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Monetary Policy and Exchange Rate in an Estimated New Keynesian model for Vietnam

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Abstract

This paper investigates optimal monetary policy in highly foreign reliant developing economies with incomplete exchange rate pass-through and strong nominal rigidity. A medium-scale New Keynesian model was estimated using Bayesian technique for Vietnam quarterly data from 1996-2016 to give empirical context for policy evaluation. Estimation results demonstrate a substantial emphasis on movement in aggregate outputs when Central Bank is assumed to pursue stabilization of fundamental macroeconomic variables. Despite the persistent "exchange rate disconnect" puzzle in international macroeconomics, this paper sees a proactive policy response to currency fluctuation in Vietnam, thus suggests the existence of actual linkages between exchange rate volatility and variability of the real sector in the featured economy.

Keywords – Optimal monetary policy, Exchange rate disconnect, DSGE, Bayesian

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1 Introduction

Empirical evidences on "exchange rate disconnect puzzles" have posed an intriguing challenges on construction of optimal monetary policy, despite strong proposition by theories on international transmission of real and monetary shocks about the roles of exchange rates. The interlink between foreign exchange and fundamental macroeconomic variables could be analyzed in non-static system developed within New Keynesian DSGE frameworks and its open economy "New open macro economics" counterparts.

Amidst large availability of empirical findings on industrial economies, this paper seeks implications on optimal response of monetary policy to exchange rate volatility for developing countries by a structural estimated model using data for Vietnam, taking into account major exogenous shocks. Vietnam faces crucial monetary policy challenges as it pursues multiple targets at the same time. On one hand, monetary policy assumes strategic role in facilitate growth that is necessary for general economic development and social welfare. On the other hand, it is tasked to control price and inflation, ensure sound development of financial sector and stabilize the economy that just recovered from the critical situation in the aftermath of Global Financial Crisis. Understanding the functioning of monetary policies matters to Vietnam as non-neutrality is shown to hold for short-run, and in reality, the Central Bank has actively applied monetary instruments to accommodate its broad mandates as well as sterilizing from foreign shocks.

Like many other developing economies, Vietnam displays an intrinsic reliance on foreign economies, which is reflected through trading of manufacturing materials, foreign investment and official development aids. The 1996-2016 period average export-to-GDP and import-to-GDP ratios in Vietnam were as high as 0.73 and 0.77 respectively (IMF International Financial Statistics). Current account surplus is contributed largely by FDI sector, in fact export-oriented FDI firms in Vietnam play a crucial role in funding imports to meet domestic consumption demand. The prevalence of outsourcing foreign invested manufacturing firms in Vietnam gives rise to this phenomenon. Besides, according to World Bank's Enterprises Survey for Vietnam (2015), while 12.8% surveyed firms were reported to participate in export activities (both direct and indirect export), the percentage of those directly taking care of their export was 9.6%. Thus, it is intuitive at first sight that policy makers should adopt proper stabilization mechanism to shield domestic producers against exchange rate uncertainty. On the contrary, excessive reaction of interest rate to currency depreciation may as well induce unnecessary fluctuation in demand and erode output growth. Thus, policy consideration must rely upon dynamic interaction of exchange rate movements with other macroeconomic variables to judge the overall impacts of exchange rate related policy.

This paper therefore aims at capturing the dynamic generated among macro fundamentals within DSGE model framework, which is particularly useful and popular in macro policy modelling but being used limited in studies about monetary policy in Vietnam. The analysis proceeds first by construction of a theoretical model that falls in the open-economy generalization for small open economy (SOE) à la Gali & Monacelli (2005). The model abstracts from the extreme assumption of complete asset market and employs necessary nominal rigidity such as habit formation and price indexation (Christiniano et.al, 2005) to generate enough persistence in the variables.

In this model, exchange rate is determined via the modified interest rate parity condition. The adoption of debt-elastic foreign interest rate offers two convenient services. First, it helps induce stationary for SOE model with incomplete asset market, which is essential to solve the steady state of the model (Schmitt-Grohé & Uribe, 2003). Second, it serves as a mechanism to determine exchange rate. Here, risk premium shock factor was also included to allow for deviation from the strict parity condition and replicate sufficient volatility in exchange rate. Exchange rate related monetary rule comes in the generalized Taylor-form that embraces multiple targets apart from currency deviation. It is more realistic that Central Bank in Vietnam decides its period policy rate based on multiple accounts instead of a strict exchange rate peg rule as in Gali & Monacelli (2005). Tradition exchange rate determination theories like purchasing power parity or current account flow approach fail to adapt nicely within this model due to the presence of the signature differentiated goods market in New Keynesian economics.

I leverage the incomplete exchange rate pass-through (ERPT) as emphasized in Smets & Wouters (2002), yet widen the horizon of price stickiness to cover both import and export sectors as well as employ a greater extent of price adjustment cost. Then, the paper also calibrates and estimates the model using Bayesian approach with Vietnam data series. Calibration was carried out in a way to replicate crucial moments condition such as high degree of trade openness. The aforementioned dominant share of direct exporters among the entire sample of firms involving in exporting has given rationale for modelling producers in this model as direct exporters of its own outputs. I also assume local currency pricing to reflect the common practice of Vietnam exporters.

