Modelling East Asian economies in a small open economy VECM: the influences of international and domestic shocks*

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December 2011

Abstract

The contribution of international and domestic shocks to macroeconomic outcomes in Asian countries is of significant policy importance to both these economies and their trading partners. This paper applies a data and theory-consistent SVECM model which specifically identifies and separates temporary and permanent shocks to Singapore, Thailand, the Philippines, Malaysia and Indonesia. We show the differences and similarities in these economics in response to shocks and assess whether Chinese shocks have a more pronounced effect than those originating from the US.

Keywords: Open economy model, structural vector error correction model, Asia, China
JEL classification: F41, C32

*We are grateful to Enzo Weber for comments and Sharon Raymond and Jay Gordon for research assistance. Author contacts are Dungey: mardi.dungey@utas.edu.au; Vehbi: mtv20@cam.ac.uk.

1 Background

Economic modelling for open economies in an empirically coherent and theoretically acceptable manner is a pressing problem. The increasing global financial integration of Asian economies over the past few decades and the effects of two significant financial crises in 1997-1998 and 2007-2008 emphasise the effects of international conditions in models of Asia, making this an important research imperative.

Developments in the modelling frameworks used by many central banks internationally have favoured the use of DSGE models. These have a coherent theoretical structure based on fundamental microeconomic relationships and can be reduced to a tractable empirical specification. However, they also present a number of problems. Firstly, the parameter estimates produced across a range of countries do not seem to reflect the diversity observed in the data (see for example Canova and Sala, 2007, Beltran and Draper, 2008). Second, these models have not yet produced credible open economy results; for example in Justiniano and Preston (2010), the DSGE does not come close to replicating the basic observed correlation between Canadian and US GDP growth.

An alternative approach is provided by Structural Vector Autoregression (SVAR) models, which combine empirical coherence with restrictions imposed by a broad theoretical framework chosen by the researcher. A number of contributions use Structural VARs for identifying structural shocks in small open economies, such as the work of Dungey and Vehbi (2010), Dungey and Pagan (2009), Kim and Roubini (2000), Cushman and Zha (1997), Mountford (2005) and Buckle et al. (2007). A distinctive characteristic of these studies is the evolution of the way in which they identify the structural shocks from the system.

This paper takes the open economy SVAR approach developed in Dungey and Pagan (2009) and Dungey and Vehbi (2010), previously applied to Australia and the UK respectively, and applies it to countries in the ASEAN region. Specifically, the applications are to Singapore, Thailand, the Philippines, Malaysia and Indonesia. The purpose of the paper is to investigate the historical evolution of domestic responses to domestic and external output shocks originating from the USA and China during the period 1986-2009. Despite their structural differences, the majority of the industrialized countries in the East Asian region can be considered as small open economies which are heavily dependent on the economic performance of the US. The most dramatic instance of this is the recent US originated sub-prime crisis, which adversely affected most of the East Asian economies. Policy responses to the sub-prime crisis varied across the Asian economies depending on individual economic stances prior to the onset of the crisis, and ranged from significant tightening of monetary policy in Korea and Taiwan to fiscal stimulus in China and Japan.

A key advantage of the modelling framework in comparison with the methods used in previous studies is that it specifically accounts for the mixed nature of the data and potential cointegration between some of the variables. The approach takes into account, and indeed takes advantage of, the known empirical and theoretical relationships linking open economies to the international environment. The novel identification scheme of the structural shocks on the other hand ensures that the model has similar theoretical underpinnings to a standard New Keynesian DSGE model.

This paper contributes to a mounting literature on small open economy modelling, including for example Dennis et al. (2007), Leitemo (2006), Ravn (1992) and Beenstock and Longbottom (1981), and to the emerging literature on combining methods of identification in VAR models in Dungey and Fry (2009). The model strives to maintain empirical coherence in the spirit of Akram and Nymoen (2009) who demonstrate the policy-related importance of models providing sound representations of the underlying data. The combination of identification methods harnesses the empirical properties of the data, employing a mix of I(1) and I(0) variables while identifying and recovering the effects of permanent and temporary shocks.

2 Related Literature

Several papers have examined the effects of structural shocks on East Asian economies using open economy structural VARs. A commonly raised motivating question is the feasibility of an Asian monetary union, along the lines of the European Monetary Union. Using a three variable VAR model comprising global, regional and local outputs of 7 East Asian economies and European countries, Chow and Yoonbai (2003) compare the degree of homogeneity among the East Asian countries with that of EMU countries. Their main finding is that each country in the region is sufficiently unique implying that it would be costly to adopt a common currency peg. Zhang et al. (2004) also use a three variable SVAR model to identify the respective demand, supply and monetary policy shocks in 10 East Asian countries in order to explore the feasibility of a monetary union in the region. Overall, they do not find strong evidence in favour of the integration. While Huang and Feng (2006), using a four variable SVAR model find results in line with Zhang et al. (2004), they also point out that several countries in the region have symmetric responses to shocks with equal magnitudes suggesting the possibility of a feasible monetary union in the future. More recently, Hsu (2010) finds that most East Asian economies have become relatively symmetric in terms of economic shocks and adjustments implying that a common currency area may become viable through deepening regional integration. A recent working paper by Zhang et al. (2010) is closest to our study from a methodological perspective, using a structural VAR model with block exogeneity to investigate whether external shocks originating from the USA played a dominant role in influencing the macroeconomic fluctuations in East Asia during the period 1978-2007. The authors find that the influence of US shocks on real output fluctuations in the East Asian region are very strong.

Our methodology contributes to and extends the existing literature in two main areas. First, by incorporating long-run cointegration restrictions, the model specifically accounts for stationary and non-stationary data properties and explicitly identifies permanent and temporary shocks. Second, the model framework strongly emphasises the role of exchange rates in the transmission of foreign shocks to the domestic economy by allowing the real exchange rate to react to all variables contemporaneously. This in turn is a reflection of the forward looking nature of this variable. This paper also uses extended samples which include the recent sub-prime related financial crisis.

3 Theoretical Framework

The standard macroeconomic framework for small open economies with inflation targeting monetary policy represented in contemporary research revolves around a three equation model. Closed economy representations include those in the standard graduate text book of Woodford (2003), while extensions to the open economy can be found in Gali and Monacelli (2005), Monacelli (2005) and the papers gathered in Gali (2008). The Gali and Monacelli (2005) framework underpins the theoretical specification of this paper.

Building from standard New Keynesian assumptions of utility maximizing consumers in an economy with profit maximizing producers who face Calvo pricing and where consumers have preferences over both domestic and foreign produced consumption goods, the model can be summarised with three standard equations representing an open economy IS curve, a Phillips curve and an exchange rate equation. In the Monacelli (2005) extension to the Gali and Monacelli (2005) approach, imperfect pass-through of exchange rate shocks is assumed, and we maintain that case here. In addition to these three equations the system includes a monetary policy reaction function taking the form of a Taylor rule. The structure of the theoretical model takes the form:

$$y_t = \mu E_t y_{t+1} + (1-\mu) y_{t-1} - \phi(r_{t-1} - E_{t-1}\pi_t) + \theta_1 \Delta q_t + \theta_2 y_t^* + \varepsilon_{AD_t}. \tag{1}$$

$$\pi_t = \delta E_t \pi_{t+1} + (1-\delta)\pi_{t-1} + \lambda y_t + \theta_3 \Delta q_t + \varepsilon_{AS_t}. \tag{2}$$

$$r_t = \rho r_{t-1} + (1-\rho)(\beta E_t \pi_{t+1} + \gamma y_t) + \varepsilon_{MP_t} \tag{3}$$

$$E_t \Delta q_{t+1} = (r_t - E_t \pi_{t+1}) - (r_t^* - E_t \pi_{t+1}^*) - \varepsilon_{RER_t}. \tag{4}$$

where y_t and y_t^* represents domestic and foreign output gaps, r_t and π_t are the interest rate and inflation, q_t is the real exchange rate and ε_{AD_t}, ε_{AS_t}, ε_{MP_t} and ε_{RER_t} represent the aggregate demand, aggregate supply, monetary policy and real exchange rate shocks respectively. The parameter loadings set comprises $\{\mu, \phi, \delta, \rho, \theta_1, \theta_2, \theta_3\}$.

The theoretical specification should not be viewed as a constraining influence on the empirical coherence of the application. Rather the theory helps to motivate and justify empirical restrictions. Thus, we do not propose to follow the Bayesian approach of partially-calibrating this model and estimating the deep parameters of the particular theoretical specification. Rather, the empirical relationships in the data will be dominant, but identification will be aided by the use of a coherent theoretical framework. This will be achieved using the specification outlined in the next section.

4 Econometric Specification and Identification

Suppose that the economy is described by a VAR (p) model of the form

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_p y_{t-p} + u_t \tag{5}$$

where $A_i's$ are $(n * n)$ coefficient matrices, y_t is a $(n \times 1)$ vector of observable variables and u_t is an $(n * 1)$ vector of unobservable error terms with $u_t \sim (0, \Sigma_u)$.

Assuming that all the variables are at most difference stationary the generic model can be written as a VECM of the form

$$B_0 \Delta y_t = \Pi^* y_{t-1} + \Gamma_1^* \Delta y_{t-1} + ... + \Gamma_{p-1}^* \Delta y_{t-p+1} + \varepsilon_t, \tag{6}$$

where the $\Gamma^{*\prime}s$ are $(n \times n)$ matrix of short-run coefficients, Π^* is the structural matrix and ε_t is a $(n \times 1)$ structural form error with zero mean and covariance matrix I_K. B_0 is a $(n \times n)$ matrix of contemporaneous relations among the variables in y_t.

