayesian Method

Introduction of Bayesian approach

The term "Bayesian" comes from the prevalent usage of Bayes' theorem, which was named after the Reverend Thomas Bayes, an 18th century Presbyterian minister. The use of Bayesian methods has become increasingly popular in modern statistical analysis, with applications in a wide variety of scientific fields. The Bayesian method relies on a model-based multivariate filter, using economic theory to guide the estimation of parameters. The Bayesian estimation procedure combines researcher's *priors* with information contained in the data. The present model treats parameters and unobservable variables as unknown quantities to be estimated (elements of Γ). The prior information is the prior density $g(\Gamma)$ for all parameters of the model Γ. It will be combined with data y to produce a posterior density $f(\Gamma|y)$:

$$f(\Gamma|y) = g(\Gamma)\frac{f(y|\Gamma)}{f(y)}$$

where $f(y|\Gamma)$ and $f(y)$ are conditional and marginal densities of y.

The main outcomes of a Bayesian analysis are the *posterior* distributions of a model's parameters, rather than point estimates and their standard errors. Access to a model's parameters' posterior distributions enables you to address scientific questions of interest directly, because once the model parameters are estimated, it is easy to compute the posterior distributions for any functions of the parameters or any quantities of interest. All of the Bayesian procedures rely on Markov chain Monte Carlo (MCMC) methods to obtain all posterior estimates.

Application of the Bayesian Approach in Estimating the Output Gap

The Bayesian approach applied in this paper combines the unobservable components (UC) model for output with a complete New Keynesian dynamic stochastic general equilibrium (DSGE) model. The latter is added to allow for the addition of more variables (in particular the rate of inflation) in a model-consistent way so as to bring the gap estimate more in line with its theoretical definition. In addition, mindful of the findings by Del Negro and Schorfheide (2004), the additional structure imposed by the model may also help in improving the real time properties of the gap estimate. Willems (2011) takes the model by Kuttner one step further by appending a full New Keynesian model to the UC setup. In doing so, the approach takes the cross-equation restrictions and rational expectations implied by that model into account. Taking the advantages of this, my paper closely follows the modeling and estimation strategy employed in Willems (2011) approach.

(i) Univariate Unobservable Component (UC) Models for Output

The UC model includes behavioral equations describing the evolution of the output gap, and equations governing the dynamics of potential output which are assumed to follow a random walk process with a time-varying slope *t.*

$$y_t = y_t^n + y_t^g \qquad (1)$$

$$y_t^g = \rho_{g,1} y_{t-1}^g + \rho_{g,2} y_{t-2}^g + \zeta_t \qquad (2)$$

$$y_t^n = \rho_y y_{t-1}^n + \mu_t + \varepsilon_t^y, \qquad \varepsilon_t^y \sim \mathcal{N}\left(0, \sigma_y^2\right) \qquad (3)$$

$$\mu_t = \mu_{t-1} + \varepsilon_t^{\mu}, \qquad \varepsilon_t^{\mu} \sim \mathcal{N}\left(0, \sigma_{\mu}^2\right) \qquad (4)$$

$$\zeta_t = \rho_\zeta \zeta_{t-1} + \varepsilon_t^\zeta, \qquad \varepsilon_t^\zeta \sim \mathcal{N}\left(0, \sigma_\zeta^2\right) \qquad (5)$$

Where

y_t is actual output

y_t^n is output's natural level or potential output

y_t^g is output gap

ζ_t is a stochastic disturbance to the output gap (a demand shock)

μ_t is the time-varying trend in output's natural level

ε represents shocks to the different variables

(ii) Structural Model

Recognizing the fact that the rate of inflation should contain useful information about the output gap, Kuttner (1994) (and later Gerlach and Smets 1999) enriched the standard UC model with the rate of inflation by adding a Phillips-curve like equation to the benchmark UC model above. In particular, Kuttner added:

$$\Delta\pi_t = \eta + \xi \Delta y_{t-1} + \psi \tilde{y}_{t-1} + \varepsilon_t^\pi + \lambda_1 \varepsilon_{t-1}^\pi + \lambda_2 \varepsilon_{t-2}^\pi + \lambda_3 \varepsilon_{t-3}^\pi \qquad (a)$$

While Gerlach and Smets (1999) combined the UC model with the following equation:

$$\pi_t = \sum_{i=1}^{4} \alpha_i \, \pi_{t-i} + \kappa \tilde{y}_t + \varepsilon_t^\pi \qquad (b)$$

However, both of these equations lack microfoundation and are only backward-looking. Therefore, Basistha and Nelson (2007) augmented the univariate UC model

for output with the forward-looking, microfounded New Keynesian Phillips curve:

$$\pi_t = \beta \mathbb{E}\{\hat{\pi}_{t+1}\} + \kappa \tilde{y}_t + \varepsilon_t^\pi \qquad \text{(c)}$$

Willems (2011) in turn considered a complete New Keynesian DSGE model with the standard model. The New Keynesian DSGE model includes the New Keynesian Phillips curve (which takes into account both backward- and forward-looking information of inflation), the dynamic IS equation and the interest rate rule. The model has shown to be useful in matching the data (such as the hybrid New Keynesian Phillips curve and habit formation). In particular, this paper augments equations (1), (3), (4) and (5) with the followings:

- *The New Keynesian Phillips curve*

$$\hat{\pi}_t = \gamma\hat{\pi}_{t-1} + (1-\gamma)\mathbb{E}_t(\hat{\pi}_{t+1}) + \kappa y_t^g + \varepsilon_t^\pi\,, \qquad \varepsilon_t^\pi \sim \mathcal{N}(0, \sigma_\pi^2) \qquad (6)$$

Parameter γ allows for a backward-looking component. The hat denotes the deviation from the trend (obtained by HP-filter).

- *The dynamic IS equation*

The dynamic IS curve or the AD which describes the evolution of the output gap can be defined as below:

$$y_t^g = \vartheta y_{t-1}^g + (1-\vartheta)\mathbb{E}_t\left(y_{t+1}^g\right) - \frac{1}{\sigma}\left(\hat{R}_t - \mathbb{E}_t(\hat{\pi}_{t+1})\right) + \zeta_t \qquad (7)$$

Where $\hat{R}_t$ is the real interest rate, the hat denotes the deviation from the trend (obtained by HP-filter). Parameter ϑ allows for habit information.