In the last step, a well-informed policy maker in this structural estimated model is supposed to optimize over Taylor-type interest rate rule to minimize total weighted variances in CPI inflation, output and exchange rate depreciation. Our approach resembles mostly Justinianno & Preston (2010), yet diverges fundamentally in the policy results. The model economy in this paper prefers proactive response from interest rate to currency fluctuation. This magnitude of feedback varies according to relative weights assigned on output variability, yet maintain equally important to attention on changes in inflation. This result gives a hint about the existence of non-trivial short-run linkages between currency movements and real sector in an economy with high openness and weak competitive advantages as Vietnam.

2 Literature

Literature on financial economics have been puzzled by the weak linkages between exchange rates and fundamentals. Using empirical micro evidences, Meese & Rogoff (1983) pointed out that the prevailed models of exchange rate determination failed to outperform simple random walk process in predicting the fluctuation of exchange rate. Baxter & Stockman (1989), while conditioning on exchange rate regimes change in 23 OECD and 21 Non-OECD countries, found no systemic dependence of real variables such as consumption, outputs and trade volatility on exchange rate system. It triggered a heated debate on appropriate policy reaction to movements in forex market and rationale of government intervention in stabilizing exchange rates.

Obsfeld & Rogoff (2000) took the dynamic stochastic general equilibrium approach in modelling the exchange rate dynamic. While exchange rate was concluded in their study to "disconnect" with the rest of the economy, there are subsequent studies that explored and deciphered the phenomenon from vast perspectives. Devereux & Engel (2002) posed a hypothesis that high volatility of real and nominal exchange rates might be tracked down from the fact that local currency pricing by a specialized exporter, if in place, absorbed the pass-through from changes in exchange rates to consumer prices; excessive volatile exchange rate does not affect macroeconomic variables in such a way. Thus the choice between local currency pricing or producer currency pricing will have non-trivial implication about exchange rate influence to performance of local economy. It was also emphasized that the export channels, i.e. whether goods were directly exported from the producers or through a distributor, can changes the pass-through mechanism. Smets & Wouters (2003) looked into the similar problem of incomplete exchange rate pass-through and empirically found a responsive monetary policy to exchange rate fluctuation has welfare implication in the context of staggered import price setting. Optimal monetary policy investigated in Justiniano & Preston (2010), on the contrary, is attained regardless of any feedback to currency depreciation. A general takeaway from this inconclusive debate is that exchange rate role would differ as the economy model construction differs.

Optimal monetary policy question in general equilibrium framework relies on core architects of New Keynesian economics: i) a traditional RBC model with monopolistic competitions and nominal frictions, ii) a Taylor rule monetary policy and iii) minimization of Central Bank's loss function. Medium-scale New Keynesian factors can also be incorporated to generate higher persistence by introducing wage stickiness, capital utilization, habit formation and investment adjustment cost (Christiano et.al 2005). New Keynesian literature has been fast in developments and rich in model components, however, so far it has mainly been crafted and estimated for advance economies. Focus starts to switch to developing world in recent years with some studies on African countries (Baldini, et al., 2012, Peiris Saxegaard, 2007).

Literature about Vietnam shows that exchange rate & credits channel play pivotal role in monetary policy transmission in Vietnam (Le, V. H., Pfau , W. D. (2009)). The studies of IMF (2003) shows that movements in the nominal effective exchange rate explain 10 percent of the variation in core inflation over the period 1995–2003, and a pass-through level at 0.25 in the first year. By VAR estimation, Camen (2006) saw a greater magnitude that fluctuations in the nominal effective exchange rate explained 19 percent of the forecast variance of CPI inflation. The high ERPT is quite consistent with theories by Taylor: countries with low dollarization and low inflation can have lower pass-through level. Exchange rate shock plays important role in GDP growth because of large proportion of imported raw material needed for production (Anh, 2015). Meanwhile, there are also a large set of literature that criticizes the non-dynamic of exchange rate regimes and argue for more flexible regime changes (Nguyen TP & Nguyen 2009, Goujon, 2006). There are study indeed pointed out that parallel ”market-governed” forex market may perform better in counter-cyclical target (Vuong & Ngo, 2002). Most papers use VAR and VECM model with little room to consider alternative policy options and it is harder to separate the linkages and interaction of different agents in the economy.

Meanwhile, the use of New Keynesian could be designed specifically to capture dynamic of main macroeconomic forces. This paper differentiates itself from other researches by its empirical efforts to illustrate New Keynesian optimal monetary problem in Vietnam context.

3 Small Open Economy Model

3.1 Household

The household sector features a representative infinitely lived agent, who maximizes his inter-temporal discounted utility subject to inter-temporal budget constraint.