Assuming that the B_0 matrix is invertible, equation (6) can be written as

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + ... + \Gamma_{p-1} \Delta y_{t-p+1} + u_t, \tag{7}$$

where $\Pi_t = B_0^{-1}\Pi^*$, $\Gamma_j = B_0^{-1}\Gamma_j^*$ $(j = 1, ..., p-1)$ and $u_t = B_0^{-1}\varepsilon_t$ which relates the reduced form errors, u_t', to the underlying structural errors ε_t. When Π has a reduced rank of r$\leq n-1$ then Π can be written as $\Pi = \alpha\beta^{'}$where β is a $(n \times r)$ matrix that contains the long run relationship, α is a $(n \times r)$ matrix of the speed of adjustment coefficients, and u_t is a white noise error with zero mean and covariance matrix Σ_u. Substituting Π into equation (7) produces the model in error correction form

$$\Delta y_t = \alpha\beta^{'} y_{t-1} + \Gamma_1 \Delta y_{t-1} + ... + \Gamma_{p-1} \Delta y_{t-p+1} + u_t. \tag{8}$$

As the $u_t's$ are the reduced form residuals and are generally strongly correlated, the effects of a single shock on the whole system can not be isolated without imposing restrictions on the system. Multiplying both sides by B_0 gives

$$
\begin{aligned}
B_0 u_t &= \varepsilon_t \\
\Sigma &= B_0^{-1} \Sigma_\varepsilon (B_0)',
\end{aligned}
\tag{9}
$$

where Σ, B_0, and Σ_ε are all $(n \times n)$ matrices. Exact identification of Σ_ε requires the imposition of $(n^2 - n)/2$ additional restrictions on B_0^{-1}. While traditional VAR models uses a Cholesky type recursive identification scheme to identify the structural errors, the structural approach differs by the ability to choose any restrictions on B_0 so as to achieve identification.

The existence of cointegration among the $I(1)$ variables could also provide extra identifying restrictions. According to Granger's Representation Theorem (Johannsen, 1995), equation (8) has the following Beveridge-Nelson Moving Average (MA) representation (see Lutkepohl and Kratzig, 2004 for details).

$$
y_t = F \sum_{i=1}^{t} u_i + \sum_{j=0}^{\infty} F_j^* u_{t-j} + y_0^*, \tag{10}
$$

where the matrix $F = \beta_\perp (\alpha'_\perp (I_n - \sum_{i=1}^{p-1} \Gamma_i) \beta_\perp)^{-1} \alpha'_\perp$ and y_0^* contain the initial values. The rank of F is $n - r$ where r is the number of cointegrating vectors, thus there are $n - r$ independent common trends. The second term in the expression is an infinite order polynomial with coefficients F_j^* going to zero as $j \to \infty$. Hence it represents the transitory shocks to the system. The long run effects of shocks are represented by the first term in equation (10), $F \sum_{i=1}^{t} u_i$ which captures the common stochastic trends. The common driving stochastic trends are the variables $\alpha'_\perp \sum_{i=1}^{t} u_i$ where their factor loadings are given by $\beta_\perp (\alpha'_\perp (I_n - \sum_{i=1}^{p-1} \Gamma_i) \beta_\perp)^{-1}$. Replacing the u_t by their structural counterparts we obtain

$$
y_t = F \sum_{i=1}^{t} B_0^{-1} \varepsilon_t + \sum_{j=0}^{\infty} F_j^* B_0^{-1} \varepsilon_{t-j} + y_0^* \tag{11}
$$

where the effects of short and long run structural shocks can be obtained. The long run effects can be captured by $F B_0^{-1}$ which has a rank $n - r$ since $rk(F) = n - r$

and B_0 is not singular. Therefore, while r of the structural shocks have transitory effects, $n - r$ of them will have a permanent effect (linearly independent) and can be restricted to zero providing $r(n-r)$ independent restrictions. Given exact identification of the Σ_ε requires $(n^2 - n)/2$ independent restrictions, $r(n-r)$ of them can be identified using the cointegration relationship alone.

Using the Wold decomposition theorem Δy_t can be written as

$$\Delta y_t = C(L)u_t \tag{12}$$

or as its structural counterpart as

$$\Delta y_t = C(L)B_0^{-1}\varepsilon_t, \tag{13}$$

where $C(L)$ is a polynomial of order q in the lag operator. Assuming that the first $(n-r)$ shocks are permanent (ε_{1t}) we can write Δy_t as

$$\Delta y_t = C(L)B_0^{-1}\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix} \tag{14}$$

For the remaining shocks ε_{2t} to be transitory requires

$$FB_0^{-1}\begin{pmatrix}0_{(n-r)*r}\\ I_{r+k}\end{pmatrix} = F\alpha = 0 \tag{15}$$

which implies that $\alpha_1 = 0$, where α_1 is the $(n-r)*r$ matrix of adjustment coefficients of the $I(1)$ variables that give rise to the permanent shocks driving the cointegrating relationships (see Pagan and Pesaran (2009) for details). An important implication of this result is that it precludes the use of error correction terms in equations that define the permanent shocks.

Using (15) the permanent component of Y_t can be written as

$$\Delta y_t^p = FB_0^{-1}\varepsilon_t. \tag{16}$$

Given equation (16) and following Dungey and Pagan (2009) equation (8) can be written in "gap deviation" form $\widetilde{y}_t = y_t - y_t^p$ as the following

$$B^*(L)\Delta\widetilde{y}_t = \alpha^*\beta' y_{t-1} - \Sigma_{j=1}^{p-1}\Delta y_{t-j}^p + B_0^{-1}\varepsilon_t \tag{17}$$

where $\alpha^* = B_0^{-1}\alpha$. Since the gap variables are correlated with both the error correction terms and the changes in permanent components, exclusion of error correction terms will result in misspecification (see Dungey and Pagan, 2009). Therefore the conventional use of output gap will be replaced by the differenced output together with the corresponding error correction term for this variable.

4.1 Handling exchange rate regime changes

A significant feature of recent history for many ASEAN economies is the change from fixed or managed exchange rate regimes to a floating environment during the 1997-1998 Asian crisis. This poses considerable challenges to the empirical identification of the model presented above. In particular, in a fixed exchange rate regime, a monetary policy reaction function of the form of equation (3) does not pertain, nor do the Phillips or IS curves react to exchange rate changes in the same way across fixed and floating regimes. Furthermore, the exchange rate equation given in equation (4) is not relevant. One way to address this problem within the New Keynesian framework described above is to augment the expression of equations (1) to (4) to incorporate the regime shift as follows:

$$\begin{aligned} y_t &= \mu E_t y_{t+1} + (1-\mu) y_{t-1} - \phi(r_{t-1} - E_{t-1}\pi_t) + \theta_2 y_t^* + \qquad (18) \\ &\quad I_t \left[\mu E_t y_{t+1} + (1-\mu) y_{t-1} - \phi(r_{t-1} - E_{t-1}\pi_t) + \theta_1 \Delta q_t + \theta_2 y_t^*\right] + \varepsilon_{AD_t} \qquad (19) \end{aligned}$$

$$\pi_t = \delta_1 E_t \pi_{t+1} + (1-\delta_1)\pi_{t-1} + \lambda_1 y_t + I_t\left[\delta_1 E_t \pi_{t+1} + (1-\delta_1)\pi_{t-1} + \lambda_1 y_t + \theta_3 \Delta q_t\right] + \varepsilon_{AS_t}. \qquad (20)$$

$$r_t = I_t\left[\rho r_{t-1} + (1-\rho)(\beta E_t \pi_{t+1} + \gamma y_t)\right] + \varepsilon_{MP_t} \qquad (21)$$

$$E_t \Delta q_{t+1} = I_t\left[(r_t - E_t \pi_{t+1}) - (r_t^* - E_t \pi_{t+1}^*) - \varepsilon_{RER_t}\right]. \qquad (22)$$

where I_t is an indicator variable taking the value 1 in the floating exchange rate regime period and 0 in the fixed rate period. This provides a straightforward means of accounting for the structural shift induced by the exchange rate regime. Its advantage is that it retains the use of longer term relationships in the model, particularly the relationship across international output, while respecting that the relationships between different parts of the economy must change with such a dramatic policy change. This representation can be easily accommodated within the econometric framework laid out in the previous subsection. However, given the lack of sufficient data available in the sub periods identified as fixed and floating regimes, this adaptation is not practically feasible. Instead, we estimate the individual country models using the whole sample period of 1986Q1-2009Q4, while imposing a step dummy for the crisis period to avoid parameter instability.

5 Empirical Results

The model presented in Section 4 suggests that data for output, inflation, interest rates and exchange rates are pertinent inputs to the model. Figures A1-A5 in Appendix 1 map these data from 1986Q1 to 2009Q4 for each of Singapore, Thailand, Philippines, Indonesia and Malaysia. Variable definitions and their sources are provided in Table 1.

The most immediately notable feature of these figures is the Asian crisis in 1997-98. The switch from a fixed to floating exchange rate regime is immediately obvious for all countries with exception of Singapore which already had a floating exchange rate regime prior to Asian crisis. A serious recession eventuated in many cases and IMF support programs were implemented shortly thereafter. Likewise, inflation shows a dramatic decrease and as a general consequence of the adoption of an inflation targeting/floating exchange rate regime, interest rate volatility generally declines. Singapore and the Philippines weathered the crisis more easily than the other economies and didn't experience prolonged periods of recession. For Singapore, this was due to the fact that it was already operating under floating exchange rate regime prior to the crisis.