- *The interest rate rule*

$$\hat{R}_t = \delta\hat{R}_{t-1} + (1-\delta)\phi_\pi\hat{\pi}_t + \varepsilon_t^r, \qquad \varepsilon_t^r \sim \mathcal{N}(0, \sigma_r^2) \qquad (8)$$

Equation (8) is close to the New Keynesian model. Here, as follow Willems (2011), the paper also does not take the Taylor-rule into account (which assumes that the monetary reacts to both inflation and the output gap), but uses the pure inflation targeting rule instead. This is due to the fact that current monetary authorities can not observe the true output gap in practice either. Therefore, it makes no sense to assume that they respond to it in real time.

Parameter δ governs the degree of interest rate smoothing, and parameter ϕ_π is the monetary authority's reaction coefficient on inflation, while ε_t^r represents the monetary policy shock.

To obtain the output gap, the above system uses the cross-equation restrictions imposed by both the New Keynesian and the UC model. Notably, this paper does not employ survey data to approximate expectations, but uses the model-implied rational expectations instead.

As the paper is dealing with a linearlized model, I can write it in state-space form and evaluate the likelihood of the model by using the linear-Gaussian Kalman filter. Also, since it is not possible to obtain closed-form solutions for these posteriors, they are evaluated numerically with the Metropolis-Hastings algorithm. The results are obtained after simulating 100,000 draws. The model is estimated in Dynare (in Matlab platform).

There is no prior information about parameters in the Bayesian models for Vietnam. Even Maliszewski (2010) when applied Bayesian methods to an aggregate demand – aggregate supply model to estimate the output gap for Vietnam did broadly base on the value reported in the literature (i.e. Berg et al. 2006a, 2006b) for the priors of parameters in the output gap and inflation equation. Therefore, the priors for the model in my paper are broadly based on the values reported in Willems (2011).

Table 1 provides an overview of the prior distributions of the parameters. In the table, $\beta(\mu, \sigma, p1, p2)$ indicates a beta distribution with mean μ and standard deviation σ over the interval [p1, p2]; U [p1, p2] is a uniform over the interval [p1, p2]; $\Gamma(\mu, \sigma)$ represents a gamma distribution with mean μ and standard deviation σ, while $\Gamma^{-1}(\mu, \sigma)$ refers to the same for an inverted-gamma.

The priors for the standard deviations of all shocks follow an inverted-gamma distribution with mean 0.01 and infinite variance.

Advantages and disadvantages of Bayesian Approach

The Bayesian approach takes structural changes in the economy as well as backward- and/or forward-looking inflations, especially when integrated with a complete DSGE model, into account. It, thus, overcomes limitations of the classical approaches mentioned above and is suitable for developing countries with various structural changes in their economies.

Nevertheless, the Bayesian approach is more challenging in terms of econometric technique, because it is different from frequentist approaches and often uses specific econometric techniques that have not been integrated in popular econometric softwares such as Stata, Eviews, etc. Also, it more or less depends on choosing priors and building up models.

4.2. **Data**

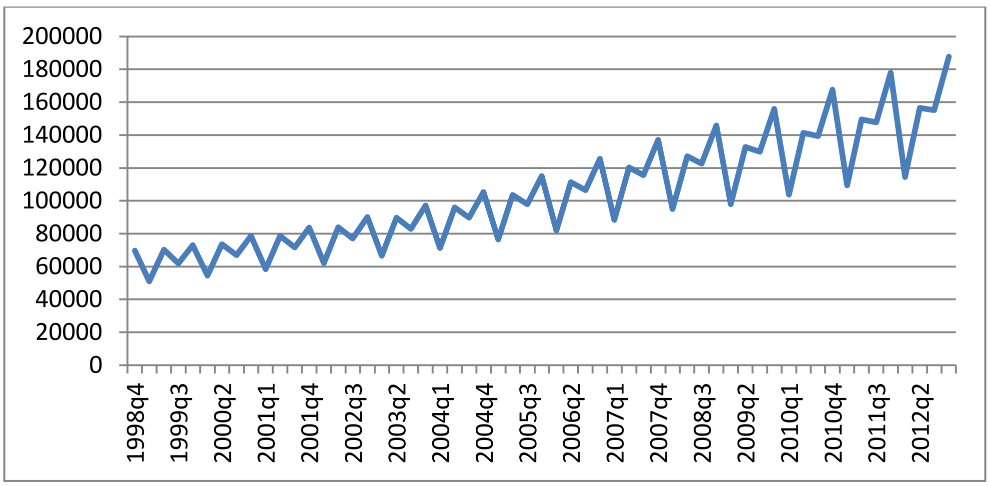
For the HP filter, I use quarterly data from 1998Q4 to 2012Q4 (so 57 observations) for the real GDP which is collected from the Vietnam General Statistical Office. This series is seasonally adjusted using X12 procedure and used in logarithm form.

For the production function approach, data on real GDP, real physical capital stock, and labour is required. The paper uses quarterly data from 1994Q1- 2012Q4 (so 73 observations) for the real GDP which is seasonally adjusted by X12 procedure. However, data on the real physical capital stock is not available in Vietnam; therefore I have to use gross fixed capital formation to compute the capital stock with a number of assumptions. Moreover, Vietnam statistics only has annually data on gross fixed capital formation and labour force, and these series are available mostly since 1990s (so less than 30 observations). There is no quarterly data on capital stock and labour. With less than 30 observations, the regression using in the production approach is statistically insignificant. To deal with this issue, I use Eviews to change the frequency of these series from annually to quarterly data to increase the number of observations. This helps with increasing the statistical significance but does not help much regarding economic intuition. In addition, there is no information about NAIRU in Vietnam which creates difficulties in getting the data on potential labour. All the data series on GDP, gross fixed capital formation and labour are collected from the World Bank.

In terms of Bayesian approach, a part from the real GDP, I also use quarterly data from 1999Q1 to 2012Q4 (so 56 observations) for the rate of inflation (CPI), real effective exchange rate (REER), real interest rates, and output of the US. These time series are provided by the State Bank of Vietnam and collected from the International Financial Statistics of the International Monetary Fund (commercial banks prime lending rate, CPI).

As can be seen from the graph of real GDP (Figure 2), there is a global upward trend, every year a similar cycle starts, and the variability within a year seems to increase over time. Therefore, I transform the series using a log transformation to stabilize the variability. Therefore, the output gap will be defined as the percentage difference between actual and potential output in the paper.