Objective function:

$$E_0 \sum_{t}^{\infty} \beta^t \omega_t U_t(C_t, N_t)$$

where

$$U_t(C_t, N_t) = \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$$

β is the inter-temporal utility discount factor and ω_t is demand shock that is assumed to follow AR(1) exogenous process with a persistence factor ρ_ω bounded between (0,1) interval: $log(\omega_t) = \rho_\omega log(\omega_{t-1}) + \epsilon_{\omega t}$.

Household is assumed to have access to incomplete asset market with the only type of tradable asset is domestic bond B_t and foreign bond B_t^* that matures every period, pays interest in domestic and foreign currency, at rate R_t and $R_t^* \Psi_t$ respectively.

$$P_tC_t + B_t + B_t^* e_t = W_tN_t + R_{t-1}B_{t-1} + R_{t-1}^* B_{t-1}^* e_t \Psi_{t-1} + \int_0^1 \Pi_t(z)dz$$

Following Schmitt-Grohé & Uribe (2003), agent in home country faces debt-elastic foreign interest rate that subject to a risk premium term Ψ_t of this form:

$$\Psi_t = exp(\Phi_{Rt} - \chi D_t) \tag{3.1}$$

Where $log(\Phi_{Rt}) = \rho_\Phi log(\Phi_{R,t-1}) + \epsilon_{\Phi,t}$ is exogenous risk premium shock and the second term is debt-to-GDP ratio $D_t = \frac{e_t B_t^*}{P_t Y_{SS}}$. Household is then maximizing their utility subject to their budget constraint:

$$\max_{\{C_t, N_t, B_t, B_t^*\}} E_0 \sum_{t}^{\infty} \beta^t \omega_t \Big\{ U_t(C_t, N_t) \\ - \lambda_t \big[P_tC_t + B_t + B_t^* e_t - (W_tN_t + R_{t^1}B_{t-1} + R_{t-1}^* B_{t-1}^* e_t \Psi_{t-1} + \int_0^1 \Pi_t(z)dz) \big] \Big\}$$

First order conditions on C_t, N_t, B_t, B_t^* yield the following consumer optimality conditions:

$$\frac{U'_C(C_t,N_t)}{U'_C(C_{t+1},N_{t+1})} = E_t\Big[\beta R_t \frac{P_t}{P_{t+1}}\Big] \qquad \text{(Euler Equation)} \tag{3.2}$$

$$\frac{U'_N(C_t,N_t)}{U'_N(C_{t+1},N_{t+1})} = E_t\Big[\beta R_t \frac{W_t}{W_{t+1}}\Big] \qquad \text{(Labor Supply Equation)} \tag{3.3}$$

$$\lambda_t = E_t[\beta R_t \lambda_{t+1}]$$

$$e_t \lambda_t = E_t[\beta R_t^* \lambda_{t+1} e_{t+1} \Psi_t]$$

$$\frac{R_t}{R_t^*} = E_t\Big[\frac{e_{t+1}}{e_t}\Psi_t\Big] \qquad \text{(Uncovered Interest Rate Parity)} \tag{3.4}$$

3.2 Production sector

3.2.1 Final goods producer

There is a unique retailer that supplies homogeneous final goods Z which is aggregated over a continuum of domestically produced (non-tradable) and imported inputs. The aggregate technology follows this functional form, for some structural elasticity of substitution between home and import goods θ:

$$Z_t = \Big[\zeta^{\frac{1}{\theta}} Q_{Ht}^{\frac{\theta-1}{\theta}} + (1-\zeta)^{\frac{1}{\theta}} Q_{Ft}^{\frac{\theta-1}{\theta}}\Big]^{\frac{\theta}{\theta-1}} \tag{3.5}$$

which can be linearized to become $\hat{Z}_t = \zeta \hat{Q}_{Ht} + (1-\zeta)\hat{Q}_{Ft}$.

Q_{Ht}, Q_{Ft} are aggregated Dixit-Stiglizt indices for home-produced and import goods:

$$Q_{it} = \Big[\int_0^1 Q_{it}(z)^{\frac{v-1}{v}} dz\Big]^{\frac{v}{v-1}}, \quad \text{i=H,F}$$

Solving inter-temporal and intra-temporal firm optimization yields demand function for import and home-produced goods:

$$Q_t^H = \zeta \Big[\frac{P_t^H}{P_t}\Big]^{-\theta} Z_t; \quad Q_t^F = (1-\zeta)\Big[\frac{P_t^F}{P_t}\Big]^{-\theta} Z_t \tag{3.6}$$

where demand for each differentiated goods is:

$$Q_t^i(z) = \Big[\frac{P_t^i(z)}{P_t^i}\Big]^{-v} Q_t^i, \quad \text{i=H,F} \tag{3.7}$$

At presence of perfect international risk-sharing among countries, we assume, for the following section on export, that home-produced export goods faces world demand that comes in analogous functional form as home demand for imported goods. The difference lies in value assigned for structural parameters.