A further feature in most of the countries' data is the relatively large rise in inflation in 2007-08 and the subsequent falls in 2009, which were associated with oil price volatility. Consequently, in the following, we augment the specification of the Phillips curve with exogenous oil price inflation; Kim and Roubini (2000) are among a number of authors who include oil prices in VAR models.

Table 2 presents Augmented Dickey Fuller (ADF) test results of the data for each of the country's variables. In each case the results show that the output and exchange rate series can be regarded as non-stationary. Inflation rates are well known to fail to reject the null of a unit root. In general, this outcome represents a highly persistent price process which is estimated with poor precision. In the case of the inflation rates for Singapore, Philippines, Thailand and Malaysia, the AR (1) coefficients in ADF regressions are 0.49, 0.68, 0.34 and 0.29 respectively. Therefore, it is appropriate to treat the inflation rates as I(0) processes together with the inflation rate of Indonesia which is shown to be stationary. Interest rates for all countries except Thailand are found to be stationary. All interest rates are treated as I(0) processes, given that they are the policy instruments of monetary authorities.

This section implements the SVECM models for each country, for the sample period of 1986Q1 to 2009Q4. Two additions to the generic specification are made. The first is the addition of a dummy for the East Asian crisis period, defined as 1997Q3 to 1998Q4 in each equation. The second is the addition of oil price inflation as an exogenous variable entering the AS equation. As the interest rate and inflation rate are I(0) variables, this is respected by the addition of pseudo-ecm terms, consisting of the lagged level of the dependent variable to correct for the levels effect which would be lost if using a standard VECM. The structural form specification of the system can be represented as follows, using the form of equation (6) and clearly showing the restrictions in the system.

$$
\begin{aligned}
&\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ b_{21}^0 & 1 & 0 & 0 & 0 \\ 0 & b_{32}^0 & 1 & 0 & 0 \\ 0 & b_{42}^0 & b_{43}^0 & 1 & 0 \\ b_{51}^0 & b_{52}^0 & b_{53}^0 & b_{54}^0 & 1 \end{bmatrix} \Delta Y_t \\
= &\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & \alpha_{32} & 0 \\ 0 & \alpha_{42} & \alpha_{43} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} \end{bmatrix} \begin{bmatrix} \beta_{11} & 1 & 0 & 0 & \beta_{51} \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix} Y_{t-1} \\
+ &\begin{bmatrix} b_{11}^l & 0 & 0 & 0 & 0 \\ b_{21}^l & b_{22}^l & 0 b_{23}^l & b_{24}^l & b_{25}^l \\ 0 & b_{32}^l & b_{33}^l & 0 & b_{35}^l \\ 0 & b_{42}^l & b_{43}^l & b_{44}^l & 0 \\ b_{51}^l & b_{52}^l & b_{53}^l & b_{54}^l & 1 \end{bmatrix} \Delta Y_{t-l} + \begin{bmatrix} 0 \\ 0 \\ c \\ 0 \\ 0 \end{bmatrix} Oil + \begin{bmatrix} \varepsilon_t^{AD*} \\ \varepsilon_t^{AD} \\ \varepsilon_t^{AS} \\ \varepsilon_t^{MP} \\ \varepsilon_t^{RER} \end{bmatrix}
\end{aligned} \tag{23}
$$

The set of restrictions defined in equation (23) follow several considerations regarding the structure of the model. First, in line with the small open economy assumption, the foreign economy does not respond to the current values of domestic variables. More importantly, the international linkages apply only through output with no direct linkages through inflation and interest rates, reflecting a New Keynesian IS curve. The monetary authority sets the interest rates with respect to current values of output and inflation. Finally, the real exchange rate equation reacts to all of the variables contemporaneously, reflecting the fact that exchange rates are forward-looking variables (Kim and Roubini, 2000).

5.1 Singapore

The impulse responses for the Singaporean economy to foreign and domestically sourced aggregate demand shocks are presented in Figures 1 and 2.

A shock to the foreign output equation results in permanently higher foreign output and permanently higher domestic output which reflects the permanent nature of the shock as shown in Figure 1. Initially, Singaporean output rises by around 0.8 of the rise in the foreign output, after three years the multiplier of the foreign shock on domestic output is greater than 1, settling at around 1.06 in the longer term. This implies that the Singaporean economy will bear the full impact of foreign output shocks in the long run, reflecting its high degree of openness. The output shock leads to an increase in Singaporean inflation resulting in a corresponding response from the monetary authorities to increase interest rates. As a result this inflationary pressure eases after approximately 4 years. The initial appreciation of Singapore's domestic currency is followed by a permanent depreciation due to the decline in real interest rates and the permanent increase in domestic output.

Domestically sourced output shocks result in a permanently higher output in Singapore although the long run multiplier on the shock is not as high as for the foreign sourced shocks; see Figure 2. The inflation increases as a result of the increased demand which is followed by a higher interest rate response of the central bank to control inflation. The increased output results in a permanent currency appreciation despite the decline in real interest rates. We do not report the other impulses from the model, but rather note that the model does not display price puzzle or exchange rate puzzle.

Figure 3 presents the contributions of shocks associated with each of foreign aggregate demand, domestic aggregate demand, aggregate supply, monetary policy and the real exchange rate to the variation in output over the entire sample period.

As initial conditions may be important, analysis is restricted to exclude the 2 years following the beginning of the sample. The most striking feature of the figure is the dramatic change in the relative importance of foreign and domestic aggregate demand shocks to variation in Singaporean output. Prior to 2001, domestically sourced shocks were the largest contributor peaking from March 1994 until the middle of 1997 corresponding to the onset of the Asian crisis. In June 2001, the foreign shocks exceeded the contribution of domestic shocks for the first time. After that time, the contribution of foreign sourced aggregate demand shocks to Singaporean output can be seen to remain high and positive while the contribution of domestic shocks shows a steep decline. This situation persisted until September 2007, after which the positive impact of foreign sourced shocks is dramatically reduced. This is unsurprising given the onset of the global financial crisis - and additionally, a relatively large negative component sourced from inflationary shocks. Singapore experienced strong inflation followed by deflation in this period, even after accounting for the effects of oil price movements at this time.

The effects of the inflationary pressures in Singapore late in the sample can also be observed in Figure 4 which depicts the historical decomposition of inflation variation over the sample.

The relatively large contribution of positive inflation shocks in the period, from March 2008 to the end of the sample, dwarfs all other sources during the period. At the same time, it can be seen that there are substantial offsetting effects on inflation from foreign sourced output shocks, again presumably relating to the downturns experienced by many economies in response to the global financial crisis. Domestic output shocks in the final two years of the sample initially contributed positively to inflation variation but more recently have been offsetting inflation pressures. Around the time of the Asian financial crisis, the impact of lower domestic output shocks can be clearly seen as reducing pressure on inflation while at the same time, foreign output shocks were providing some inflationary stimulus. In the period after the Asian financial crisis, foreign output shocks contributed more negatively than domestic output shocks and from 2004 to 2008 foreign inflation shocks were an important source of downwards pressure on inflation volatility.

In summary, the Singaporean economy has had a dramatic change of focus regarding the sources of output variation over the sample, with foreign based shocks becoming more significant than they were in the pre-Asian crisis period. Domestic conditions on the other hand have become less influential.

5.2 The Philippines

The empirical identification of the model for the Philippines is initially the same as that given in equation (23) including the crisis dummy variable and exogenous oil price inflation in the Phillips curve equation. We find that it is feasible to estimate this model for the entire sample period of 1986Q1 to 2009Q4, despite the change in exchange rate regime during this sample period.

The impulse responses of the Philippines economy to shocks sourced from foreign output are shown in Figure 5.

In this case, the long run effect of the foreign output shock on domestic output is lower than in Singapore, presumably a reflection of its less open nature. The effect dissipates very slowly over the 10 year period shown. Although there is no initial significant positive inflationary response to the shock initially, inflation picks up as the higher growth rates continue. The inflation returns to equilibrium in the long-run in response to higher interest rates. This may be a result of the mixed exchange rate regime data in the sample. The higher real interest rates are clearly associated with an initial appreciation of the Philippine peso.

A domestically sourced output shock shown in Figure 6 also results in higher real interest rates. Although the initial impact on inflation is significantly positive, it rapidly reverts to an insignificant effect, while nominal interest rates are significantly higher. In this case the Philippine peso appreciates rapidly yet this is subsequently eroded over the 10 year horizon. The presence of the price puzzle in this model also indicates that it is not yet a satisfactory representation of the Philippines economy.

The historical decomposition of output in the Philippines is shown in Figure 7. It shows the substantial impact of domestic economic output shocks throughout the period. These were particularly prominent during the decade from 1993-2003, with the impact of the Asian crisis causing a pronounced effect in 1997. This may well be interpreted as the model failing to incorporate sufficient richness to model the Philippine economy. Other potential indicators of development, population growth, climatic conditions and the effects of the US military presence may need to be incorporated in the model. The figure also shows the increased effect of international output shocks to domestic output variation during the period from

1995. This effect builds until 2001 after which international effects have a less pronounced, but nevertheless positive impact on domestic output variation. In the last two years the impact of the international financial crisis on reduced international demand is clearly evident in the negative contribution of international output shocks to domestic output variability.

Figure 8 shows the historical decomposition of inflation for the Philippines. The contributions of shocks other than domestic shocks to inflation variation are minimal. This reflects that the model is limited in providing an empirical specification of the inflationary process in the Philippines.