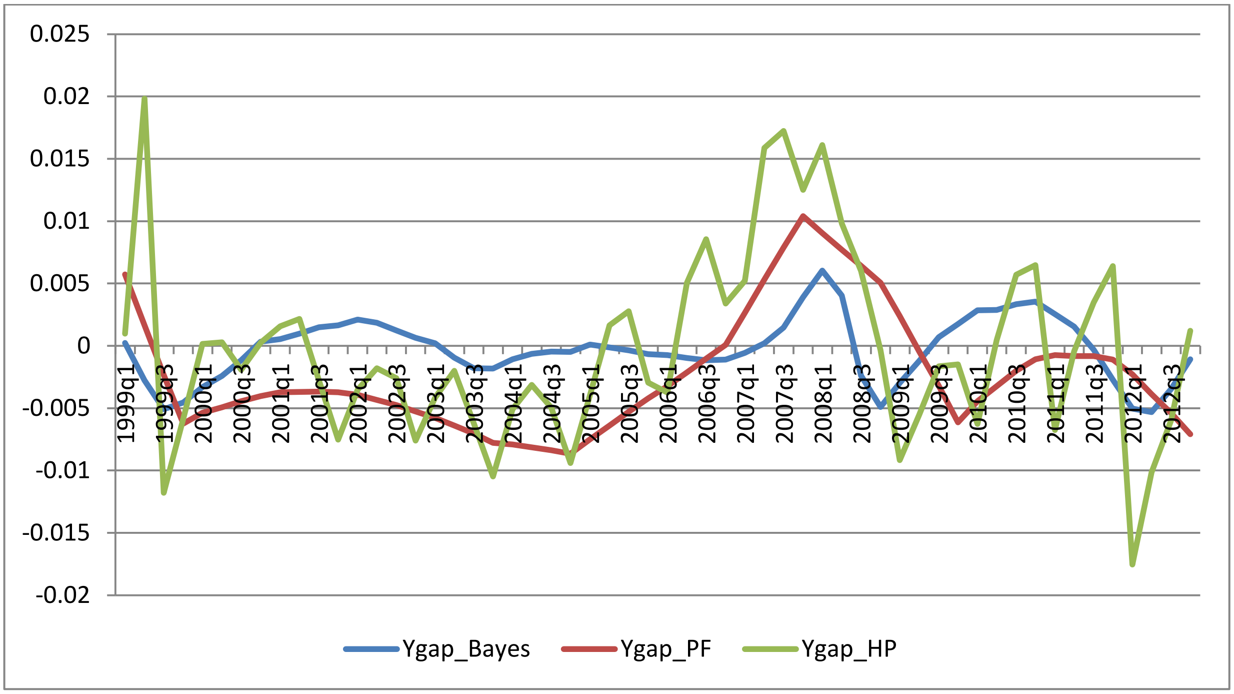
Figure 2. Real GDP of Vietnam (in billion Vietnam Dong)



Source: Vietnam General Statistics Office

5. RESULTS

Figure 3. Output gap estimated by HP filter, PF and Bayesian approach



Source: Author's calculations

Figure 3 illustrates the output gap obtained by HP filter (the green line), production function approach (the red line) and Bayesian approach (the blue one). The HP-filtered output appears to fluctuate most as compared to the output gap of other two methods. This can be explained by a limitation of this measure mentioned above that the HP filter tends to create spurious or artificial cycles.

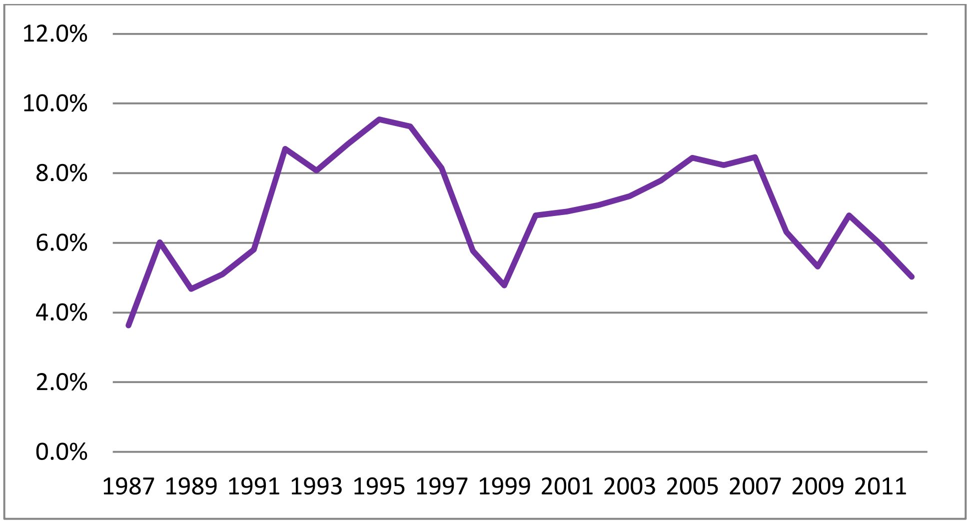
The green line shows that before 1999Q2 the output gap is highly positive, then it becomes negative and fluctuates mostly under zero. This can be explained by negative impacts of the Asian financial crisis 1997-1998 on Vietnam's economy via a drop in trade[4] and foreign investment as well as internal weaknesses of its reformed economy which had become more evident since 1996. The output gap then turns around to rather positive value during 2006Q2-2008Q3, especially in 2007. It matches to the overheating economic growth in Vietnam during this period that leads to a high inflation rate in 2008 (Figure 4). After the boom, the potential economic activity is rather low triggered by the 2008 global financial crisis.[5] Then the output gap fluctuates around zero in 2010 and 2011, and becomes deeply negative in the first half of 2012.

[4] Demand from the world and region markets, especially demand and world prices for the major exports of Vietnam dropped sharply following the Asian financial crisis 1997-1998 that resulted in a decrease in economic growth of Vietnam.

[5] Vietnam is an export-driven country. Therefore, once again, the 2008 global financial crisis had indirect negative impacts on Vietnam's economy through the shrinking demand from the world and region markets.

The economy tends to recover corresponding to a lightly positive output gap in the last quarter of 2012. This end point might not reflect the difficult situation of the economy of Vietnam during the period 2012-2013 as it presents over optimistic prospect of the economy.

