A Small Semi-structural Model for Thailand: Construction and Applications

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Abstract

This paper aims to document the construction of a small semi-structural model at the Bank of Thailand (BOT) as well as its applications. The model constructed here can be used as a supplementary model to existing Bank of Thailand large-scale models, namely, the BOT Macroeconomic Model (BOTMM) and the BOT DSGE. The paper outlines the procedure involved in the construction of the model, from the formulation of the model structure, its theoretical underpinnings and rationales as well as the estimation process using Bayesian techniques. The paper also shows that the model is comprehensive enough to capture the relationship and dynamics between important macroeconomic variables, yet, due to its compact size, it is sufficiently versatile to enable a wide spectrum of applications – understanding shock propagation, conducting policy analyses as well as forecasting. Further work, particularly on the development of forecasting process is well under way.

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I. Motivation

A Small Model was built to supplement existing large-scale models at the Bank of Thailand. The primary aim of the construction was to build a semi-structural model, small enough to allow tractability yet large enough to sufficiently capture the relationship between major macroeconomic variables as well as their dynamics. Moreover, due to its compact size, the model should also be sufficiently versatile to enable a wide range of applications – for example, policy analyses and forecasting. The Model in this paper was constructed to answer the calls for aforementioned issues. Bearing in mind, the construction of a Small Model by no means aims to replace or substitute other existing models since its apparent drawbacks lie in its simplicity. It is, therefore, unable to address deeper structural and policy issues, which a large-scale structural model such as the Bank of Thailand DSGE model was capable of answering.

The first version of the Model appeared in the Bank of Thailand Symposium paper on roles of exchange rate in monetary policy.[1] The Symposium version of the Model was a bilateral model of the Thai economy vis-à-vis that of the US. Accounting for comments by the Symposium paper commentators[2] and senior staffs at the BOT, the US may not truly represent 'the rest of the world'. This paper proposes a multilateral version of the model – with a weighted combination of 10 important trading partners/competitors as 'the rest of the world'. The new Model should, therefore, better reflect reality. Existing literature on small models are bilateral. Examples include Berg, Karam and Laxton (2006) model on the Canadian economy and Harjes and Ricci (2008) model on South Africa to analyze the impacts of various shocks, Aiyar and Tchakarov (2008) model on the Thai economy to assess the possible impact of a US slowdown on Thai growth, Hunt (2006) models on Iceland, New Zealand, Canada, the UK and the US to derive efficient monetary policy frontiers under a range of alternative monetary policy rules and Argov *et al.* (2007) model on Israel to examine credibility issues of monetary policy.

This paper aims to provide the details on the construction and applications of a Small Model, at the same time, enhance the understandings of the Model as well as the techniques involved. It is organized as follows: the basic features of the model will be

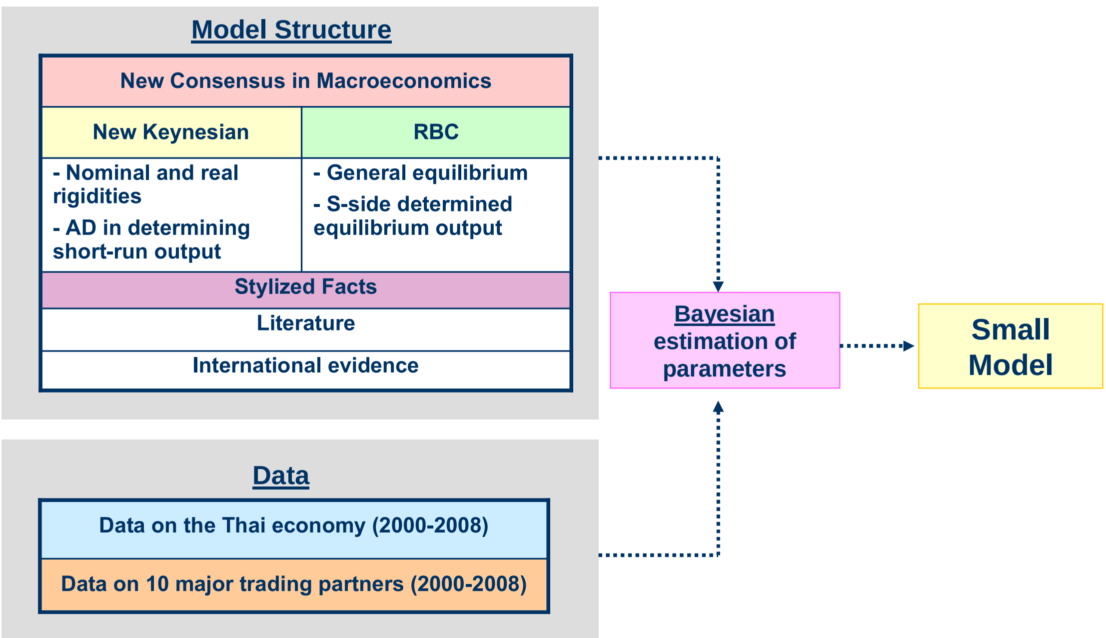
[1] See Chai-anant, Pongsaparn and Tansuwanarat (2008)
[2] Dr. Praipol Kumsap and Dr. Somchai Jitsuchon

outlined and compared against existing models in Chapter II. Chapter III focuses on the model construction and the chapter is partitioned into 4 main parts. The first part describes the model structure, along with its theoretical underpinnings and rationales, while the following part describes the data features. Bayesian estimation technique is then accounted for in the third part and the last part of Chapter III examines the estimation results. In Chapter IV, model applications are examined in three main aspects: understanding the dynamics of the economy through the model, conducting policy analyses and forecasting. Conclusion is drawn in Chapter V.

II. A Small Model: Features

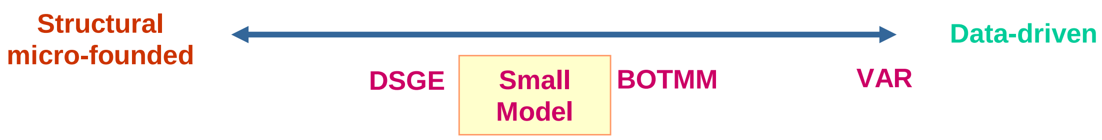
A Small Model postulates the relationship between major macroeconomic variables. The structure of the model is drawn both from the theoretical framework and stylized facts as evidenced by international empirics. The model, thus, is semi-structural in nature since each particular equation in the model can partly be traced back to its theoretical underpinnings, at the same time, modifications are made to capture empirical expositions. Once the model structure is readily set up, the parameters of the model are estimated by means of Bayesian estimation to incorporate stylized facts along with judgments and the information from the data. The details on both the theoretical framework and Bayesian techniques will be elaborated in Chapter III.

Figure 1: Model Construction



Semi-structural nature of the Small Model places it in between the two extreme classifications of models: purely data-intensive and purely structural (or theoretical) micro-founded. (Unrestricted) Vector-autoregressive model (VAR) is a good example of purely empirical regression-based model, whereby the relationship between variables is determined solely by historical data. Amongst the structural based model, a structural micro-founded Dynamic Stochastic General Equilibrium (DSGE) model can be an example. Nonetheless, recent developments on both extremes have brought them closer to the common ground. For example, Structural VAR (SVAR) imposes a theoretical structure on the VAR while empirical-based calibration and Bayesian estimation of the structural DSGE model has brought the DSGE model closer to the data. Existing Bank of Thailand models, namely Bank of Thailand Macroeconomic Model (BOTMM) and Bank of Thailand DSGE model, have both elements of empirics and theoretical framework, albeit at different proportions. While the structure of BOTMM[3] is partly governed by economic reasoning and theoretical framework, estimation of its parameters is based on regressions. On the other hand, the current structure of the BOT DSGE model[4] is micro-founded and parameters are calibrated mainly from stylized facts of the Thai economy.