5.3 Thailand

After experiencing a period of export-led economic growth during 1986-1995, the Thai economy began slowing by the end of 1995 as a result of weakening export performance. Heightened by growing concerns regarding the economy's ability to maintain a fixed exchange rate regime, capital inflows reversed substantially, exerting significant pressure on the exchange rate. The subsequent devaluation of Thailand's currency in July 1997 is largely responsible for igniting the Asian financial crises. Using the same identification structure applied in Singapore and Philippines models, we estimate the model for Thailand for the entire sample period of 1986Q1-2009Q4. Figure 9 shows the impulse response functions of Thailand's domestic variables to a US shock. The permanent US shock increases Thailand's output significantly, with an average multiplier of 1 within the first year following the shock. As a result, inflation increases and the central bank responds by increasing interest rates above the level of inflation thereby reducing the prevailing excess demand and increased inflation. Consequently, the currency appreciates as a result of higher real interest rates.

The impulse responses from a domestically sourced output shock are shown in Figure 10, showing an output, inflation and interest rate increase in response to the shock. The long run response of output is similar in magnitude to the original shock, while the inflation response peaks in the second year following the shock and takes over 5 years to fully dissipate. Interest rates follow a similar pattern which mirrors the inflation outcome. This is not unexpected since Thailand follows an inflation targeting monetary policy regime for the period post-1997.

Figure 11 shows the historical decomposition of Thailand's domestic output. It can be seen that the contribution of foreign shocks begin to increase following the Asian crisis, reflecting the increasing openness of the economy due to the floating exchange rate regime and matches the contribution of domestic shocks after 2006. Figure 12 shows the historical decomposition of Thailand's inflation and strongly suggests that the majority of the inflationary pressure in Thailand is driven by domestically sourced inflationary shocks (traditionally associated with supply shocks in many VAR models).

5.4 Malaysia

Figure 13 shows the impulse responses of real output growth in Malaysia to the US output shock. It can be seen that domestic output increases at the same pace as both inflation and foreign output increase. The interest rate increase is only slightly higher than the increase in inflation which results in an initial currency appreciation. The overall responses to a domestic output shock, shown in Figure 14, follow a similar pattern to other countries examined.

The historical decomposition of Malaysian output is shown in Figure 15. Similar to the case of Singapore, we observe an increase in the contribution of foreign sourced shocks following the Asian crisis, and a corresponding decline in the contribution of domestically sourced shocks. The historical decomposition of inflation shown in Figure 16, on the other hand shows that inflation is rather persistent and is mainly affected from its past behaviour.

5.5 Indonesia

Indonesia's output response to a foreign output shock shown in Figure 17, is relatively milder than in other economies, and not persistent. Inflation initially drops which is followed by a subsequent decline in interest rates. Inflation picks up again after 8 quarters and in turn, interest rates increase. The initial increase in real interest rates causes currency appreciation which quickly reverts as real interest rates decline. The overall responses of Indonesia's endogenous variables to domestic and foreign shocks, shown in Figure 18, on the other hand shows that further work is needed to enhance the model dynamics.

The historical decomposition of output shown in Figure 19 reflects the relatively closed structure of the Indonesian economy where the domestically sourced shocks play a major role in output variations. The negative impact of foreign sourced shocks is evident after 2008. The decomposition of inflation shown in Figure 20 on the other hand does not point to any major contributor to the inflation variation where all the shocks have sizeable impacts.

6 The Source of Foreign Output Shocks

Over the past two decades China has had a growing influence on the world economy; in 2004 it became the world's third largest exporting economy, with export growth of over 500% between 1992 and 2005 (Amiti and Freund, 2010). Given its proximity to the ASEAN economies, the influence of China on these economies is perceived to be of great importance. In the following section we attempt to observe whether this growing influence is discernible in the empirical time series evidence. There are a number of difficulties in attempting this problem: potentially the two most pressing in this paper are first, that the story of China is one of growth, so that a static parameter model will only capture the average and not time-varying effect, the second data availability restricts us to examining only relatively limited aspects of the Chinese economy.

Bearing these caveats in mind we approach the problem by comparing how well the individual models of the ASEAN economies perform under two alternative specifications; the first when the US represents the source of external output shocks and the second when China represents the source of external output shocks. Thus, in the model, we replace y^* with Chinese output for the second case. The following analysis presents the resulting output, inflation, interest rate and exchange rate responses for each of the ASEAN economies when faced with the same sized output shock originating from either the US or from China.

6.1 US Output Shock

Panel (a) of Figure 21 shows that output in Singapore is most sensitive to a foreign shock followed by Thailand and Malaysia, where the Singaporean response is almost double that in Thailand. These results are unsurprising given the high degree of openness of these 3 countries with the shares of total trade to GDP of 283, 146 and 108 percent in 2009, respectively. The responses do not monotonically relate to the trade openness - Thailand is more open than Malaysia in these measures and yet Malaysia has a larger initial response to the shock than Thailand (although this is reversed in the longer term). This may also reflect the changes in regime occurring for both Thailand, which adopted a flexible exchange rate and inflation targeting during the Asian crisis, and Malaysia which conversely reduced capital inflow and decreased exchange rate flexibility during the crisis. Alternatively, in the Philippines and Indonesia the expansionary response of output to a foreign output shock is less pronounced, consistent with the relatively more closed characteristics of these two economies (trade represents 51 and 39 percent of GDP respectively in these economies).

Figure 21 panel (b) presents the responses of inflation to the US output shock. It can be observed that the responses of Singapore, Thailand and Malaysia are highly synchronized where inflation picks up following the increased aggregate demand in the economy. The responses of Philippines and Indonesia on the other hand are negative with a more pronounced deflationary effect in the case of Indonesia. The impact of the recession in Indonesia following the IMF programs there in 1997 on these results needs to be examined further.

The interest rate responses to the US shock presented in panel (c) of Figure 21 show that the central banks react to the inflation increases by increasing the interest rates with the exception of Indonesia where an initial reduction in interest rates is observed. This price puzzle for the Indonesian economy leads us to suspect further analysis on the Indonesian situation is required. This is consistent with the inflationary outcomes observed previously.

Finally, panel (d) of Figure 21 presents the responses of each countries real exchange rate to the US output shock. The initial impact of the shock on the currencies of all countries is an appreciation which is very short lived in the case of Singapore. This is partly a reflection of the relatively mild interest rate response we observed in the case of Singapore. However, it is important to note that it is notoriously difficult to explain the behaviour of real exchange rates.

6.2 Chinese Output Shock

The impulse responses of each of the five ASEAN countries to an external output shock originating from China are shown in Figure 22. Overall, the output responses are positive in the short and medium term with the exception of Philippines, where a small negative result is evident. On the other hand, the Chinese shocks are comparatively less important as a source of real output fluctuations in East Asia. This is consistent with the findings of Zhang et al. (2010). The inflation and interest rate responses are positive in the short-run with the exception of Philippines and Indonesia. All the countries experience currency depreciations with similar magnitudes in response to the output shock from China. The evidence from this section strongly suggest that when modelling East Asian economies, more explanatory power is gained by using the US economy as the proxy for global economic conditions than by using China. This is despite China's growing importance to these economies and to the world as a whole. Some of this may be due to the importance of the US as the final source of much consumer demand for Asian production as well as the fact that many international trade contracts continue to be priced in US dollars. Both of these factors lead to the concept that the US is a closer indicator of international economic conditions than fluctuations in Chinese conditions at this point. The exchange rate responses to the Chinese output shock shown in panel (d) of Figure 22, compared with the exchange rate responses to US output shocks in panel (d) of Figure 21 strongly support the importance of the US dollar in international transactions which impact the Asian economies. Further work is required in this area which specifically incorporates both the US and China as external influences allowing for the interaction between these economies in order to more effectively model the effect of international conditions on Asian economies.

7 Conclusion

Modelling the macroeconomic relationships in the small open economies of Asia presents a number of challenges. The relatively short data samples and changing monetary policy and exchange rate regimes during the past 20 years have proven to be significant impediments to the implementation of many modelling frameworks. This paper has, however, successfully applied a SVECM framework with underlying modern New Keynesian theoretical foundations taking into account the nature of the underlying data. We harness the mixed I(0) and I(1) nature of the data to provide additional identification and specifically account for the presence of cointegrating relationships between variables where the empirical evidence is compelling. The framework is applied to each of the economies of Singapore, Malaysia, Thailand, the Philippines and Indonesia. In all but the case of Indonesia we are able to find a specification which does not result in the macroeconomic price and exchange rate puzzles common in this modelling framework. This is a particularly rewarding outcome in a challenging empirical environment. We present the historical analysis of the evolution of shocks in each country, and are able to successfully tie these to the underlying economic events during the sample period.

The framework particularly allows us to investigate the response of the Asian economies to international shocks. In the first instance we examine how the economies of Singapore, Malaysia, Thailand, the Philippines and Indonesia respond to shocks generated via the US economy. We show that the responses generally reflect the degree of openness of each of these economies - with Singapore (the most open) responding to a far greater degree to US generated shocks than Indonesia (the least open economy). The growth of the Chinese economy over the last two decades leads us to consider the alternative of shocks driven by Chinese output shocks in a separate implementation of the model. We find that the Chinese shocks do not have the same impact as US-generated shocks on any of the Asian economies which we suggest reflects both the role of the US as the source of much final consumer demand for Asian trade and the importance of the US dollar as the currency of denomination for much of international trade and portfolio flow. An important extension of work in this area will be to accommodate the inter-linkages between the US and China in understanding the ultimate sources of shocks and the direct and indirect effects that influence the economic outcomes in the Asian economies.