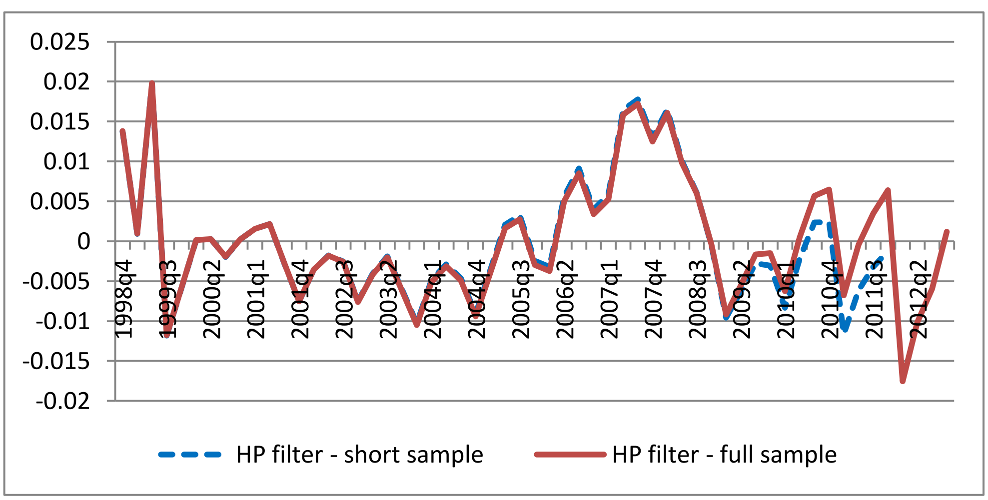
Figure 4. Economic growth of Vietnam in the period of 1987-2012



Source: Vietnam General Statistics Office

Substantial revisions over time - which are related to the end-point bias - are a significant drawback of the HP filter. Figure 5 illustrates the problem in the case of Vietnam, where short-sample HP based estimates of output gap (dashed line—estimated on the sample ending in 2011Q4) would underestimate excess demand at the end of 2011 compared to the full sample estimate (solid line—sample ending in 2012Q4).

Figure 5. Output Gap by HP Filter with Short Sample vs. Full Sample



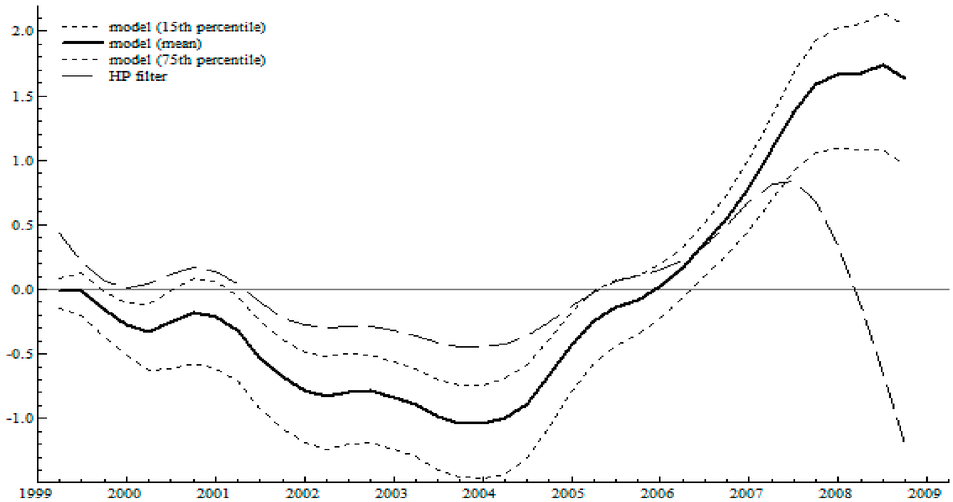
Source: Author's calculations

The estimated output gap obtained from the production function approach is significantly different from that estimated with HP. Figure 3 also points out that the economic activity is highly above the potential before 1999 and during the period of 2006-2008 and below its potential otherwise. However, the output gap is more smoothed than in the HP estimation, negative in 2010-2011 and the trend of output gap at the end of 2012 is opposite to that of HP filter with steep downward trend. It is rather fit to the downturn economic growth of Vietnam in 2012-2013 but it seems to be too steep in comparison with the recent economic developments. In addition, while the economic growth in Vietnam tended to recover from 2000 along with an increased economic growth rate from 2000 to the 2005 before overheating in 2006-2008, the figure presents a downward trend of the output gap from 2002–2004.

As can be seen also from Figure 3, the estimated output gap by Bayesian approach indicates below-potential economic activity between 1999Q2 to 2000Q3, late-2003 to 2006, and overheating in 2007-08. Then, the output gap is turnaround in the cyclical position in late 2008. The slight recovery of the economy in 2010 and early 2011 is reflected by a positive output gap during this period. After that, from late 2011 onwards, the economy grows below its potential. Indeed, the output gap estimated with the Bayesian approach is well-matched with the economic developments (see Figure 4). The results are easily interpretable. The initial negative output gap reflects the impacts of the Asian crises 1997-1998 and the effect of monetary tightening at the end of 1999. In terms of trend at the end of the sample, results of the model-based estimation is similar to that of HP filter which is opposite to the one of production function approach. However, the upward trend of the model-based output gap is more reasonable than HP-filtered output as the Vietnamese economy is only slowly recovering in 2012-13. Although the output gap series constructed from the model-based method moves in line with the HP estimate, it is also different from the HP one as it is more smoothed than and does not have a wide gap as the HP-filtered GDP. In addition, the HP based measure peaks in mid-2007, while the model-based series reaches the maximum in the first quarter of 2008. Comparing to the production function measure, both estimates have similar pattern of movement. Nevertheless, the production function often over-estimates the gap during the overheating of the economy while highly under-estimates during the rest of sample.

The result of the Bayesian method is also significant different from the Vietnam output gap estimated by Maliszewski (2010). Figure 6 shows the deeply below-potential economic activity for the whole period of 1999-2005. This seems to be not the case of Vietnam's economy.

Figure 6. Vietnam: Output Gap estimated by HP filter vs Model-based Approach in Maliszewski (2010)



Note: Solid line is the output gap estimated by Bayesian approach, long dashed line is the output gap estimated by HP filter

Source: Maliszewski (2010)

6. CONCLUSIONS

Recently, output gap estimates have become subject to considerable debate. While the theoretical definition of the output gap is clear, obtaining the output gap is not straightforward in practice. The paper applied three approaches for estimating the output gap series for Vietnam to choose an optimal methodology that provides a more meaningful measure of excess demand for policy analysis.

As mentioned above, Vietnam is a transition economy with data shortcomings. Data required for the production function approach and unemployment series are not available on quarterly basis; the potential output may be less smooth than in developed economies due to large structural changes; and the National Accounts series on quarterly basis are short, aggravating the end-point bias (Maliszewski, 2010). Therefore, in terms of data requirement, the Bayesian approach would be preferred than the other methods because it uses simulation technique and does not much depend on time series data inputs.