$$Q_t^X = \mu \left[\frac{P_t^{X*}}{P_t^*}\right]^{-\eta} Z_t^*, \quad \text{and} \quad Q_t^X(z) = \left[\frac{P_t^X(z)}{P_t^X}\right]^{-\gamma} Q_t^X \tag{3.8}$$

The domestic aggregate price level in this model is conditioned on import price, home-produced non-tradable price and the relative weights assigned on each goods type in the consumption basket:

$$P_t = \left(\zeta P_{Ht}^{\theta-1} + (1-\zeta) P_{Ft}^{\theta-1}\right)^{\frac{1}{\theta-1}} \tag{3.9}$$

Subtracting the linearized form of domestic CPI: $\hat{P}_t = \zeta \hat{P}_{Ht} + (1-\zeta)\hat{P}_{Ft}$ by its past CPI level gives us the related CPI inflation formula: $\hat{\pi}_t = \zeta \hat{\pi}_{Ht} + (1-\zeta)\hat{\pi}_{Ft}$.

3.2.2 Intermediate goods producers

Intermediate goods producers are assumed to produce differentiated goods in a monopolistic competitive market. Cobb-Douglas production function with single input and marginal cost function come in these formula:

$$Y_t(z) = A_t N_t(z) \tag{3.10}$$

$$MC_t(z) = W_t / A_t \tag{3.11}$$

Technology advancement follows exogenous process conditioning on past productivity an a stochastic shock: $log(A_t) = \rho_A log(A_{t-1}) + \epsilon_{At}$.

Monopolists are allowed to update prices every period, yet bear explicit cost measured by aggregate market demands and a quadratic adjustment cost index at sector level à la Rotemberg (1982). Aside from physical menu cost, the quadratic term is in place to capture the increasing market loss to scale of updating price, or in other word, firm reputation damages would be more severe for more noticeable price change:

$$\frac{\phi_i}{2}\left[\frac{P_{t+j}^i(z)}{P_{t+j-1}^i(z)} - 1\right]^2 Q_t^i \tag{3.12}$$

This pricing pattern demolishes heterogeneity at steady state and enables computational convenient symmetric equilibrium for the model (Appendix A). Despite the first-order equivalence between Rotemberg pricing and the prevalent Calvo price staggering, recent work by Richter & Throckmorton (2016) have shown that model with Rotemberg price adjustment cost produces higher marginal data density, endogenously generates more volatility and improves model fit.

Intermediate goods producers optimizes production plan by setting monopolist prices that maximize its revenue, taking into considerate account the costs incurred due to changing prices every period. Their discounted lifetime profits follow the functional form below, where the first two terms constitute variable profits generated as per every unit sales, and the last term depicts dead weight loss in profits according to entire market share. The discount factor coincides with the inter-temporal marginal utility discount by the consumer: $D_{t,t+j} = \beta^j \frac{U'_{C,t+j}}{U'_{C,t}}$.

$$\max_{\{P^i_t(z)\}} E_t \sum_{j=0}^{\infty} D_{t,t+j} \Big\{ \frac{P^i_{t+j}(z)}{P_{t+j}} Q^i_{t+j}(z) - mc_{t+j} Q^i_{t+j}(z) - \frac{\Phi_i}{2} \left[\frac{P^i_{t+j}(z)}{P^i_{t+j-1}(z)} - 1 \right]^2 Q^i_t \Big\} \quad \text{(i=H,X)}$$

In this model, the intermediate producers are supposed to partially serve domestic market while actively participating in export. They face different demands from local consumers versus world market, and the extent of price stickiness are also subject to each market. Consequently, they would exercise their market power and customize the posted prices in two processes for local market and exporting separately. Optimal non-tradable (aggregate) price is set at:

$$\frac{P^H_t}{P_t} = \frac{v}{v-1} mc_t - \frac{\Phi_H}{v-1}(\pi^H_t - 1)\pi^H_t + \frac{\beta \Phi_H}{v-1} \left[\frac{U'_{C,t+1}}{U'_{C,t}} (\pi^H_{t+1} - 1)\pi^H_{t+1} \frac{Q^H_{t+1}}{Q^H_t} \right] \tag{3.13}$$

In the absence of price adjustment cost ($\Phi_H = 0$), the pricing equation reduces to the typical monopolist strategy to set price with a markup over marginal cost, which reflects their market powers.

Intermediate goods firms in this economy directly handle distribution of goods on international market. As the local intermediate goods producers already possess monopolist powers to set differentiated prices, this assumption technically secures the deviation from law of one price and the consequently incomplete exchange rate pass-through posited by Monacelli (2005). Exporters specifically set export price in consumer's local currency (foreign currency)[1]. Retail price would then be converted to home currency ($P^X_t(z) = e_t P^{X*}_t(z)$) in the home profit maximization problem and export price-setting equation.

$$\frac{P^X_t}{P_t e_t} = \frac{\gamma mc_t}{\gamma - 1} - \frac{\Phi_X}{\gamma - 1}(\pi^X_t - 1)\pi^X_t + \frac{\beta \Phi_X}{v-1} \left[\frac{U'_{C,t+1}}{U'_{C,t}} (\pi^X_{t+1} - 1)\pi^X_{t+1} \frac{Q^X_{t+1}}{Q^X_t} \right] \tag{3.14}$$

Exchange rate fluctuation feeds on real outputs level through optimal production plan of exporters.