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Table 1: Variable Sources

	Description	Source
$y*$	log US Real Gdp VOL constant prices, National Currency	IFS
y	log Real GDP, National Currency	IFS, Datastream, Tilak Abeysinge's homepage (http://courses.nus.edu.sg/course/ecstabey/Tilak.html)
Π	CPI, annual.	IFS, Datastream
r	Treasury Bill Rate, %	IFS, Datastream
q	Real Exchange Rate, (nominal exchange rate:local currency per unit of foreign currency $\times P^{*}/P$	IFS
oil	Oil prices	Spot West Texas Intermediate FRED Database

Table 2: Augmented Dickey Fuller Unit Root Tests

Singapore						
Levels	y^{*}	y	Π	r	q	oil
Singapore						
ADF Statistic	-1.92	1.59	2.33	3.21*	-1.30	9.01*
Crit Val (5 %)	-3.45	3.45	2.89	2.89	2.89	1.94
Philippines						
ADF Statistic	-1.92	1.91	1.66	3.63*	1.47	9.01*
Crit Val (5 %)	-3.45	3.45	2.89	2.89	2.89	1.94
Thailand						
ADF Statistic	-1.92	2.18	2.11	2.48	1.73	9.01*
Crit Val (5 %)	-3.45	3.45	2.89	2.89	2.89	1.94
Indonesia						
ADF Statistic	-1.92	1.96	6.64*	3.50*	1.81	9.01*
Crit Val (5 %)	-3.45	3.45	2.89	2.89	2.89	1.94
Malaysia						
ADF Statistic	-1.92	1.70	2.44	3.50*	1.69	9.01*
Crit Val (5 %)	-3.45	3.45	2.89	2.89	2.89	1.94

*denotes rejection of the null of a unit root at 5% confidence level.