While the Bayesian econometric procedure is much more challenging in terms of econometric technique, it appears to be successful in producing more precised and easily interpretable results despite various data problems compared to the other two approaches. The gap estimated by the Bayesian approach is not too different from HP-filtered GDP and the output gap obtained by the production function method, with some important qualifications to be made. The output gap of the three measures has relative similarity that stands or falls with the importance of supply shocks in explaining business cycle fluctuations. The coefficient of the estimated equations of Bayesian approach are in line with economic theory, and the output gap series is consistent with a broader analysis of economic developments. Compared to the Bayesian measure, the traditional output gap measure obtained from the HP filter appears harder to interpret and seems to be bias at the end-point that is ill-suited to be used in monetary policy analysis. Meanwhile, the estimated output gap of the production function approach demonstrates some inconsistences with regard to the economic developments in some periods and also lightly faces with extreme-estimated issue at the end-point.

In addition, the production function approach does not only struggels the scarcity of data but also with the same weaknesses as the HP filter as it uses the HP filter to get the potential value of capital, labour and TFP. The Bayesian approach on the other hand estimates the output gap by combining information from a forward-looking variable (the inflation rate) with the cross-equation restrictions and rational expectations implied by the New Keynesian model. This seems to improve the real time performance considerably, which makes this paper's procedure potentially useful for monetary policy makers. Furthermore, the priors imposed in the Bayesian estimation allow for a meaningful estimation of the model even for countries with relatively weak or short data series.

To conclude, at the moment, Bayesian method appears to be the optimal approach to estimate the output gap for Vietnam in terms of policy analysis.

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APPENDIX

Table 1: Prior distributions of parameters

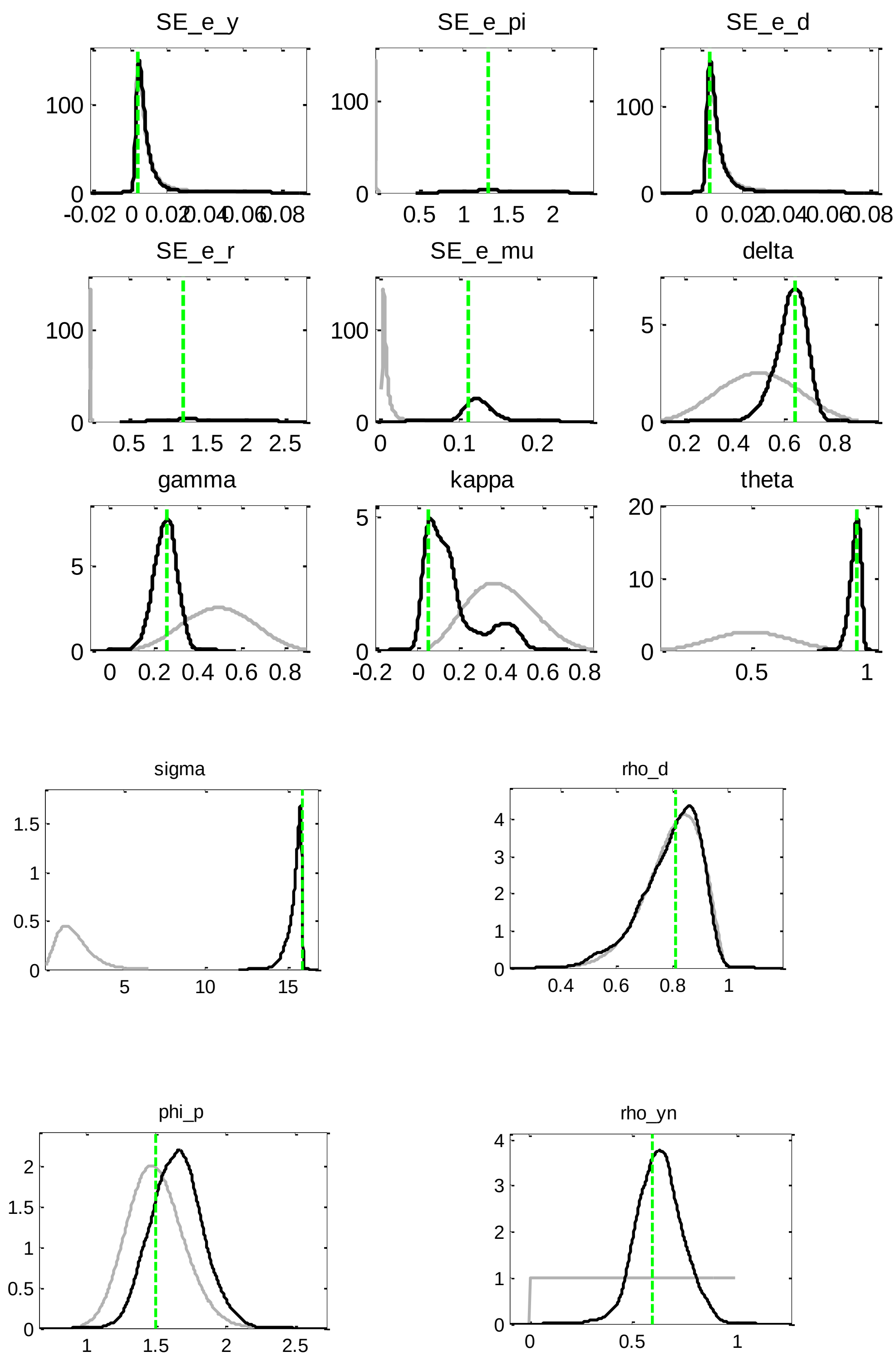
	Prior distribution	**Source**
Potential output equations		
ρ_y	U[0, 1]	Tim Willems (2011)
Demand shock		
ρ_ζ	β(0.8, 0.1, 0, 1)	Tim Willems (2011)
New Keynes Phillips curve		
γ	β(0.5, 0.15, 0, 1)	Tim Willems (2011)
κ	β(0.4, 0.15, 0, 1)	Tim Willems (2011)
Dynamic IS curve		
ϑ	β(0.5, 0.15, 0, 1)	Tim Willems (2011)
σ	Γ(2, 1)	Tim Willems (2011)
Interest rate rule		
δ	β(0.5, 0.15, 0, 1)	Tim Willems (2011)
ϕ_π	Γ(1.5, 0.2)	Tim Willems (2011)
Variances on innovations		
σ_y	$\Gamma^{-1}(0.01, \infty)$	Tim Willems (2011)
σ_μ	$\Gamma^{-1}(0.01, \infty)$	Tim Willems (2011)
σ_ζ	$\Gamma^{-1}(0.01, \infty)$	Tim Willems (2011)
σ_π	$\Gamma^{-1}(0.01, \infty)$	Tim Willems (2011)
σ_r	$\Gamma^{-1}(0.01, \infty)$	Tim Willems (2011)