Figure 2: The two extremes



III. Model Construction

This Chapter lays out each stage of the model construction. First, related literature on the theoretical framework and empirics are examined to set stage for the formation of the model structure. The model structure is then formulated consistent with the set out theoretical framework and rationales. Having obtained the model structure, the paper then investigates the data and selects the appropriate time period for estimation. Prior to estimation, Bayesian estimation technique is accounted for and compared against alternative estimation techniques. The model is then put to the data through Bayesian estimation.

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[3] See Punnarach (2008)
[4] See Tanboon (2008)

3.1 Model Structure

The underlying theoretical framework follows the New Consensus in Macroeconomics[5], a blend between New Keynesian notions of nominal and real rigidities with the real business cycle elements of general equilibrium modeling with rational expectations. In line with the New Keynesian[6] tradition, the model allows for nominal and real inertia as well as the role of aggregate demand in determining output in the short run. In the long run, macroeconomic variables gravitate towards their corresponding supply-side determined steady states or equilibrium levels. The main variables in the model are endogenous to the model in line with general equilibrium concept. Furthermore, the model set-up incorporates random shocks and rational expectations.

The model is a multi-country model featuring the Thai economy as a small open economy and the combination of 10 major trading partners/competitors, namely Japan, China, the US, the euro zone, Singapore, Malaysia, Korea, Taiwan, Indonesia and the Philippines, as the rest of the world. There are five main equations for the Thai economy: aggregate demand, aggregate supply, exchange rate equation, monetary policy rule and current account equations and three main equations characterizing the rest of the world: aggregate demand, aggregate supply and monetary policy rule equations. The model allows for internal as well as external shocks (from the rest of the world) to the Thai economy. The calculation for each variable and the complete model can be found in Appendix I and Appendix II respectively.

<u>The Thai Economy</u>

Aggregate Demand (Output)

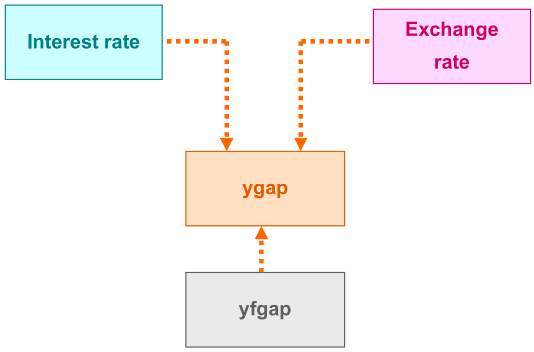
$$ygap_t = \beta_1 ygap_{t-1} + \beta_2 ygap_{t+1} - \beta_3 (r_t - r^*) - \beta_4 * (z_t - z^*) + \beta_5 ygap_t^f + \varepsilon_t^y$$

This equation to a certain extent resembles the traditional IS equation, of which the theoretical underpinnings can be traced back to household utility optimization. Household maximizes discounted stream of utility (consumption and labor supply) subjected to budget constraints (consumption expenditure and wages). Interest rate (the policy rate) is incorporated into the calculation of the present value of spending and wages. Consequently, we obtain a forward-looking part of the IS relationship ($ygap_{t+1}$) along with the real interest rate (r). To allow for some degree of habit persistence in consumption or adjustment costs of investment, lagged term ($ygap_{t-1}$) is included. As

[5] See Arestis (2007)

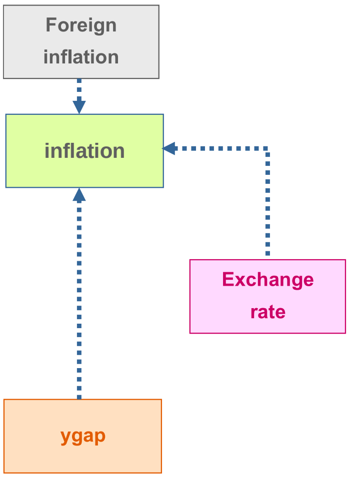
[6] See Clarida, Gali and Gertler (1999)

Thailand is a small open economy, the real exchange rate can affect the level of economic activities through the prices of imports and exports, while foreign output gap is an important determinant of export demand. The residual term captures other temporary exogenous factors such as the fiscal policy and other demand shocks.



Aggregate Supply (Inflation)

$$\pi_t^Q = \delta_1 \pi_{t+4}^A + \delta_3 \pi_{t-1}^A + \delta_2 ygap_t + (1 - \delta_1 - \delta_3)(\pi_t^{Qf} - \Delta er_t) + \varepsilon_t^\pi$$

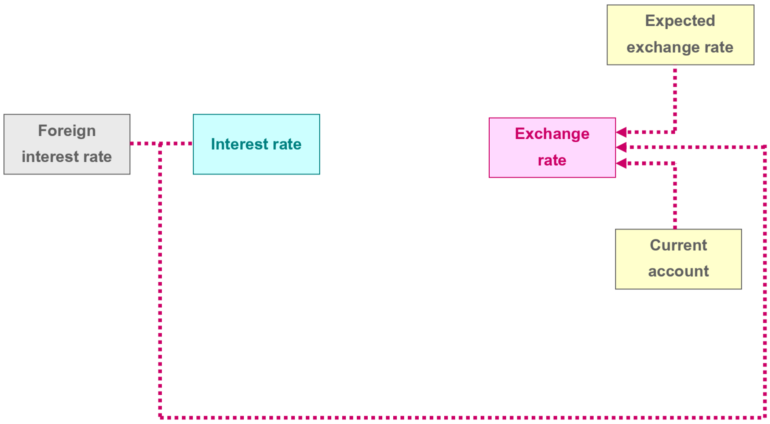


Aggregate supply or the augmented New Keynesian Phillips curve[7] in its original form was based on price-setting model by Calvo (1983). The gist of the model was profit maximization by setting prices as mark-ups over marginal costs subject to limited probability of re-setting prices in each period. Once able to reset prices, firms need to form expectations on what will happen to prices in the following periods, hence the forward-looking term of inflation. Real marginal costs are assumed to be directly related to output gap owing to a linear form of production function with a single input, which is labor. Therefore, real marginal costs, i.e. real wages are closely related to the labor supply, which in turns determines the level of output, hence output gap. The backward-looking component indicates nominal inertia, partly consequent of adjustment costs. As a small open economy, we allow for the impact of foreign inflation and changes in nominal exchange rate on domestic inflation via the change in import prices. The residual term captures other exogenous supply shocks, not present in the model, for example oil price shocks.

[7] See Svensson (2000) and Walsh (2003)

Exchange Rate Equation

$$z_t = z^e_{t+1} + \gamma_2 (r_t - r^f_t - risk)/4 + \gamma_3 ca_t + \varepsilon^z_t$$

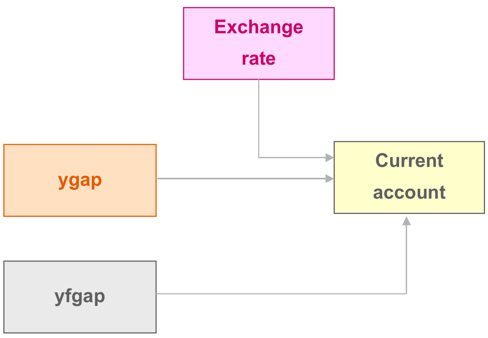


The exchange rate equation in this case is not the Uncovered Interest Parity (UIP) condition, unlike other small models in the literature cited earlier. Since the failure of the UIP was evident in the literature,[8] the exchange rate equation in this case does not restrict the relationship between interest differential and the change in exchange rate to unity like in the case of the UIP. Interest differential indicates the differential in returns on capital, thus implicitly incorporate the impact of capital flows on exchange rate. The current account position, which reflects current flows, is allowed to determine exchange rate as evident in practice. Expectation of future exchange rate does play an important role on the direction of exchange rate movement. The expectation of future exchange rate is modeled as follows:

$$z^e_{t+1} = \lambda z_{t+1} + (1-\lambda) z_{t-1} + \varepsilon^{zx}_t$$

Current account Equation

$$ca_t = \eta_1 (z_{t-1} - z_t) - \eta_2 ygap_t + \eta_3 ygap^f_t + \varepsilon^{ca}_t$$

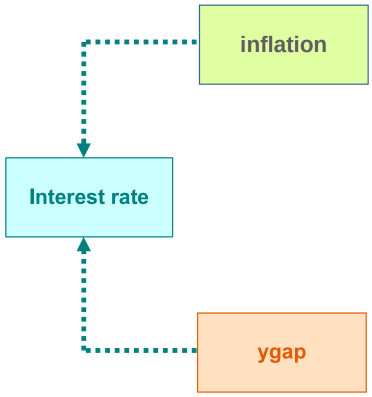


The current account position is determined by current receipt and payment flows. A large proportion of these flows is trade-related, thus exchange rate, which determines relative prices of goods and services – domestic and abroad, does have a role to play in the determination of the current account. While domestic output gap and foreign output gap determine the demand for imports and exports respectively.