Singapore: Impulse Responses and Historical Decompositions

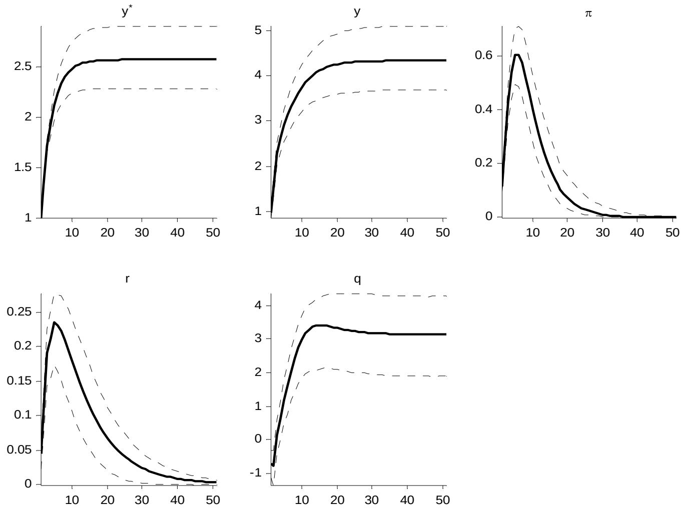


FIgure 1: Response to Foreign Output Shocks

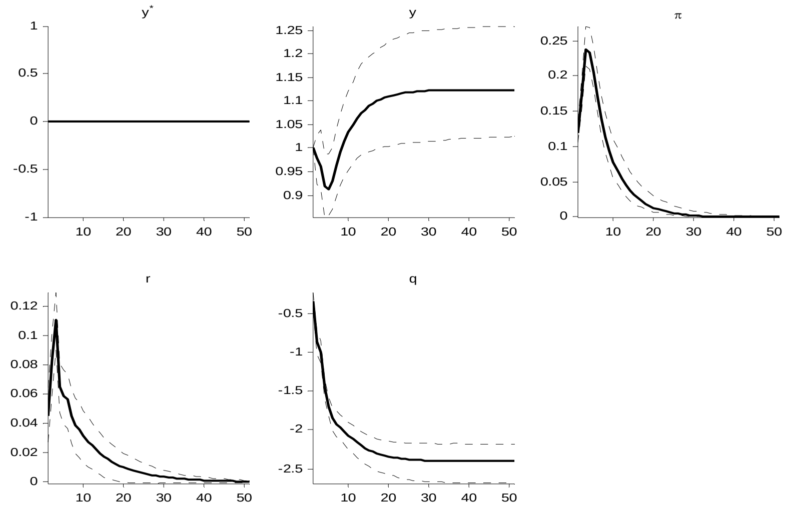


FIgure 1: Response to Foreign Output Shocks

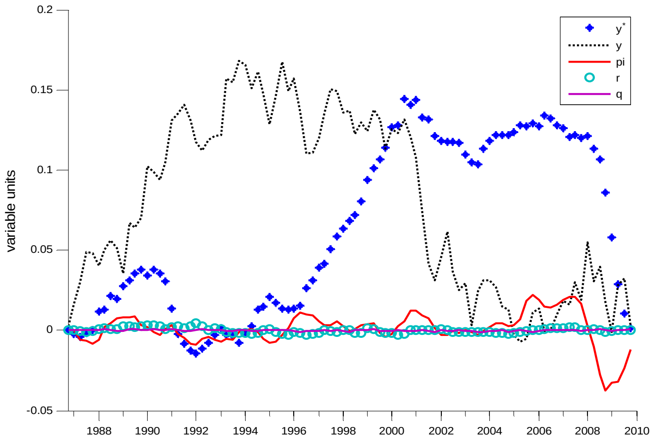


FIgure 3: Historical Decomposition of Domestic Output

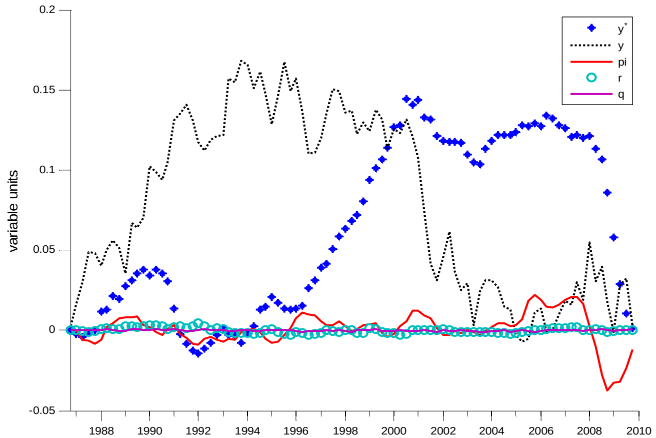


FIgure 4: Historical Decomposition of Inflation

The Philippines: Impulse Responses and Historical Decompositions

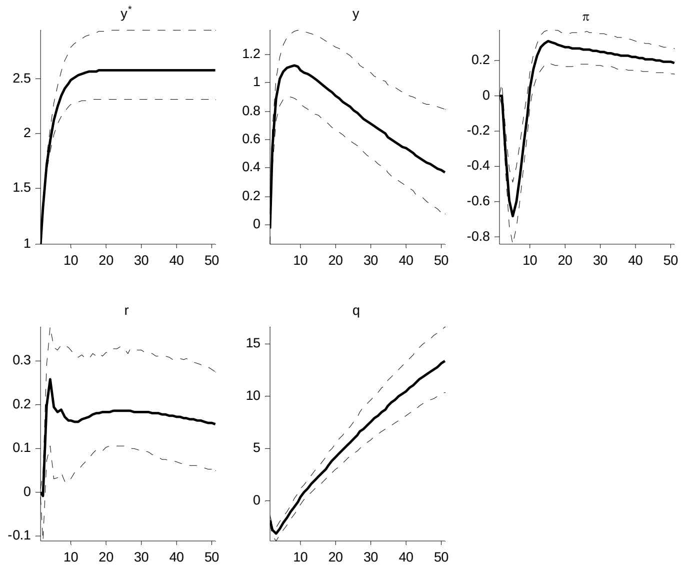


FIgure 5: Response to Foreign Output Shocks

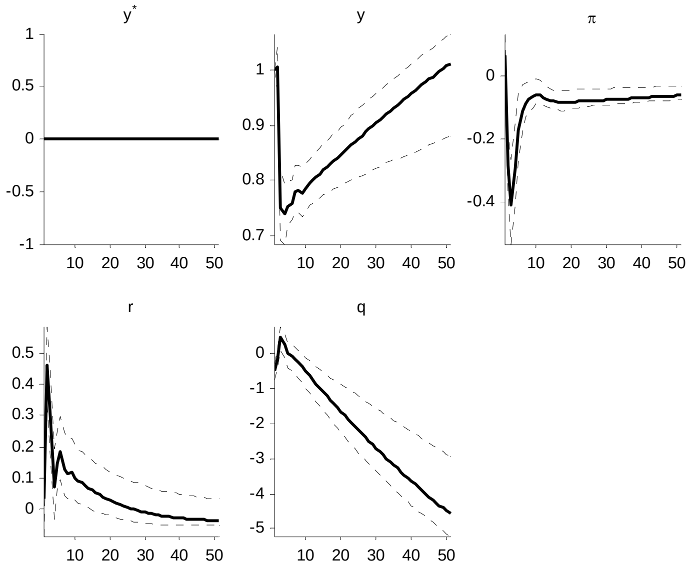


FIgure 6: Response to Foreign Output Shocks

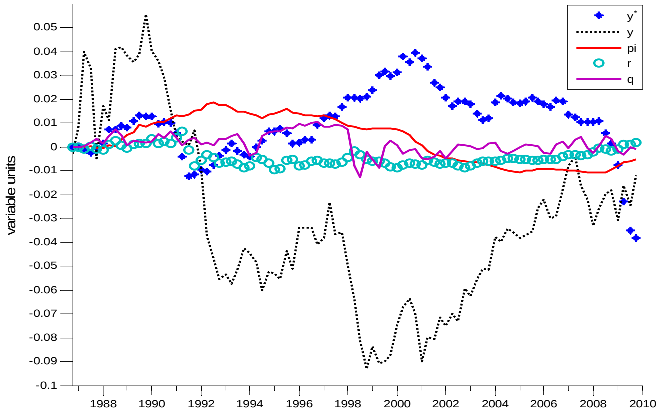


FIgure 7: Historical Decomposition of Domestic Output

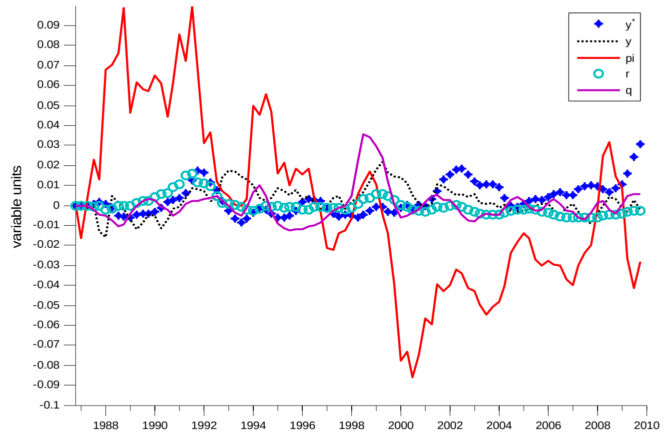


FIgure 8: Historical Decomposition of Inflation

Thailand: Impulse Responses and Historical Decompositions

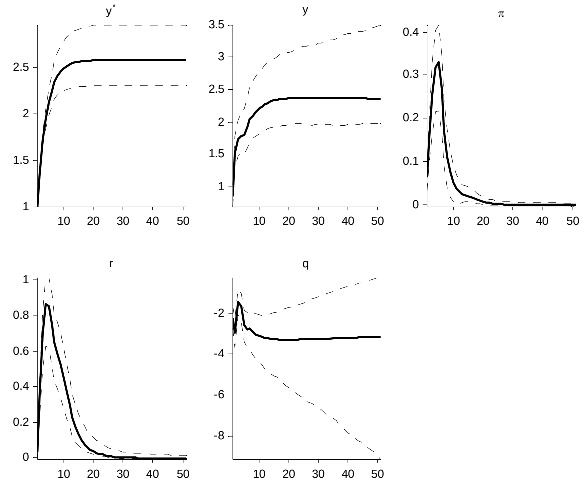


FIgure 9: Response to Foreign Output Shocks

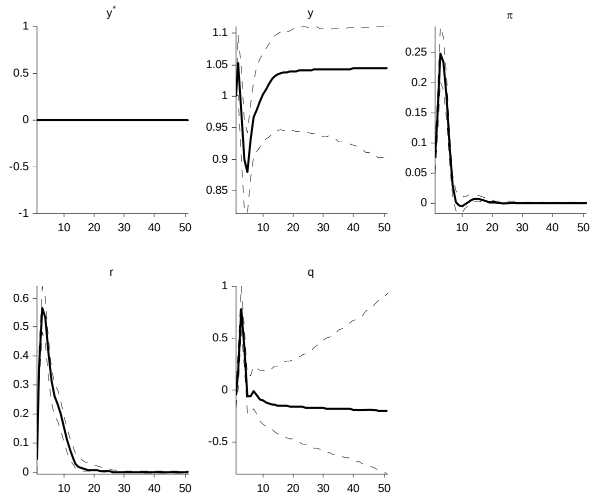


FIgure 10: Response to Foreign Output Shocks

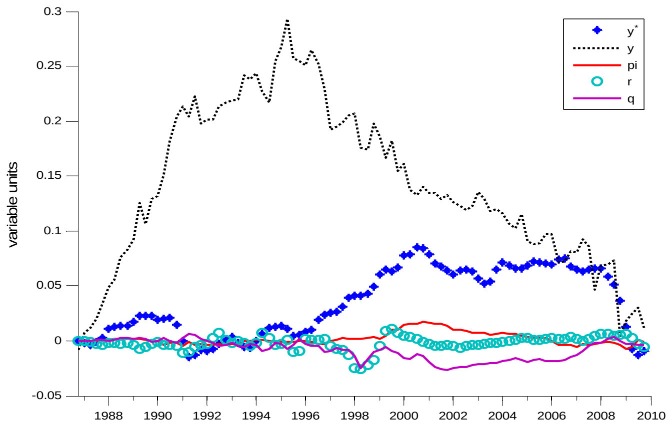