Table 2. Posterior mean and standard deviation

	Mean	**Standard deviation**
δ	0.6259	0.0214
γ	0.2545	0.0159
κ	0.1690	0.0122
ϑ	0.9499	0.0097
σ	15.4151	0.1833
ρ_ζ	0.7938	0.0213
ρ_y	0.6307	0.0337
ϕ_π	1.6512	0.0526
σ_y	0.0079	0.0077
σ_π	1.3061	0.1289
σ_ζ	0.0077	0.0054
σ_r	1.2984	0.1336
σ_μ	0.1263	0.0282

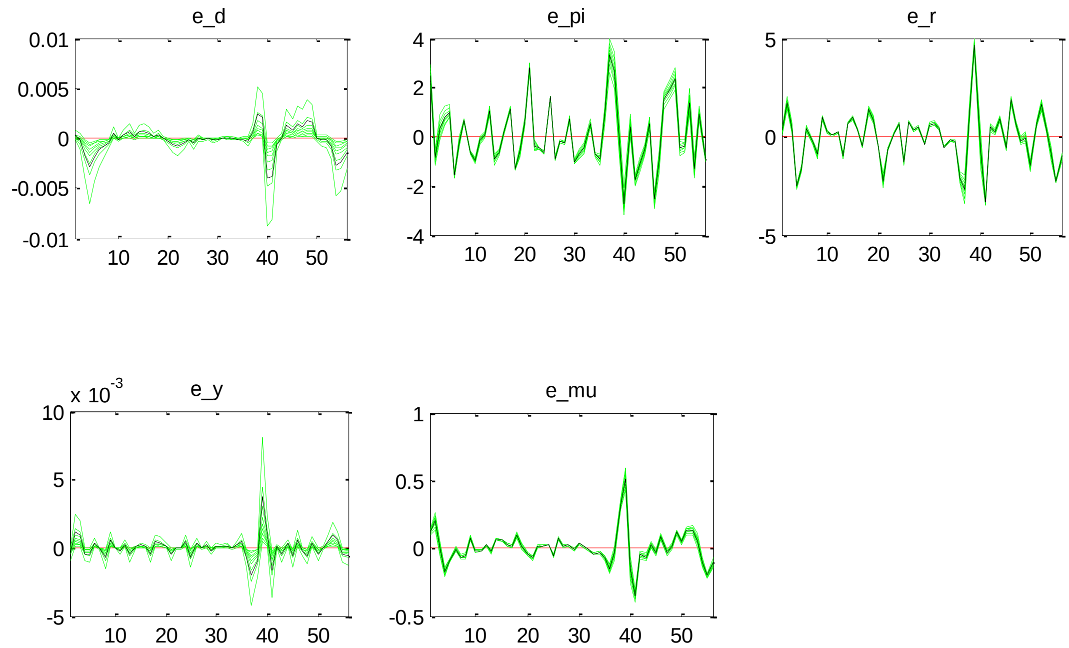