[8] See Andrew *et al.* (2004), Fama (1984), Froot and Thaler (1990), MacDonald and Taylor (1992) and Isard (1995)

Monetary Policy Rule

$$i_t = \alpha_1 i_{t-1} + (1-\alpha_1)(r^* + \pi^Q_{t+1} + \alpha_2(\pi^A_{t+4} - \pi^*) + \alpha_3 ygap_t) + \varepsilon^i_t$$



In each monetary policy decision, a central bank needs to balance risks to growth and risks to inflation, hence, the policy rate reacts to inflation deviation[9] from the target and output deviation from its potential. In the literature related to optimal monetary policy, such reaction function can be derived from minimizing the authority's objective function in the form of deviations from targets of output and inflation subject to economic structure, i.e. aggregate supply and aggregate demand. The lagged interest rate features interest rate smoothing,[10] as evident in practice.

The Rest of the World

The rest of the world is represented by the weighted combination of 10 countries. The structure of the equations are similar to that of the Thai economy, except there would be no foreign influence or feedback from the Thai economy.

Aggregate Demand (Output)

$$ygap^f_t = \beta^f_1 ygap^f_{t-1} + \beta^f_2 ygap^f_{t+1} - \beta^f_3 (r^f_t - r^{f*}) + \varepsilon^{yf}_t$$

Aggregate Supply (Inflation)

$$\pi^{Qf}_t = \delta^f_1 \pi^{Af}_{t+4} + (1-\delta^f_1)\pi^{Af}_{t-1} + \delta^f_2 ygap^f_t + \varepsilon^{pf}_t$$

Monetary Policy Rule

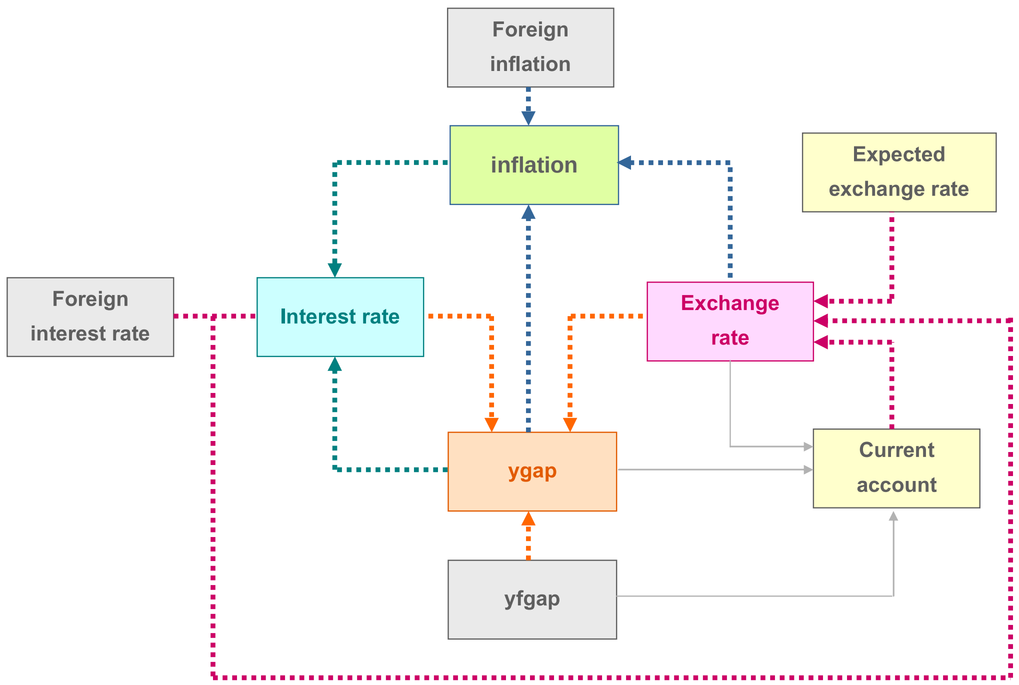
$$i^f_t = \alpha^f_1 i^f_{t-1} + (1-\alpha^f_1)\left[r^{f*} + \pi^{Qf}_{t+1} + \alpha^f_2(\pi^{Af}_{t+4} - \pi^{f*}) + \alpha^f_3 ygap^f_t\right] + \varepsilon^{if}_t$$

The overall mechanism of the model can be summarized in Figure 3. Inflation is determined by output, foreign inflation and exchange rate while output itself is driven by the real interest rate, exchange rate and foreign output. Both inflation and output then drive the interest rate via the monetary policy rule, while the interest rate feeds back into output directly and indirectly via the exchange rate.

[9] Due to lags in monetary policy transmission mechanism, the change in the policy rate needs to be forward-looking, thus forecasted inflation is more relevant in this case.

[10] See Rotemberg and Woodford (1997)

Figure 3: The Model



3.2 Data

From the model structure, it is clear that there are 4 important explicit endogenous variables: output gap, inflation, exchange rate and interest rate for the Thai economy and 3 explicit endogenous variables for the rest of the world: foreign output gap, foreign inflation and foreign interest rate. This part of the Chapter provides explanations and clarifications on each variable.

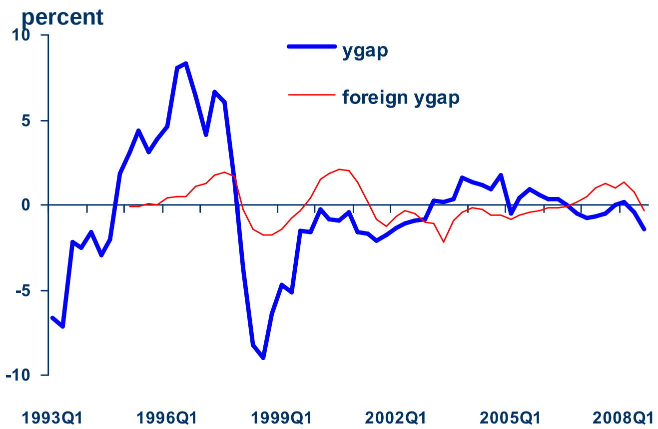
Output gap: domestic and foreign

Output gap is a widely-used concept. It is the discrepancy between the actual output and potential output[11], whereby potential output generally refers to the level of output that an economy is able to produce without resulting in inflationary pressure. To put this simply, output gap represents the degree of slackness in the economy. A positive output gap is interpreted as the output level that is above its potential, i.e. tight resource utilization, which could then lead to inflationary pressure. The calculation of output gap, however, requires estimation of unobserved potential output. Such estimation is subject to measurement errors and significant degree of uncertainty. Two of the most popular

[11] See Bank of Thailand, Inflation Report (October 2008)

techniques in estimating potential output are the production function approach and filtering approach, such as Hodrick-Prescott (HP). However, both methods have their own flaws. Univariate statistical method such as filtering is short of economic justification, while there are large degrees of uncertainty surrounding the estimates of components that go into the growth-accounting formulas in the production function method.[12] Chuenchoksan, Nakornthab and Tanboon (2008) estimated potential output for the Thai economy in the previous years to be in the range of 5.2-5.3 percent, while the output gap was estimated to be approximately zero in recent quarters. In this paper, the combination of HP-filter for the beginning of the estimation period in combination with potential growth of 5.3% for recent years and going forward is used. Foreign output gap is simply calculated from the actual output, which is the weighted combination of output, and its HP-filtered. The weight for each particular country reflects how important the country is to Thailand as an export destination.