FIgure 11: Historical Decomposition of Domestic Output

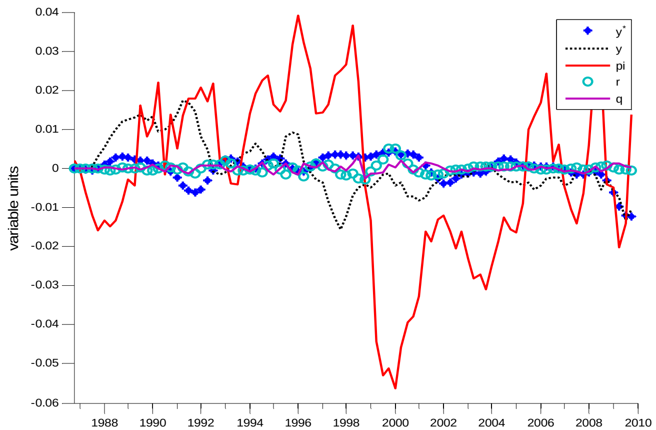


FIgure 12: Historical Decomposition of Inflation

Malaysia: Impulse Responses and Historical Decompositions

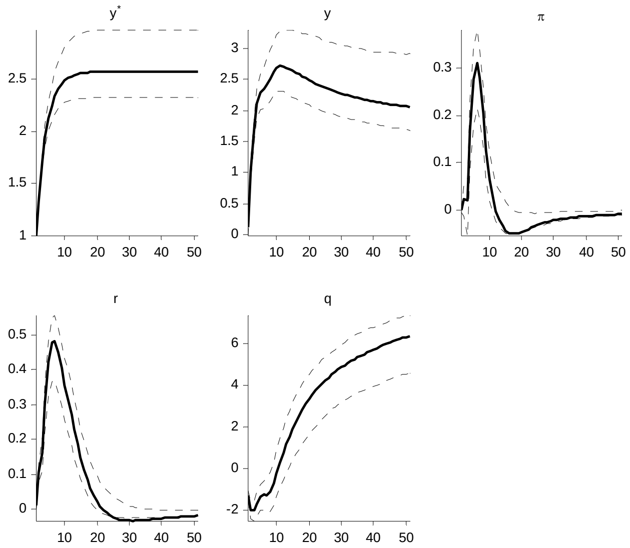


FIgure 13: Response to Foreign Output Shocks

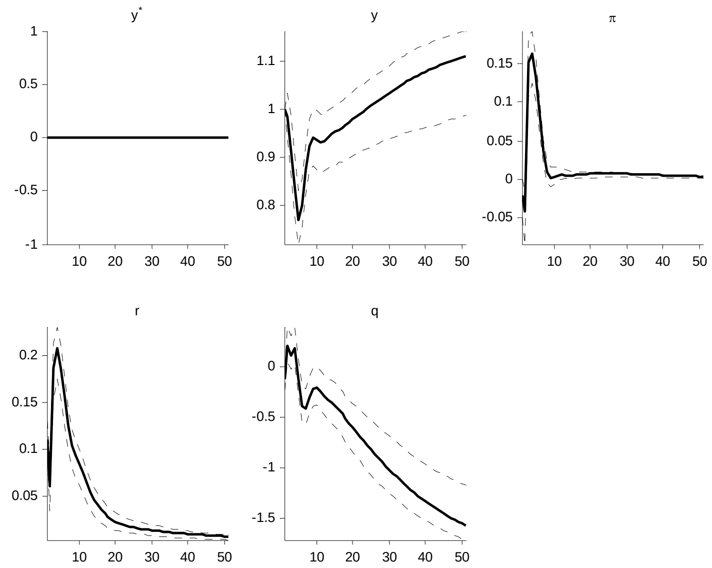


FIgure 14: Response to Foreign Output Shocks

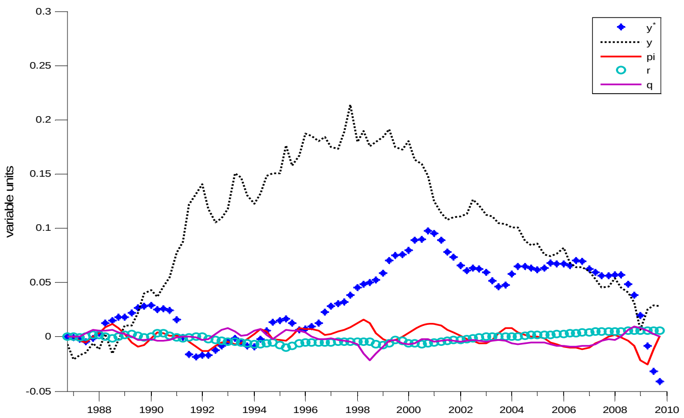


FIgure 15: Historical Decomposition of Domestic Output

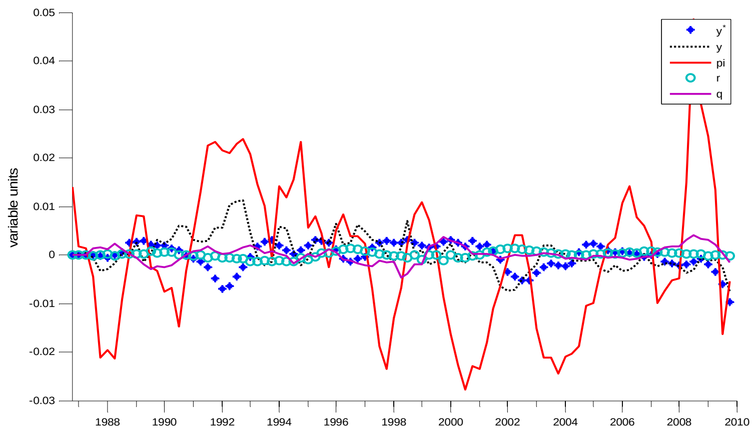


FIgure 16: Historical Decomposition of Inflation

Indonesia: Impulse Responses and Historical Decompositions

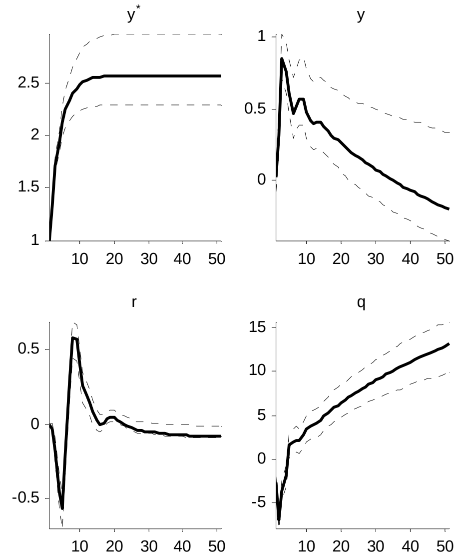


FIgure 17: Response to Foreign Output Shocks

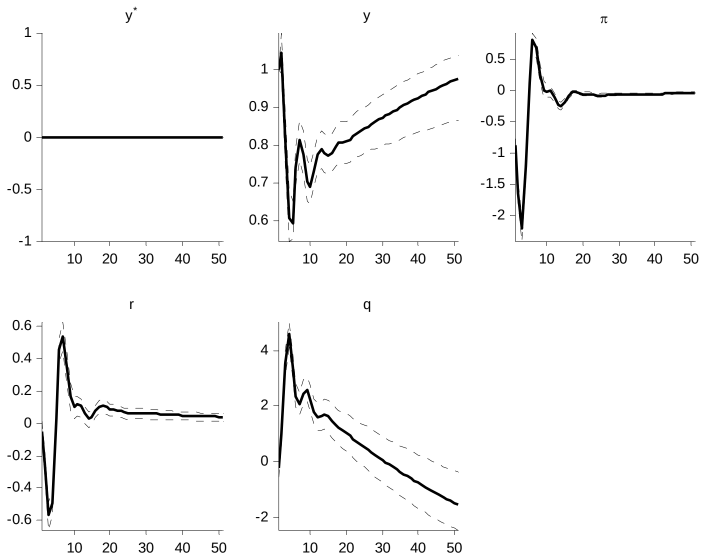


FIgure 18: Response to Foreign Output Shocks

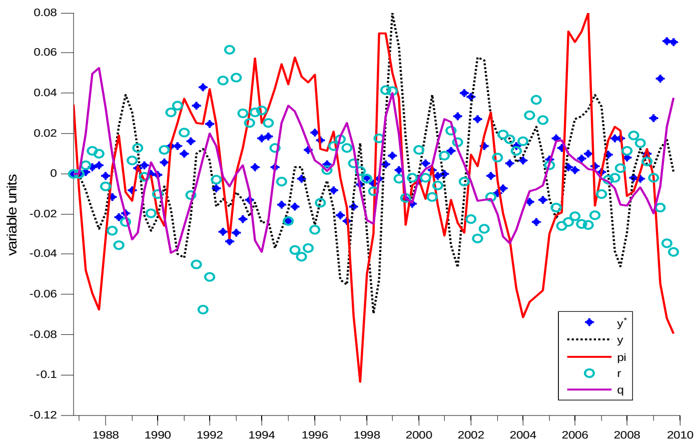


FIgure 19: Historical Decomposition of Domestic Output

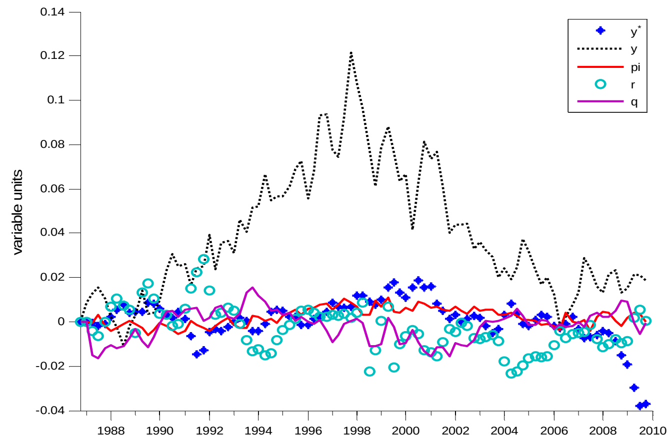
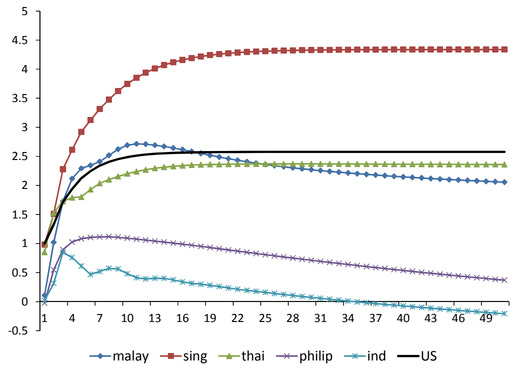
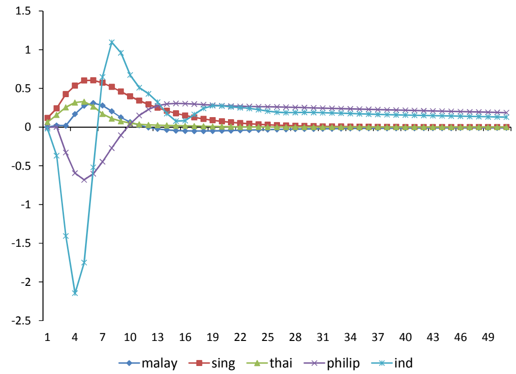


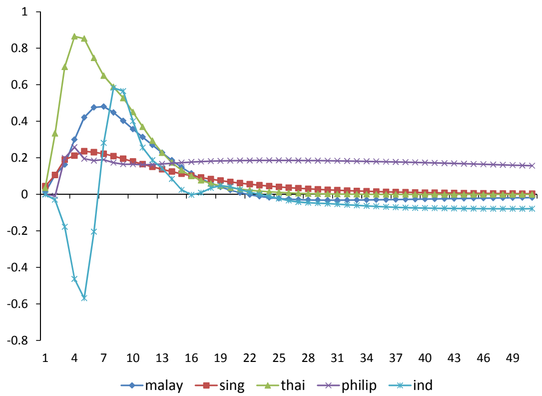
FIgure 20: Historical Decomposition of Inflation