3.2.3 Importers

There exists retailers that import differentiated in foreign market, then process through branding and packaging to distribute at home market at retailers' monopolist price. As in Monacelli (2005), this importer faces world price at dock, where marginal cost is kept at $mc_t(z) = e_t P^*_t(z)$. It then sets importer price by solving the monopolist optimization problem.

$$\max_{\{P^F_t(z)\}} E_t \sum_{j=0}^{\infty} D_{t,t+j} \Big\{ \frac{P^F_{t+j}(z)}{P^H_{t+j}} Q_{t+j}(z) - e_t P^*_t(z) Q_{t+j}(z) - \frac{\Phi_F}{2} \left[\frac{P^F_{t+j}(z)}{P^F_{t+j-1}(z)} - 1 \right]^2 Q_{Ft} \Big\}$$

[1] For consistency, this paper uses superscript * for any nominal variable that denominated in foreign currency

The pricing equation in the import sector is here to explain the incomplete pass through from currency movements and the import price. At presence of the adjustment cost in the last two terms, exchange rate cannot move one-to-one with P_t^F.

$$\frac{P_t^F}{P_t} = \frac{v}{v-1} e_t P_t^*(z) - \frac{\Phi_F}{v-1}(\pi_t^F - 1)\pi_t^F + \frac{\beta\Phi_F}{v-1}\left[\frac{U'_{C,t+1}}{U'_{C,t}}(\pi_{t+1}^X - 1)\pi_{t+1}^F \frac{Q_{t+1}^F}{Q_t^F}\right] \quad (3.15)$$

3.3 Market Equilibrium

General equilibrium achieved when all markets clear. Specifically, labor market clearing condition ensure that total labour supply from household equal firm demand such that $\int_0^1 N_t(z) = N_t$. Bond is traded domestically so in steady state B=0.

Equilibrium in goods market should be attained for both intermediate and final goods.

$$Y_t = Q_t^X + Q_t^H \quad \text{(Intermediate goods market)} \quad (3.16)$$

$$Z_t = C_t \quad \text{(Final goods market} \quad (3.17)$$

Model is closed also by Taylor-type interest rate setting rule that incorporates simultaneously Central Bank's backward-lookingness on past inflation, output level, contemporaneous output growth and exchange rate depreciation. The rule also specifies a monetary shock term.

$$R_t = R_{t-1}^{\rho_R}\left[\pi_{t-1}^{\phi_\pi} y_{t-1}^{\phi_y} \Delta y_t^{\phi_g} \Delta e_t^{\phi_e}\right]^{1-\rho_R} exp(\epsilon_{Rt})$$

Log-linearization of the interest rate rule gives the Taylor-rule policy used in this analysis:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)(\phi_\pi \hat{\pi}_{t-1} + \phi_y \hat{y}_{y-1} + \phi_g \Delta\hat{y}_t + \phi_e \Delta\hat{e}_t) + \epsilon_{R,t} \quad (3.18)$$

In this paper, I place particular interest in the last parameter ϕ_e which displays the degree of policy response to fluctuation in the foreign exchange market.

Foreign blocks and other shocks are assumed to be exogenously given following AR(1) process.

$$log(Z_t^*) = \rho_{Z^*} * log(Z_{t-1}^*) + \epsilon_{Z^*} \quad (3.19)$$

$$log(P_t^*) = \rho_{P^*} * log(P_{t-1}^*) + \epsilon_{P^*} \quad (3.20)$$

$$log(R_t^*) = \rho_{R^*} * log(R_{t-1}^*) + \epsilon_{R^*} \quad (3.21)$$

4 Empirical Findings

4.1 Estimation Approach

I estimate this model using Bayesian method. Given prior density for the parameters, and observable data series, Bayes rule implies that the posterior distribution is proportional to the product of prior and the likelihood function. Posterior draws for this density can be generated using a random-walk metropolis algorithm and Kalman filter. Projections and likelihood are inputs into the Metropolis-Hastings Markov chain Monte Carlo simulator to obtain the mode of parameters posteriors.

4.2 Data

Bayesian estimation method restricts the number of observable series to the total number of shock to avoid singularity. For a total of seven stochastic shocks feature in this model, I use seven data series that are measured at quarterly frequency, ranging from 1996:QI to 2016:QIV. Macro variables for Vietnam include GDP (y_t), CPI inflation (π_t), Central Bank policy rate (R_t) and nominal bilateral VND/USD exchange rate (e_t). Because the highest frequency available for Vietnam GDP is at annual level, I interpolated yearly data using Chow-Lin interpolation approach. Data on foreign block are proxied by those of US economy and including GDP (Z_t^*), Treasury bill rate (R_t^*), and CPI inflation (π_t^*).