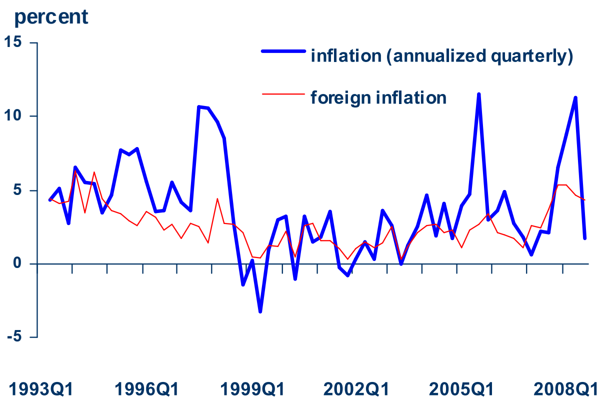
Figure 4: Output gap: domestic and foreign



Inflation: domestic and foreign

In the model, both annualized quarterly inflation and annual inflation are present, denoted by π^Q and π^A respectively. Annualized quarterly inflation is calculated from annualized percentage change in seasonally-adjusted Consumer Price Index (CPI). Annual inflation, on the other hand, is the annual change in CPI, or 4-quarter moving average of annualized quarterly inflation. Since annual inflation

Figure 5: Inflation: domestic and foreign



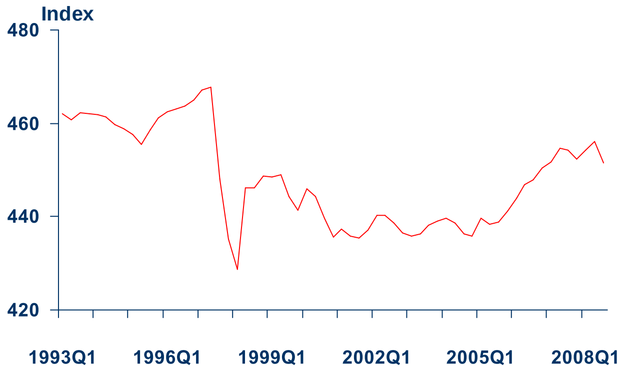
12 Areosa (2008)

is a more familiar notion of changes in the costs of living, the variables related to expectations – both forward- and backward-looking are therefore, annual inflation. However, since the theoretical framework presented earlier is quarterly in nature, endogenous inflation is also quarterly to be consistent with the rest of the model. Regarding 'the rest of the world', foreign inflation is calculated from consolidated CPI, which is constructed from the weighted combination of individual country's CPI, where the weight reflects the importance of each country as a trading partner/competitor.

Exchange rate

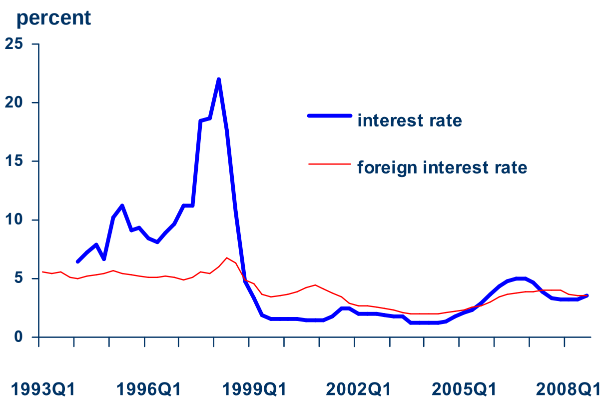
Exchange rate in the exchange rate equation is the real effective exchange rate (REER) of the baht vis-à-vis trading partners/competitors currencies corresponding to foreign inflation. According to equilibrium exchange rate literature[13], the level of exchange rate is determined by economic fundamentals. In a steady state, where output is equal to its potential and inflation is at its steady state, this yields consistent equilibrium real exchange rate.

Figure 6: Real Effective Exchange Rate



Interest rate

Figure 7: Interest rate: domestic and foreign



To be consistent with monetary policy rule, interest rate used in this case is the policy rate. In the case of foreign interest rate, it is the weighted combination of 10 policy rates, corresponding to other foreign variables described earlier.

[13] See, for example, Isard (2007) and MacDonald (2000)

The data sample can be distinctly divided into two parts – pre-2000 and post-2000 samples. Pre-2000 sample period includes the pre-crisis period, the crisis as well as the period right after. During this period, macroeconomic variables are subject to large fluctuations, moreover, there is a monetary policy regime shift to inflation targeting in 2000. To avoid inclusion of structural changes within the sample period of estimation, it is by far more appropriate to use post-2000 sample for estimation.

3.3 Bayesian estimation

The model will now be brought to the data using Bayesian estimation techniques. This part of the Chapter explains the Bayesian concept as well as accounts for the rationale behind the use of Bayesian method in comparison to other estimation techniques.

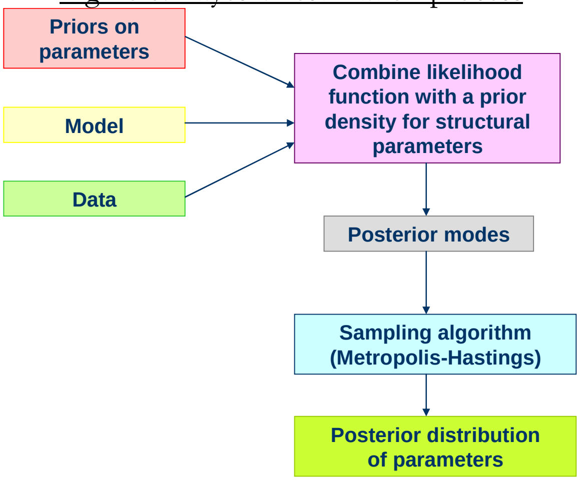
Bayesian method

Bayesian method was popularized by Schorfheide (2000)[14] to compare the fit of two competing DSGE models of consumption. The Bayesian method is a bridge between calibration and maximum likelihood via specification of priors and confronting the model with the data respectively. Priors can be seen as weights on the likelihood function to give more importance to certain areas of the parameter subspace, thus, Bayesian allows contributions from both the priors and the specific features of the data. The basics of Bayesian techniques is based on the Bayes formula, assuming that both data and parameters are random variables, where Y is a set of observable data over a sample period, M is the model and θ is the a set of the model parameters.

$$p(\theta | Y, M) = \frac{L(Y | \theta, M)\, p(\theta | M)}{p(Y | M)}$$

[14] See the application of Bayesian estimation on comprehensive DSGE models in Smet and Wouters (2003) as well as Juillard *et al.* (2006)

Figure 8: Bayesian estimation process



Information on parameters independent on the data can be summarized by a prior distribution $p(\theta)$ which could be obtained by various means – prior research (parameter distributions from estimation on different dataset), expert judgment, mathematical constraints (e.g. avoiding exploding solutions) or technical priors (e.g. failure of estimation algorithm). The prior is then combined with the likelihood function, the density of the data defined by the model given the parameters, $L(Y|\theta, M)$. The combination of the prior and the likelihood function is maximized and scaled by marginal data density ($p(Y|M)$) to yield the posterior mode, $p(\theta|Y, M)$.With these posterior mode, we can use Markov-Chain-Monte-Carlo method[15] to generate θ draws and produce posterior distribution of parameters. Bayesian estimation[16] process in this paper is programmed in Dynare[17] on Matlab[18].

Why Bayesian?