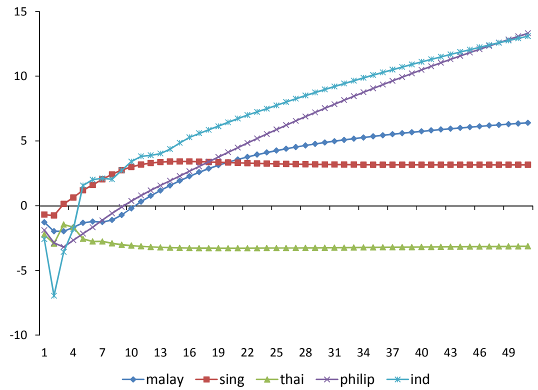
(a) Response in Domestic Output



(b) Response in Domestic Inflation

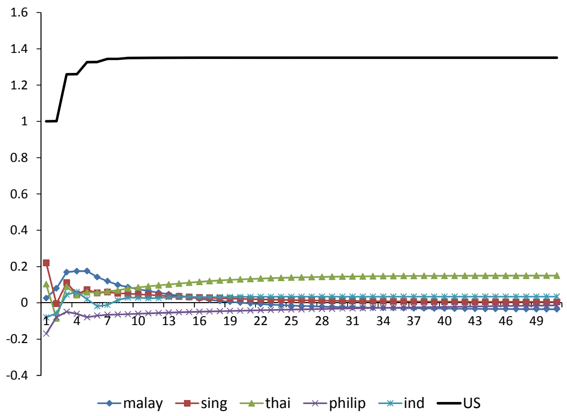


(c) Response in Domestic Interest Rates

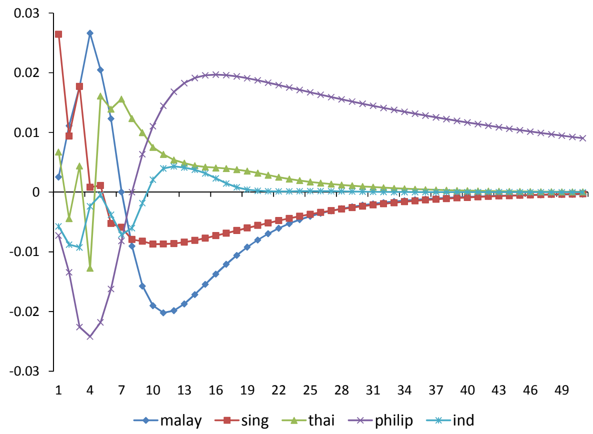


(d) Response in Real Exchange Rates

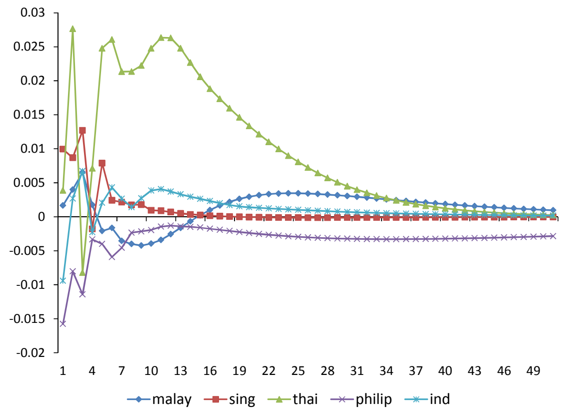
Figure 21: Responses to US Output Shocks



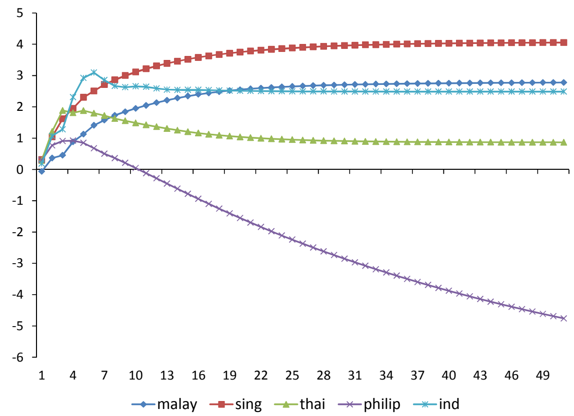
(a) Response in Domestic Output



(b) Response in Domestic Inflation



(c) Response in Domestic Interest Rates



(d) Response in Real Exchange Rates

Figure 22: Responses to Chinese Output Shocks

APPENDIX

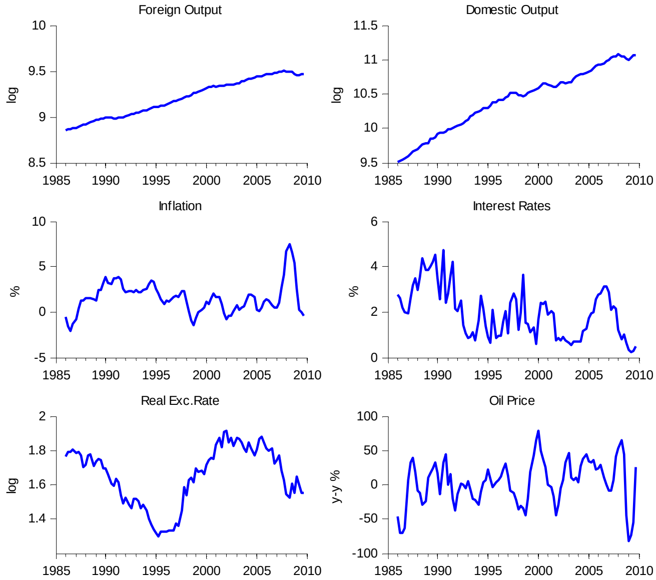


Figure A1: Singapore's Variable Plots

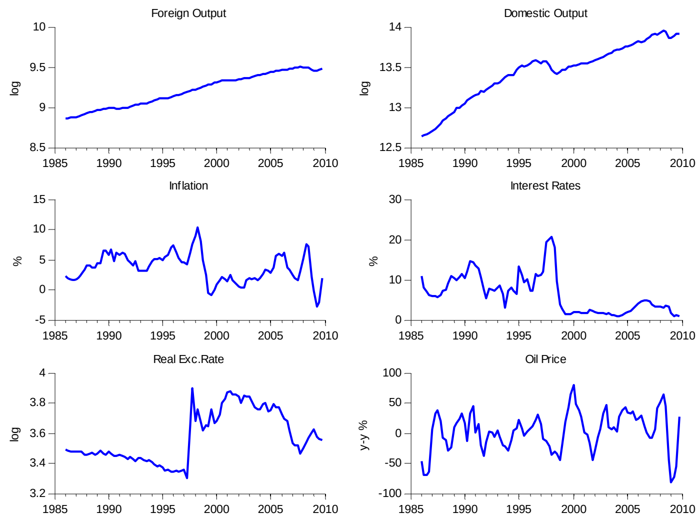


Figure A2: Thailand's Variable Plots

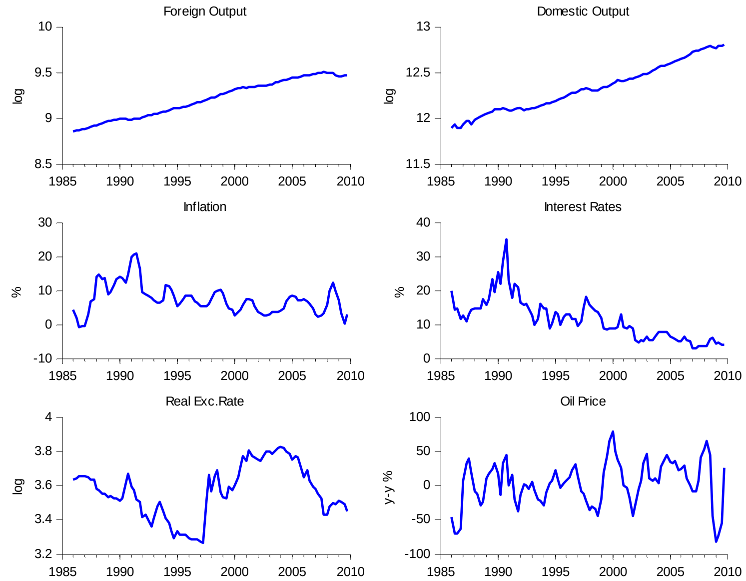


Figure A3: Philippine's Variable Plots

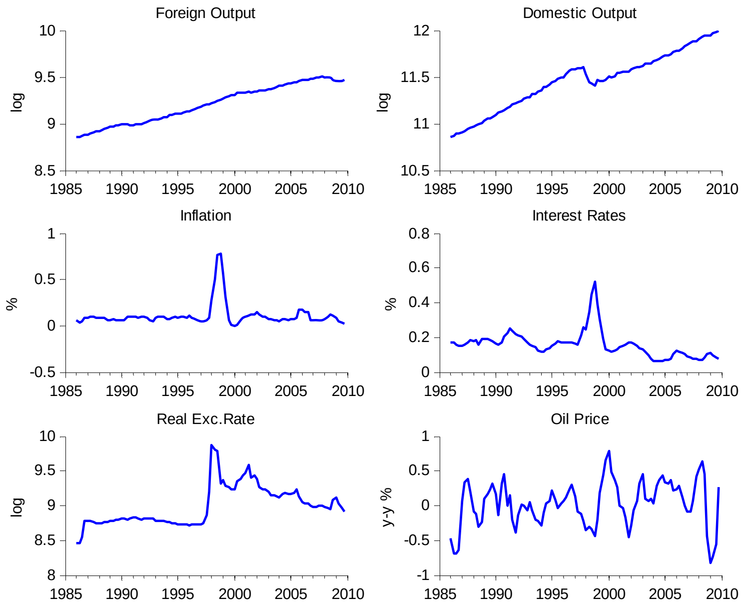


Figure A4: Indonesia's Variable Plots

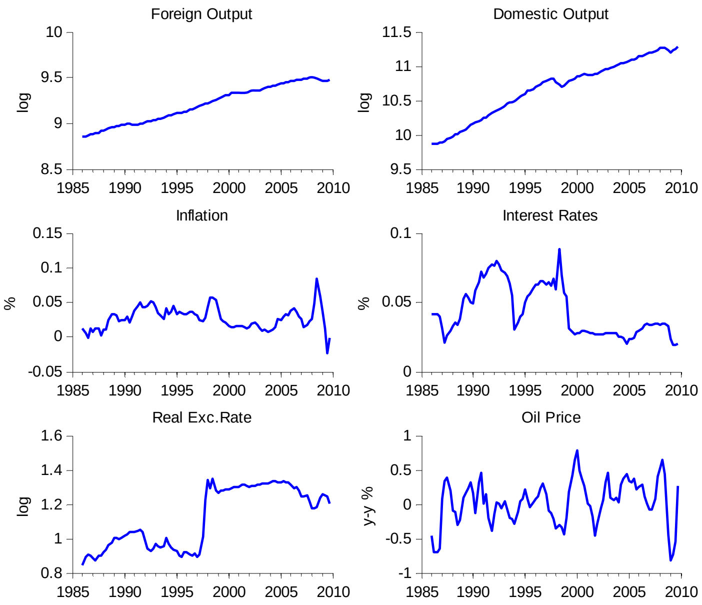


Figure A5: Malaysia's Variable Plots