Source: Author's calculations

Figure A1. Prior and posterior distributions



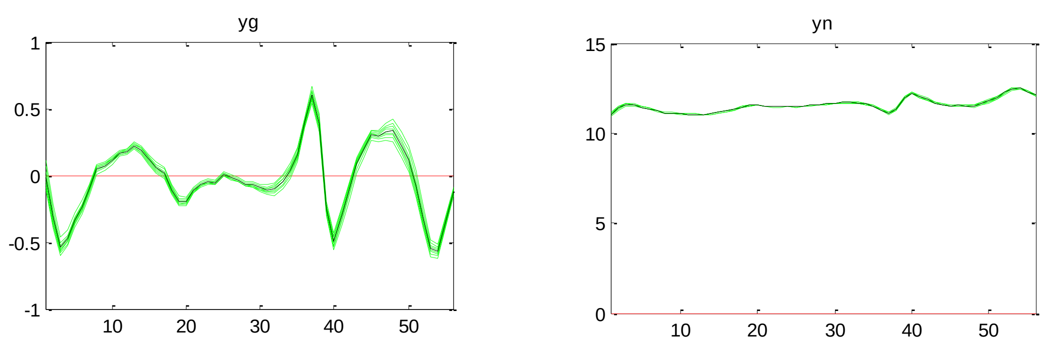
Source: Author's calculations

Figure A2. Smoothed shocks



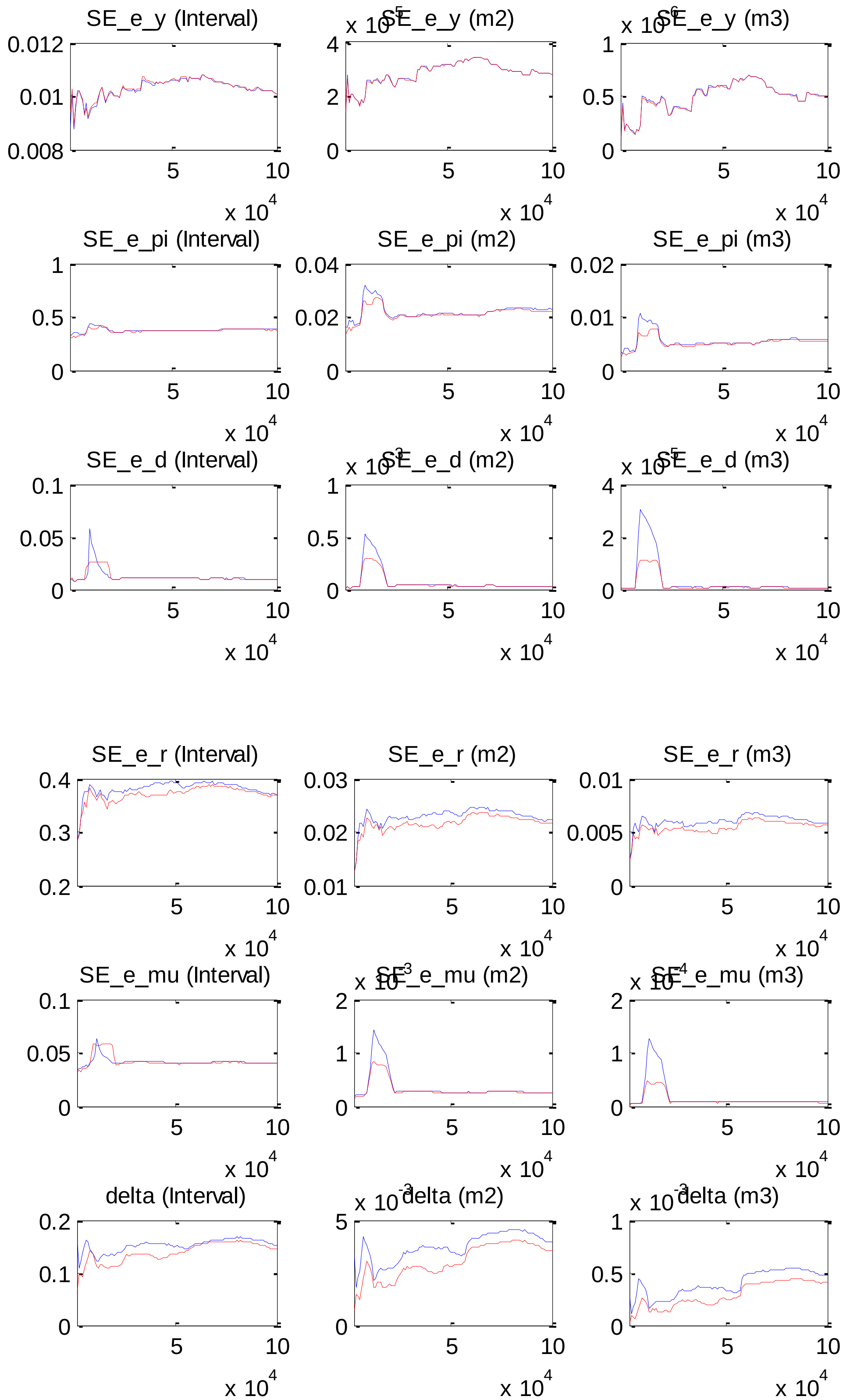
Source: Author's calculations

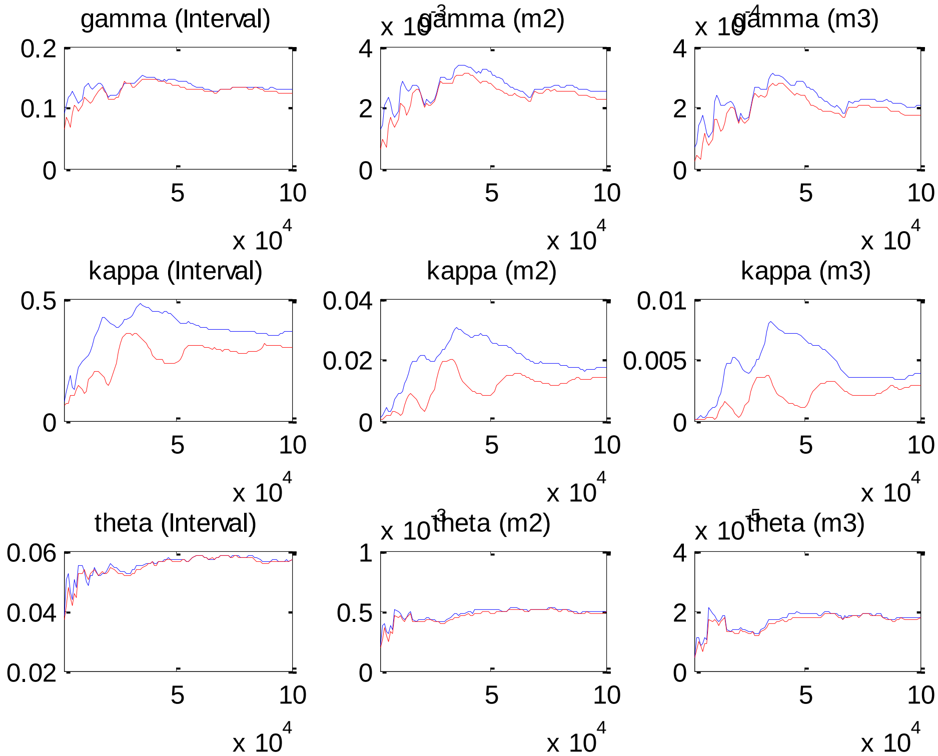
Figure A3. Smoothed variables (output gap and potential output)