Bayesian estimation method has gained increasing popularity, particularly with DSGE-type model. Since it brought together the elements of calibration (through priors) and maximum likelihood (through the likelihood function maximization), it is able to cope with shortcomings of both calibration and maximum likelihood analysis. By allowing the consideration of priors, it avoids the posterior distribution peaking at strange points where the likelihood peaks, on the other hand, the inclusion of priors helps identifying parameters in the case where the likelihood function is flat, which are the major drawbacks of maximum likelihood method. Moreover, Bayesian estimation explicitly addresses model misspecification by including shocks or observation errors in the structural equations, at the same time, it allows model comparisons based on fit.

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[15] The Metropolis-Hastings algorithm with 2,000 replications is used with the acceptance rate of 20 percent for each draw.

[16] Refer to Kamenik (2007), Griffoli (2007) and Ermolaev *et al.* (2008) for further details on Bayesian estimation using Dynare.

[17] Dynare isa Matlab-based software provided by Michel Juillard and his team (See Dynare website for further details: www.cepremap.cnrs.fr/dynare)

[18] Versions R2006a and R2007a

Since calibration[19] does not allow formal statistical inferences, comparison between models based on fit is difficult.

Considering other methods of estimation, for example, Generalized Methods of Moments (GMM)[20]. GMM has fully developed econometric framework with inference methods for parameters and specification tests and rather easy to implement without requiring equilibrium solution. Nonetheless, GMM only consider the model in parts not 'general equilibrium' and ignore cross-coefficients restrictions, thus identification problems tend to be more pronounced. A model of the type we are constructing requires the state of 'general equilibrium' to ensure that the whole system of the model is consistent, particularly at the steady state, therefore, GMM estimation does not appear to fit in well. Other simpler estimation method such as OLS, requires certain conditions[21] be satisfied to ensure unbiasness and efficiency, moreover, estimated coefficients may not conform to economic theory. All in all, we chose Bayesian estimates over other alternatives.

Estimation results

Parameters of the model were estimated by Bayesian technique using the data sample between 2000-2008. Prior distributions were obtained from empirical evidence on Thailand and other countries[22], wherever comparable, as well as the author's calculation. Prior distribution and posterior mean of parameters are presented in Table 1.

[19] See an example on calibration in Kydland and Prescott (1982) on time to build model
[20] See an example on GMM estimation of the Euler equation in Hansen (1982)
[21] For example, homoscedasticity and no autocorrelation in the error terms.
[22] Aiyar and Tchakarov (2008), Berg *et al.* (2006), Hunt (2006), Harjes and Ricci (2008) and Argov *et al.* (2007)

Table 1: Priors and Posteriors of parameters

	priors			Post. (00-08)
	mean	Std.	distr	
β1	0.7	0.2	Beta	0.683
β2	0.10	0.03	Beta	0.086
β3	0.10	0.03	Gamma	0.073
β4	0.10	0.03	Gamma	0.057
β5	0.10	0.03	Beta	0.096
δ1	0.30	0.06	Gamma	0.196
δ2	0.25	0.06	Gamma	0.268
δ3	0.30	0.06	Gamma	0.255
α1	0.50	0.10	Beta	0.561
α2	1.50	0.50	Gamma	2.134
α3	0.50	0.10	Beta	0.537
η1	0.30	0.50	gamma	0.0003

	priors			Post. (00-08)
	mean	Std.	distr	
η2	0.90	0.50	gamma	1.323
η3	1.30	0.50	gamma	0.770
βf1	0.70	0.20	Beta	0.735
βf2	0.10	0.03	Beta	0.075
βf3	0.10	0.03	Gamma	0.094
δf1	0.20	0.06	Beta	0.195
δf2	0.30	0.06	Gamma	0.290
αf1	0.50	0.10	Beta	0.815
αf2	2.00	0.40	Gamma	1.855
αf3	0.50	0.10	Beta	0.470
λ	0.50	0.20	Beta	0.499
γ2	0.50	0.50	Gamma	1.05
γ3	0.50	0.50	Gamma	0.041

General guidelines[23] on posterior mean are satisfied. For instance, lags in monetary policy transmission mechanism imply relatively higher inertia than forward-looking components in aggregate demand equation, therefore, β_1 should be greater than β_2 while the sum of β_3 and β_4 should be less than β_1. In aggregate supply equation, the forward-looking component δ_I should be well below 0.5 from empirical evidence. Most posterior mean are also in the vicinity of the prior distribution, except for η_1 in the current account equation and β_4 in the aggregate demand equation, which are significantly smaller than the prior mean. It appears that the change in exchange rate may not have a significant impact on the current account position, which is consistent with a small impact of exchange rate on output. This could be accounted for by the domination of high-tech manufacturing products in the structure of exports rendering overall exports less sensitive to exchange rate changes.

23 See Berg *et al.* (2006)

IV. Model Applications

In this Chapter, we consider the plausible applications and usage of the model. First, we employ the model to gain understandings of the mechanism how shocks are propagated through the economy. Then we turn to policy analysis by conducting policy simulations from various dimensions, the policy rate and the real exchange rate, unanticipated and anticipated policy shocks, temporary and permanent policy shocks. The policy analysis will facilitate further understandings of policy transmission mechanism. In the last part of the application, we present here the methodology and how to utilize the model for forecasting purposes. Further studies are well under way to improve forecasting process based on a small model.

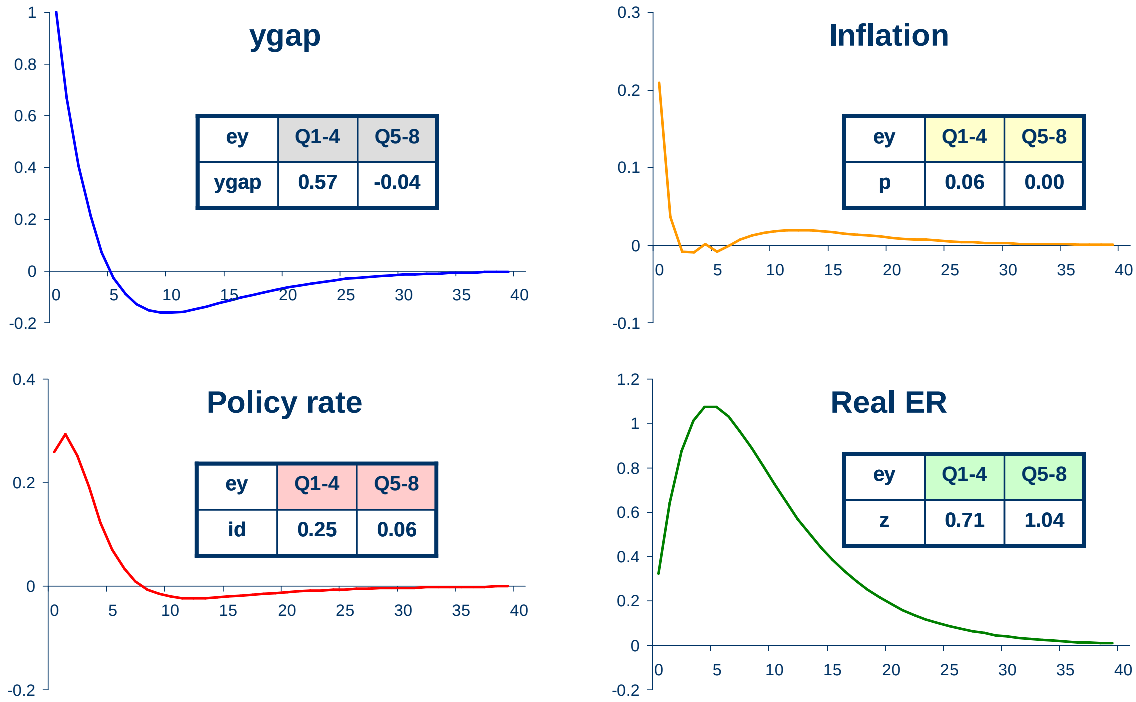
4.1 Shock propagation: understanding the dynamics

A small model can facilitate the understandings of the mechanism of the economy. In this part we examine how shocks to inflation and output propagate. The shocks we refer to here are shocks relative to the steady states.