All series are seasonally adjusted using X-12-ARIMA decomposition algorithm developed by the U.S. Census Bureau. As real business cycle model does not deal with trend growth, GDP series of Vietnam and USA were transformed into per capita variables and detrended using one-sided HP filter. The remaining data are known to be non-trending. To fit in log-linearized model outcome, all data were converted into logarithm form and demeaned.

4.3 Calibration and Simulation

Parametration for model structural parameters employs calibration, estimation using observable data or a mixture of both. I restricted point estimate to some certain parameters whose values can be explicitly pinned down by actual data, or empirical findings from previous studies so that selected steady state properties of the model match the data moments for Vietnam. This allows inducement of unique set of estimated parameters and model behaviours that replicates specifically features of the investigated economy, and effectively assists if likelihoods fail to provide additional information for some parameters (Smets & Wouters, 2003). I calibrated discount factor in a standard fashion, $\beta = 1/(1 + R_{SS})$, where R_{SS} was steady state value of interest rate. Consequently, β was set at 0.92, corresponding to the average deposit rate of 6% in Vietnam during 1996-2016.

Home bias in consumption basket was set at 0.23 to match the import-to-GDP ratio averaged at 77% over the sample period. This high degree of foreign reliance itself promised a different estimation results compared to existing New Keynesian literature on advance economies where openness indexes were seen to fluctuated around 0.1-0.3 interval. This magnitude of foreign goods share is indeed expected in many low income developing economies where domestic production sector remains premature and heavily relies on imported manufacturing materials, equipment and the active role of FDI assembly factories that contracted to imported parts and accessories.

The elasticity of risk-premium with respect to foreign debt (χ) was not well identified within the model, thus I chose to set $\chi = 0.01$, following Justiniano Preston (2010). For the same reason, the Frisch labor supply elasticity parameter, which represents the percent change in aggregate working hours due to a one percent change in aggregate real wages, was proxied by ratio between period annual average labor force participation growth and GDP growth. This index was then set for Vietnam at 1.49, also quite in line with the choice in standard literature.

The remaining parameters were estimated given their prior information and real data feeds. The choice of distribution was guided by theoretical restrictions on parameters or suggestion by empirical evidences. I assigned beta distribution on parameters feasible only within unit interval. All structural shocks persistence parameters, namely technology, preferences, risk premium and other three foreign shocks fell in this categories, with mean value at 0.85 and standard deviation at 0.1, following Andolfson et. al (2005).

For parameters that should assume positive value, I imposed gamma distribution which confines variables on $[0, \infty)$ space. Inverse gamma distribution was imposed for all standards deviation of shock, mean is set at 0.5. I followed Justinianno & Preston (2010) on the choice of priors for Taylor rule coefficients. Mean of coefficients on inflation, output and output growth are respectively 1.5, 0.5 and 0.5, as per original principle suggested by Taylor (1993). Specifically, magnitude of feedback from interest rate before inflation fluctuations should be greater than unity to ensure actual response has real term effect. Otherwise, while nominal interest rate is still governed by the rule to increase as inflation increases, real interest rate would indeed reduced and its counter-cyclical effect on demand and inflation curbing would be eliminated. Coefficients were all assumed gamma distribution, except interest rate smoothing level that is bounded within unit interval and takes mean value at 0.5.

Price indexations, v and θ, have gamma distribution and were set at 10 and 8, indicate 10% and 14% markup over marginal costs respectively. Price adjustment cost indexes were borrowed from Peiris & Saxegaard (2007) and set at 100. One limit of Rotemberg pricing specification is the absence of any appropriate direct interpretation to the adjustment cost coefficients. Literature often utilizes the first-order equivalence between Rotemberg model and Calvo-style counterpart to translate the Rotemberg price stickiness index into the price rigidity duration implied in Calvo model. Here, $\Phi_F = \Phi_H = 100$ can be understood as a non-updating period of price lasting 5 cycles. On the other hand, export price in Vietnam resists more strongly to frequent price changes. This assumption expresses the fact that Vietnam export sector is largely dominated by heavy industrial products (mining, chemical, steelmaking) and minerals[2], which are presumably less differentiated.

[2]35.35% total export, average period 1996-2016. Author's calculation based on statistics from Vietnam General Statistics Office, available at https://www.gso.gov.vn/default$_en.aspx?tabid = 780$

Export price stickiness was set to double those of non-tradable and import sector in order to accommodate the relatively weak market power of Vietnam firms in global market; adjusting price would be thus costly.

4.3.1 Impulse Response Functions

We decipher the dynamic generated within the model economy by simulating various structural shocks and the resulting impulse response behaviours of relevant macro variables.

Variations generated by technology advancement largely complies with standard literature and stylized facts. Productivity improvement boosts up the economic performance by promoting output growth in a low inflationary environment. The effect is more profound in the real sector, nominal exchange rate is rarely influenced.