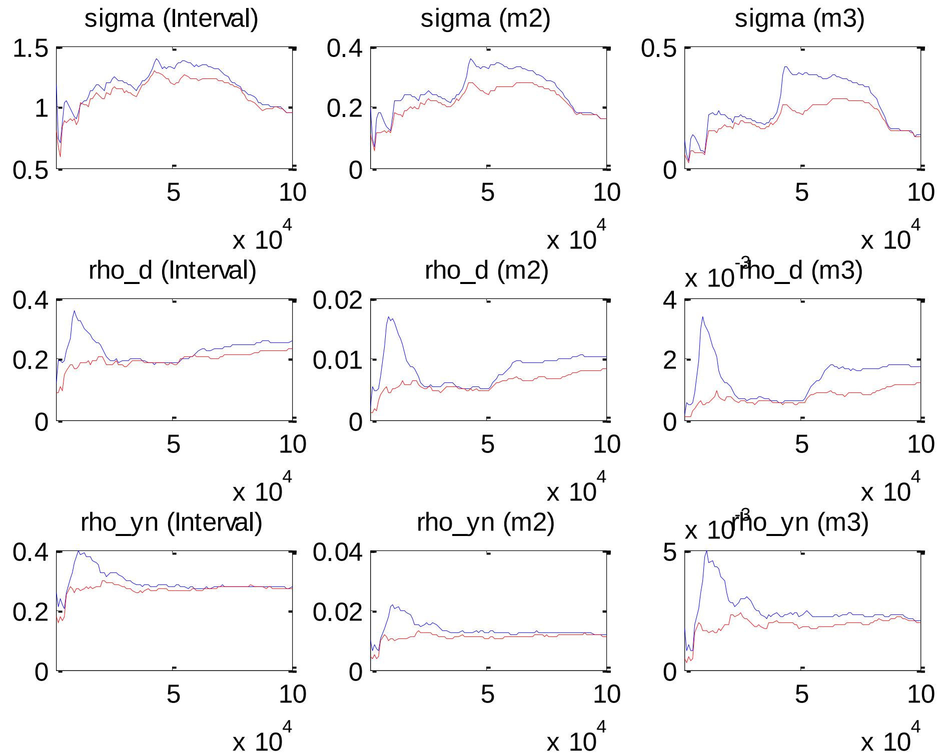


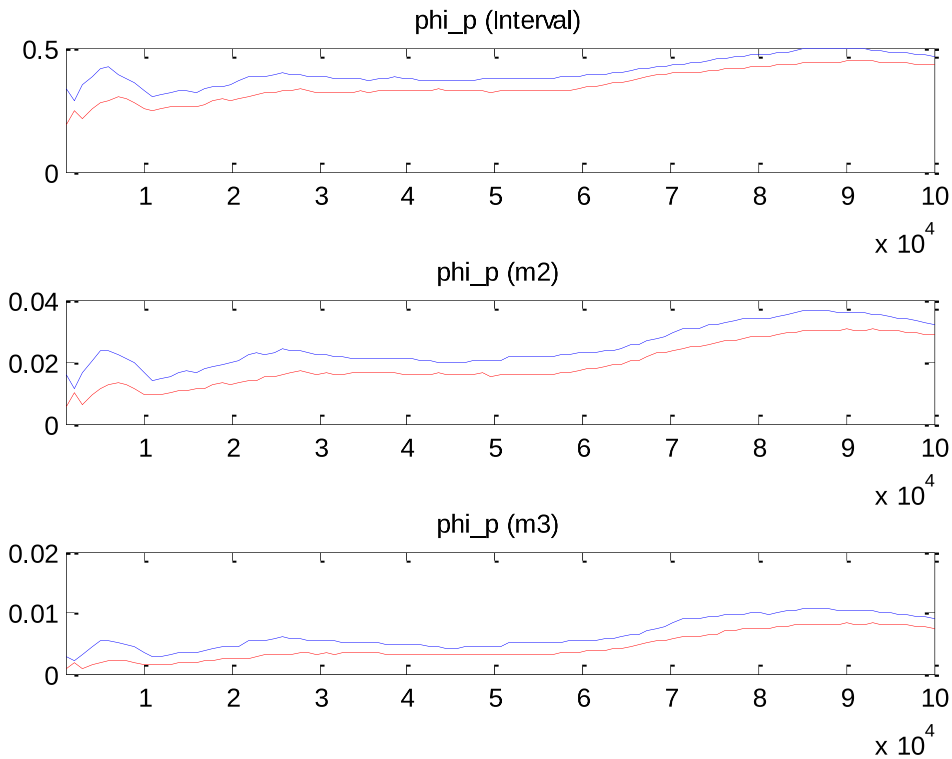
Source: Author's calculations

Figure A4. MCMC univariate diagnostic (Brook and Gelman, 1998)



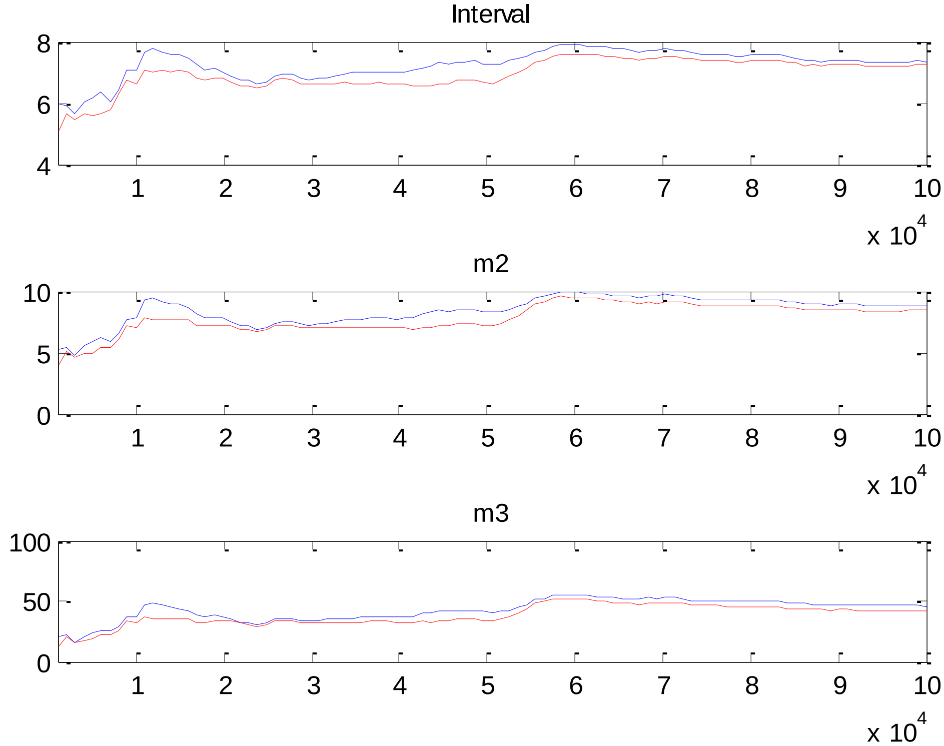

gamma (Interval)
gamma (m2)
gamma (m3)
kappa (Interval)
kappa (m2)
kappa (m3)
theta (Interval)
theta (m2)
theta (m3)


sigma (Interval)
sigma (m2)
sigma (m3)
rho_d (Interval)
rho_d (m2)
rho_d (m3)
rho_yn (Interval)
rho_yn (m2)
rho_yn (m3)



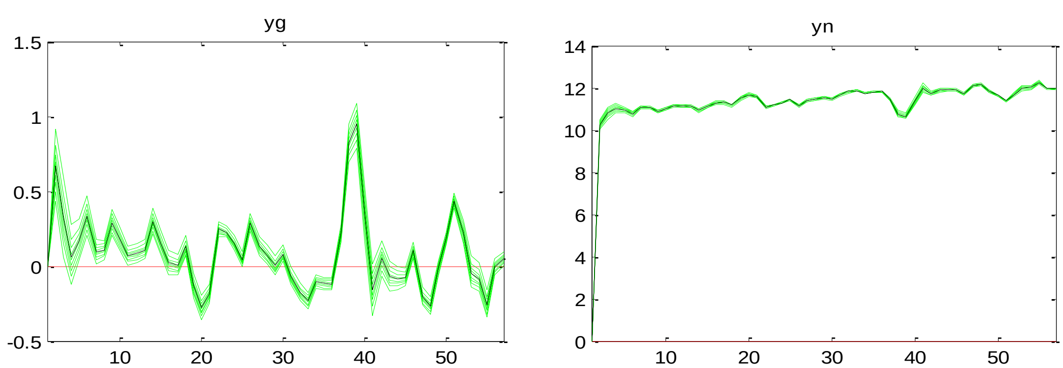
Source: Author's calculations

Figure A5. Multivariate diagnostic



Source: Author's calculations

Figure A6. One step ahead forecast of output gap and potential output



Source: Author's calculations