Output shock

Since output is expressed in the form of actual output deviation from potential output, a positive shock to output equation can be interpreted as a demand shock, which increases the actual output beyond its potential. An interpretation of a demand shock could be, for example, an increase in the government expenditure. Figure 9 postulates the impact of an unanticipated temporary 1% shock to output equation.

Figure 9: A one-percent unanticipated shock to output equation



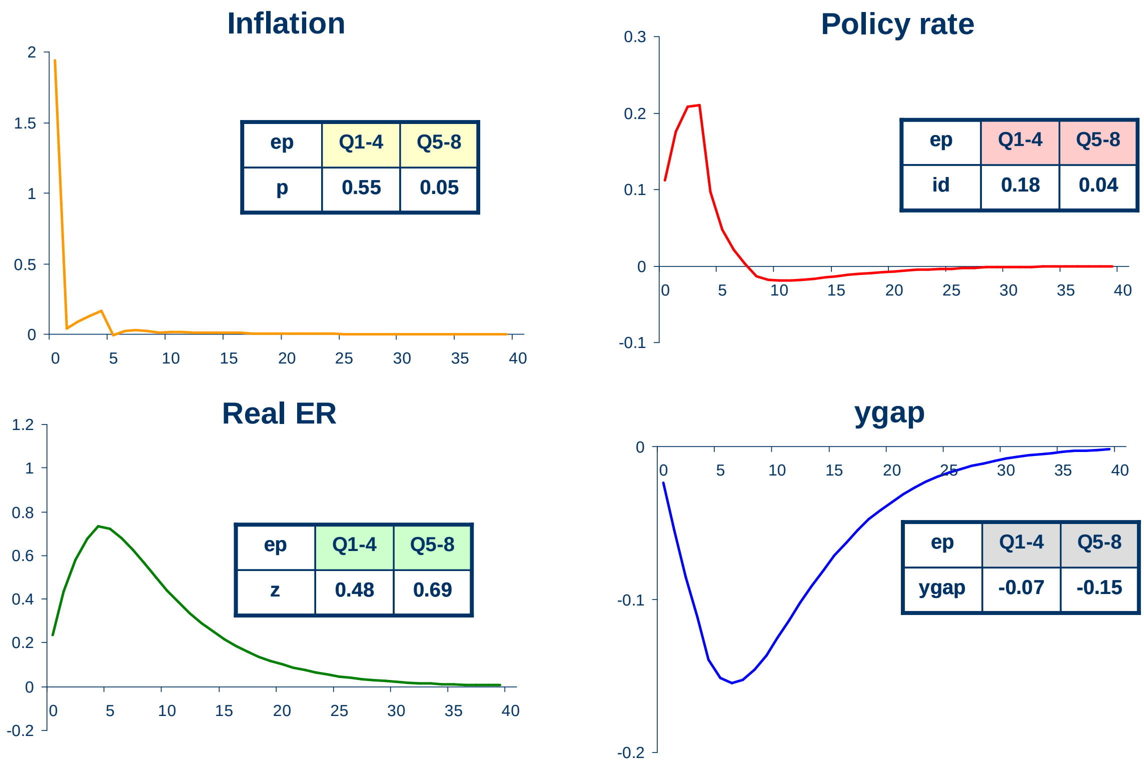
A positive shock to output equation leads to an increase in the output gap, which builds up inflationary pressure – as evident in an increase in inflation. As a result, via reaction function, increases in output and inflation then lead to a increase in the policy rate. Real exchange rate appreciates as a consequence of increases in the policy rate as well as inflation. An increase in the policy rate and appreciation in the real exchange rate altogether dampen the positive impact of the shock on output and inflation. The system adjusts and returns to the steady state.

Inflation shock

An unanticipated temporary shock of 1% to inflation equation, can be interpreted as an exogenous shock to inflation such as oil price shock, which is not related to aggregate demand. Figure 10 features the impact of the shock.

Evidently, a positive shock of 1% to inflation equation, leads to an increase in inflation by more than 1%. This is due to the dynamics of inflation, both backward- and forward-looking. An increase in inflation, leads to a gradual increase in the policy rate as well as an appreciation in the real exchange rate. Consequently, higher policy rate and real exchange rate appreciation lower aggregate demand, inducing a fall in output gap and inflation. The system then returns to its steady state.

Figure 10: A one-percent unanticipated shock to inflation equation



Clearly, a study of shock propagation helps us gain further insights into the mechanism of the economy. Such analytical study can be used to gauge the impact of various types of shocks on macroeconomic variables.

4.2 Policy analysis

Another useful application of the model is to conduct a policy analysis. The examples of policy analysis we choose here are the analysis of changes in the policy rate and exchange rate. To consider the impact of each policy instrument in isolation, we exogenize the other policy instrument. Moreover, we are able to examine the impact of the policy shock in a number of dimensions – unanticipated and anticipated as well as temporary and permanent. Policy analysis was programmed in Iris[24] on Matlab.

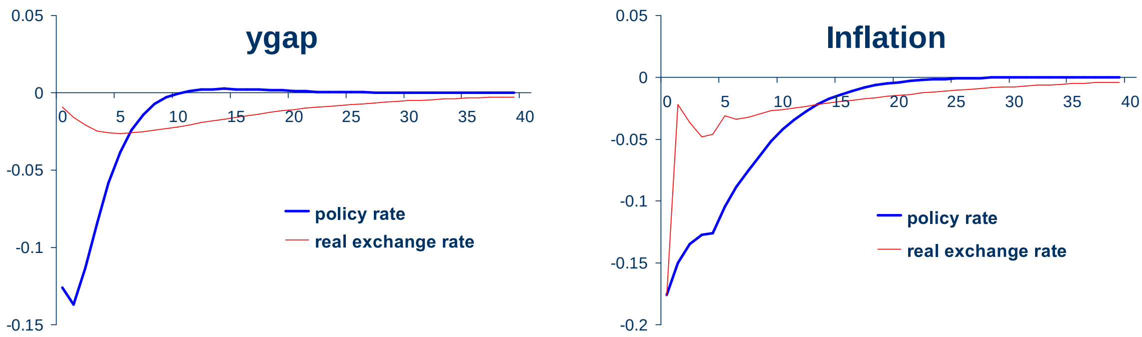
Policy rate and exchange rate

This section compares the impact of the unanticipated temporary change in the policy rate with the change in the real exchange rate. To enable the comparison, we engineer an unanticipated shock to the real exchange rate of 0.137%, which yields an equal first-period reduction in inflation as an increase in the policy rate of 1 percent. The

[24] Iris is a Matlab-based software developed by Jaromir Benes. See Iris website (www.iris-toolbox.com) for further details.

impact of a change in the exchange rate on inflation is relatively more short-lived. This is essentially because the change in the exchange rate feeds into inflation both directly through import prices and indirectly via output gap. This results in a stronger but shorter impact on inflation. Given the same first-period impact on inflation, the impact on output of the change in the real exchange rate is relatively smaller but more long-lasting than the impact of the change in the policy rate. This is unsurprising since the parameter estimates on the real exchange rate in the output equation and the current account equation are relatively small, while the long-lasting impact on output is partly due to the inertia in the exchange rate dynamics itself.