Positive shock to risk premium acts as per parity condition to increase local interest along with depreciation of exchange rate at impact, thus confines inflation and term of trade in a short instance. In a contrast manner, Taylor rule regulates movements of interest rate conversely during booming period, quickly reducing interest rate and lead to the second stage of reverse responses in most variables after first five periods.

A shock from the demand side, i.e. preference shock, feed a strong stimulus in real sector expressed through a big increase in outputs, consumption, and both export and import. The promotion effect in import sector is larger thanks to the direct composition of import goods in consumption basket. Thus, the overall effect on current account is negative.

Behaviors of local economy in front of structural foreign shocks is standard. Foreign interest rate behaves in exact same manner as risk premium shock. Increasing foreign outputs means a higher demand for export, yet at the same time, import increase at faster pace due to a sharp appreciation of the local currency. Increasing π^* induces higher domestic inflation too because inflation is imported through import goods and trading of bonds in international market.

4.4 Estimation

Posteriors estimation are reported along with respective prior density in the Table 1. All parameters are well identified in the model given the assumption on priors as well as provided data. Policy parameters show proactive responses of central banks to inflation yet not so significant to deviation of output from steady state level, Taylor coefficients $\phi_\pi = 1.6296$ and $\phi_y = 0.356$ are, however, not far from the expected. Meanwhile, there is strong feedback of interest rate to any failure in securing targeted output growth. Its posterior mean reaches 4 times higher than prior mean despite the choice of rather tight prior density. Estimate results also show that Vietnam does condition on exchange rate besides other targets when setting it policy rates. Taylor coefficient on exchange rate depreciation is indeed larger than hinted by prior mean, although it has pretty wide posterior probability bands that could embrace a degree as low as 0.006. This estimate is quite robust against several round of testing with different substitute of priors.

The estimation can also tell a fairly consistent story about relative market power in home SOE versus the rest of the world. Estimated elasticity of substitution between Home and Foreign goods in foreign market (3.13) surpasses its prior mean (2) and greatly exceeds that of home market (1.268). Foreign consumers, who appear to be more elastic to price change, have more options and incentives to abandon goods produced by home country as long as the price goes up. This results, coupled with the weaker home monopolists' power compared to world economy (markups at 1.12 versus 1.14 respectively), exhibits the disadvantage of Vietnam firms in the competition when it comes to international trade.

Intuitively speaking, lower market power could mean more costly price adjustment. This paper findings on Vietnam economy indicates the same situation by showing massive cost burden of changing prices on export goods, much higher than findings of other studies including those investigates developing economies (Smets & Wouters, 2003, Peiris & Saxegaard, 2007). This estimate is strongly supported by data as showed in the identification strength test (using Fisher information matrix) figure (Appendix E). Equivalently in a staggered price context, the results say that in domestic market, Vietnamese producers are subject to more than 5-quarter wait to re-optimize their production plan, and export prices are rigid even up to 2-year cycle. This illustration, however, does not necessarily imply CPI inflation would be better held down, but rather speaking of a greater deterioration of final aggregate products because producers would anyway bear the costs and update prices in aware of the high inflationary environment. High adjustment cost coupled with low monopolistic power of home exporter explains the choice of some SOE studies in modelling foreign block as closed economy, as interference of home economy has only negligible effects on foreign economy dynamics (Monacelli, 2005).

This paper sees a quite similar result on habit formation parameters compared with Justiniano & Preston (2010). Habit persistence degree is estimated at 0.2393 and less prominent than other studies, even though the choice of prior allows for greater value. The economy displays quite high elasticity of inter-temporal substitution, which means consumption are responsive to the real interest rate along the IS curve, i.e. a lower consumption smoothing motive. This result is somehow surprising provided the assumption of complete international risk sharing in this model economy, and may present a distinct argument against micro evidence on consumption smoothing behaviors in developing countries. This, however, should be a matter of further empirical investigation, while this model is not much sensitive to this parameter.

Table 4.1: Priors distribution and posteriors estimation

Parameter		Priors			Posteriors estimate	
		Dist.[3]	Mean	SD	Median	90% HPD
Habit formation	h	B	0.5	0.25	0.239	[0.145 0.324]
Inverse intertemporal elasticity of substitution	σ	G	1.2	0.4	0.489	[0.362 0.637]
Elasticity of substitution between H-F goods domestic market	θ	G	1.5	0.5	1.268	[0.869 1.880]