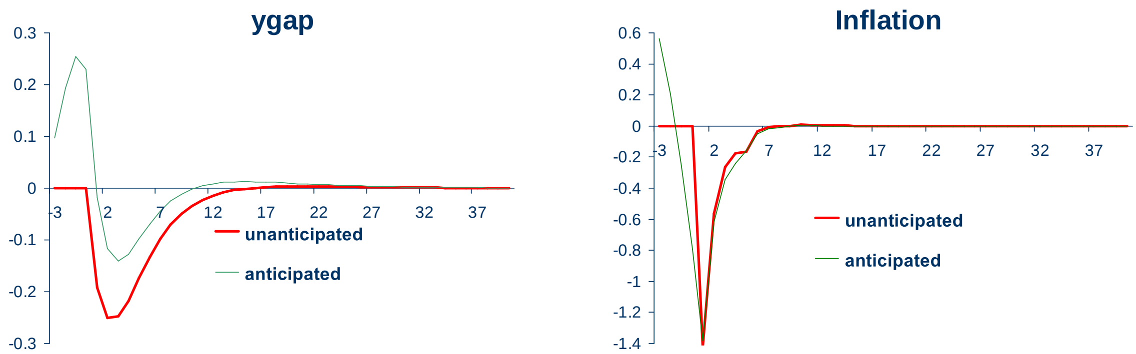
Figure 11: A 1% unanticipated shock to the policy rate and a 0.137% shock to the real exchange rate



Unanticipated and anticipated policy shock

With regard to the role of expectation on the impact of the monetary policy shock, we found that, anticipated monetary policy shock yields smaller impact on output than unanticipated at the point of impact. Furthermore, the further ahead the policy shock is anticipated, the smaller the effect would be at the point of impact. Anticipated policy shock differs from unanticipated policy shock in that the forward-looking term of inflation, which is present in the inflation equation and monetary policy rule, will be different. Without anticipation, this term will be zero until the period the policy shock arrives, therefore, inflation will be zero until then. At the point of impact, inflation along with output will be negative, consequent of the policy impact. With anticipation, on the other hand, a fall in inflation is expected and incorporated into the forward-looking inflation, leading to an implicit fall in the policy rate before the actual policy action. Consequently, before the policy action, the real exchange rate depreciates, which stimulates output and increases inflation. Once the policy shock arrives, the degree of output reduction is less. This is due to inertia in output, which somewhat softens the impact of policy changes. Intuitively, the softer impact on output of anticipated policy is consistent with rational expectation literature [See Lucas (1972) and Muth (1961)], whereby private agent incorporate the future policy action as a part of their information set and adapt their behavior accordingly.

Figure 12: Unanticipated and anticipated policy rate shock



Temporary and prolonged policy shock

The impact of the policy shock also differs by how persistent the policy shock is. The more persistent it is, the more impact it will have on inflation and output and the longer the system takes to return to its equilibrium. Persistent policy shock displaces the policy variable from its steady state, consequent in displacement of other variables from their respective steady state. Temporary shocks allow adjustments in the policy variables along with the rest of the system.

Figure 13: Temporary and permanent policy rate shock

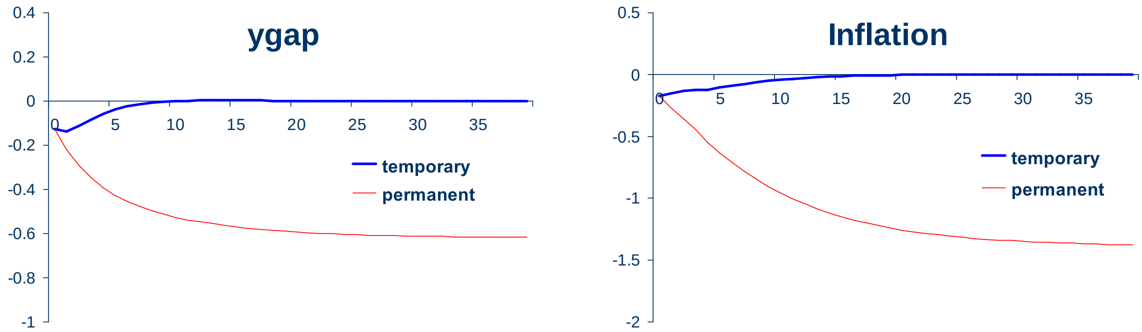
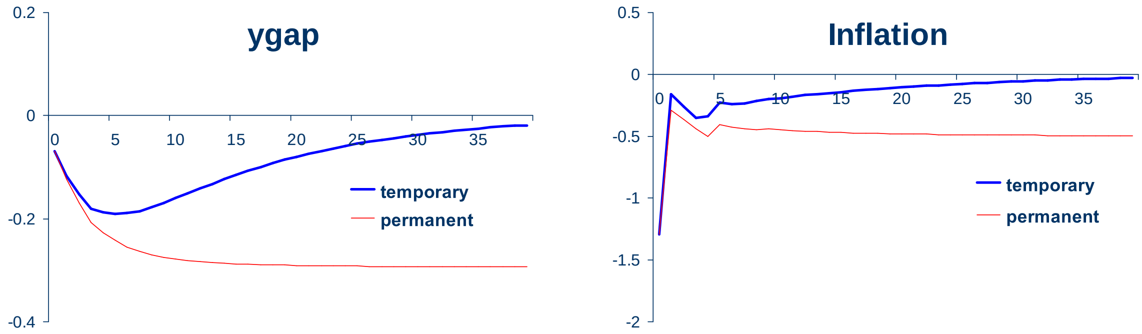


Figure 14: Temporary and permanent real exchange rate shock



4.3 Forecasting

Another useful application of a small model is its ability to do forecasting. Three important parts of forecasting are the model, the assumptions and judgments, altogether can compose a central forecast. Once the central forecast is obtained, we should also be able to determine the degree of uncertainty surrounding the central forecasts. Forecasting can be perceived as an assumption-tailored shock to the model using historical data as the base to start off with, unlike the policy simulation or shock analysis where the shock is performed on the model to see the displacement from the steady state. In this part, we demonstrate how a small model can be used to carry out forecasting. Forecasting was programmed in Iris on Matlab.

Forecasting procedure

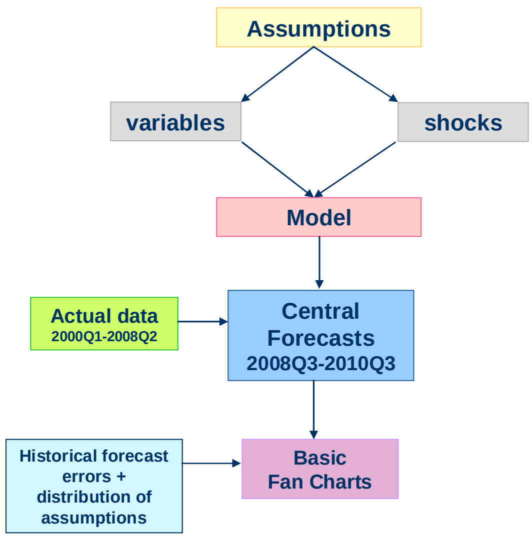
As mentioned earlier that there are 3 important parts of the forecasts – the model, the assumptions and judgments. Complications arise in the forecasting process with a small model since a small model does not explicitly incorporate certain variables of interest, particularly assumptions. Important assumptions such as oil prices, government expenditure, agricultural prices and non-fuel commodity prices do not appear as explicit variables in the model. Since these variables have important bearings on the forecasts, we need to find ways to incorporate them into the model.

In the first stage of forecasting procedure, we have to incorporate assumptions into the model. Decisions need to be made with regard to which assumptions can be input directly into the model as (exogenized) endogenous variables and which ones should be input as ε terms (or exogenous shocks), thus needs some transformation. For those that need transformation, we find the relationship between the ε terms and the assumptions, then use this relationship to provide projections on the ε terms given the assumptions. See Table 2 for classification of assumptions.

Table 2: Incorporating assumptions

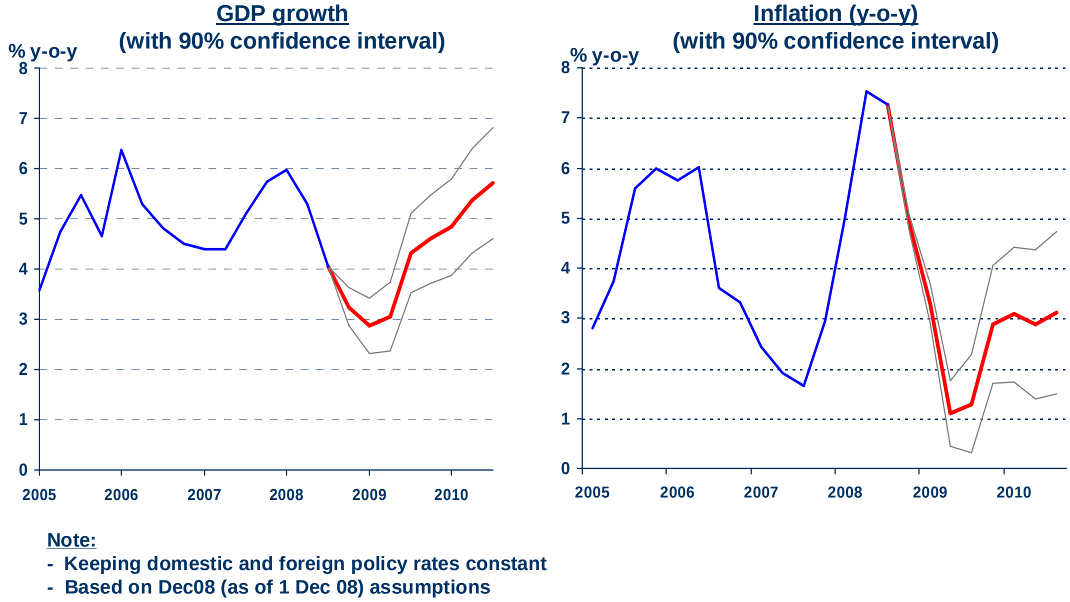
Assumption	Variables/Shocks
Public consumption/investment	ε^y
Dubai oil price, domestic farm price, non-fuel commodity price, minimum wage	ε^p
Trading partners GDP	$ygap^f$
Trading partners inflation	π^f

Figure 15: Forecasting procedure



Having transformed the assumptions into the language of the model, we then incorporate historical data into the model as the base for forecasting. In the baseline case, we assume a constant policy rate throughout the forecasting period. Once the baseline forecast is obtained, uncertainty can be incorporated in the form of fan charts. At the current state, uncertainty in the form of upper and lower bound is derived from historical model forecast error. The area enclosed by the upper and lower bounds constitutes 90% probability. Figure 16 showed baseline forecasts along with its upper and lower bounds based on December 08 assumptions. Bearing in mind, there is no judgments involved in this forecast, hence the upper and lower bound is symmetric. Moreover, at the current state, uncertainty from assumptions has not yet been incorporated. The future work plan includes incorporating the joint distribution of assumptions along with the model historical forecast errors and judgments to make the fan charts more realistic.

Figure 16: Baseline forecast



V. Conclusion

A Small semi-structural model was constructed based on a model structure, which achieved a good blend between the theoretical framework and empirical evidence. Moreover, the model was taken to the data by means of Bayesian estimation, the details of which was clearly spelled out. The paper also demonstrated the applications of the model in several dimensions: postulating the dynamics of shock propagation and policy analyses from different angles, namely the use of the policy rate and the real exchange rate, unanticipated and anticipated policy, temporary and permanent policy shocks. Furthermore, the model can also be used for forecasting.

To fully utilize the model's versatility, further work is well under way to explore the model capability – particularly in the areas of forecasting. Future work plan includes an improvement in assumption conversion process, an incorporation of judgment into the forecasts as well as a construction of fan charts to incorporate forecasting uncertainties both from the model and the joint distribution of assumptions. Once completed, the model can be used to complement other large-scale models in producing forecasts and performing policy analyses to facilitate the monetary policy decision process.

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Appendix I: Variable definitions and calculations

- y_t and y^f_t is the real GDP for Thailand and the rest of the world (10 major trading partners/competitors) respectively
- $ygap_t = 100 \times \log(y_t / potential\ y_t)$
- $ygap^f_t = 100 \times \log(y^f_t / Hodrick\text{-}Prescott\ filtered\ y^f_t)$
- CPI_t and CPI^f_t are (seasonally-adjusted) consumer price indices for Thailand and the US respectively (1994 = 100)
- $\pi^Q_t = 400 \times \log(CPI_t/CPI_{t-1})$ and likewise $\pi^{Qf}_t = 400 \times \log(CPI^f_t/CPI^f_{t-1})$
- $\pi^A_t = (\pi^Q_t + \pi^Q_{t-1} + \pi^Q_{t-2} + \pi^Q_{t-3})/4$

  and similarly $\pi^{Af}_t = (\pi^{Qf}_t + \pi^{Qf}_{t-1} + \pi^{Qf}_{t-2} + \pi^{Qf}_{t-3})/4$
- i_t is the policy rate (14-day repurchase rate until 2006 Q4 and 1-day repurchase rate from 2007 Q1 onwards)
- i^f_t is the weighted average of 10-countrty policy rates (in percentage per annum)
- $r_t = i_t - \pi^Q_{t+1}$ and $r^f_t = i^f_t - \pi^{Qf}_{t+1}$
- er_t is the nominal effective exchange rate of the Thai baht vis-à-vis 10 trading partners/competitors
- z_t is the real effective exchange rate of the Thai baht vis-à-vis 10 trading partners/competitors
- $\Delta er_t = \Delta z_t + \pi_t - \pi^f_t$
- CA_t is the ratio of current account balance to GDP (in percentage)

<u>Appendix II</u>: The Small Model

The Thai economy

$$ygap_t = \beta_1 ygap_{t-1} + \beta_2 ygap_{t+1} - \beta_3 (r_t - r^*) - \beta_4 (z_t - z^*) + \beta_5 ygap_t^f + \varepsilon_t^y$$
$$\pi_t^Q = \delta_1 \pi_{t+4}^A + \delta_3 \pi_{t-1}^A + \delta_2 ygap_t + (1 - \delta_1 - \delta_3)(\pi_t^{Qf} - \Delta er_t) + \varepsilon_t^p$$
$$z_t = z_{t+1}^e + \gamma_2 (r_t - r_t^f - risk)/4 + \gamma_3 CA_t + \varepsilon_t^z$$
$$z_{t+1}^e = \lambda z_{t+1} + (1 - \lambda) z_{t-1}$$
$$CA_t = \tau_1 (z_{t-1} - z_t) - \tau_2 ygap_t + \tau_3 ygap_t^f + \varepsilon_t^{CA}$$
$$i_t = \alpha_1 i_{t-1} + (1 - \alpha_1)\left[r^* + \pi_{t+1}^Q + \alpha_2 (\pi_{t+4}^A - \pi^*) + \alpha_3 ygap_t\right] + \varepsilon_t^i$$

The rest of the world (the US)

$$ygap_t^f = \beta_1^f ygap_{t-1}^f + \beta_2^f ygap_{t+1}^f - \beta_3^f (r_t^f - r^{f*}) + \varepsilon_t^{yf}$$
$$\pi_t^{Qf} = \delta_1^f \pi_{t+4}^{Af} + (1 - \delta_1^f)\pi_{t-1}^{Af} + \delta_2^f ygap_t^f + \varepsilon_t^{pf}$$
$$i_t^f = \alpha_1^f i_{t-1}^f + (1 - \alpha_1^f)\left[r^{f*} + \pi_{t+1}^{Qf} + \alpha_2^f (\pi_{t+4}^{Af} - \pi^{f*}) + \alpha_3^f ygap_t^f\right] + \varepsilon_t^{if}$$

Identities

$$\Delta z_t = \Delta er_t - \pi_t + \pi_t^f$$
$$\pi_t^A = (\pi_t^Q + \pi_{t-1}^Q + \pi_{t-2}^Q + \pi_{t-3}^Q)/4$$
$$r_t = i_t - \pi_{t+1}^Q$$
$$\pi_t^{Af} = (\pi_t^{Qf} + \pi_{t-1}^{Qf} + \pi_{t-2}^{Qf} + \pi_{t-3}^{Qf})/4$$
$$r_t^f = i_t^f - \pi_{t+1}^{Qf}$$