[3]B: Beta distribution, G: Gamma distribution, INV: Inverse gamma distribution

Elasticity of substitution between H-F goods foreign market	η	G	2	0.75	3.136	[1.986	4.093]
Home price indexation	v	G	10	0.75	9.528	[8.387	10.547]
Foreign price indexation	γ	G	8	0.5	7.762	[7.018	8.558]
Price adjustment cost for non-tradable goods	Φ_H	G	100	20	123.2	[101.7	146.2]
Price adjustment cost for export goods	Φ_X	G	200	30	344.7	[299.8	391.3]
Price adjustment cost for import goods	Φ_F	G	100	20	122.2	[89.4	158.8]
Interest rate smoothing	ρ_R	B	0.5	0.1	0.523	[0.407	0.647]
Taylor coefficient inflation	ϕ_π	G	1.5	0.25	1.629	[1.192	1.929]
Taylor coefficient output	ϕ_y	G	0.5	0.13	0.356	[0.258	0.464]
Taylor coefficient output growth	ϕ_g	G	0.5	0.13	2.013	[1.746	2.345]
Taylor coefficient exchange rate depreciation	ϕ_e	G	0.2	0.1	0.222	[0.062	0.380]
Tech shock persistence	ρ_A	B	0.85	0.1	0.544	[0.409	0.648]
Preference shock persistence	ρ_ω	B	0.85	0.1	0.994	[0.989	0.999]
Foreign interest rate persistence	ρ_{Z^*}	B	0.85	0.1	0.826	[0.698	0.949]
Foreign output persistence	ρ_{R^*}	B	0.85	0.1	0.797	[0.608	0.912]
Foreign inflation persistence	ρ_{π^*}	B	0.85	0.1	0.746	[0.593	0.896]
Risk premium shock persistence	ρ_Φ	IVG	0.5	0.1	0.937	[0.896	0.983]
SD technology shock	ϵ_A	IVG	0.5	inf	0.1003	[0.084	0.119]
SD preference shock	ϵ_ω	IVG	0.5	inf	0.265	[0.139	0.430]
SD foreign output shock	ϵ_{Z^*}	IVG	0.5	inf	0.046	[0.042	0.053]
SD foreign inflation shock	ϵ_{π^*}	IVG	0.5	inf	0.045	[0.041	0.049]
SD risk premium shock	ϵ_Φ	IVG	0.5	inf	0.076	[0.063	0.088]
SD Taylor rule	ϵ_R	IVG	0.5	inf	0.056	[0.049	0.062]

Shocks are persistent in general with the smoothing factor varies between 0.74 and 0.99. Sole exception is technology shock, which performs most flat posterior PDF with mean at 0.5444 and large standard deviation at 0.1. Preference, on the other hand, is the most volatile disturbance in this economy, standard deviation of shock is estimated at most 0.2646.

5 Monetary Policy

5.0.1 Central Bank Optimization Problem

We apply the approach proposed by Justiniano & Preston (2010) and let Central Bank assume its mandate in stabilizing macro-economy by minimizing the objective function:

$$W_0 = E_0 \sum_{t=0}^{\infty} \beta^t L_t$$

where the loss function is measured by deviation of inflation, output and nominal interest rate from its steady states: $L_t(\rho_R, \phi_\pi, \phi_y, \phi_g, \phi_e) = \pi_t^2 + \lambda_y y_t^2 + \lambda_R R_t^2$. For the sake of simplicity, I considered the case when discount factor goes to unity and loss function is specified as the weighted total of $var(\pi_t)$, $var(y_t)$ and $var(R_t)$.

The weights (λ_y, λ_R) indicating priority given to output and nominal interest rate variation are normalized by that of CPI inflation. Rather than endogenously determined within the model, a number of arbitrary weights coordinates will be assigned to compare the optimal policy parameters. Model structural parameters are assumed to be known in the model and stay at posterior median estimated from Vietnam observable data in the earlier section.

Policy maker employs a backward-looking Taylor-type interest setting rule that conditions on past inflation, output and contemporaneous currency depreciation. A modified version featuring all contemporaneous policy factors was also used in several testing rounds.

$$R_t = \rho_R R_{t-1} + \phi_\pi \pi_{t-1} + \phi_y y_{t-1} + \phi_g \Delta y_t + \phi_e \Delta e_t + \epsilon_{Rt}$$

The $(1 - \rho_p)$ term in original model is omitted to allow for the stance of policy that governs first different in interest rate rather than level (witnessed in Justinianno & Preston (2010)). Interest rate smoothing coefficient is bounded between 0 and 1. Optimality would be achieved for the set of policy parameters that produces the mimimum theoretical variance in the loss function.

5.0.2 Optimal Taylor Rule Coefficients

This subsection provides optimal sets of Taylor rule coefficients that solve the Central Bank optimization problem described above, given various arbitrary designs on weights. These results represent an argument on the appropriate level of policy responsiveness that should be placed on fluctuation of fundamental macroeconomic variables. Parameters are estimated based on structural parameters of Vietnam economy, then would be compared to the policy parameters found to be in practice there.

In the first exercise, interest smoothing parameter and all four Taylor rule coefficients were allowed to vary simultaneously while weights were assigned equally on inflation, outputs and interest rate. This setting yielded a unit root in interest rate processes and unrealistically high value for the other four parameters $(\phi_\pi, \phi_y, \phi_g, \phi_e) = (4.79, 9.94, 70.6, 3.96)$. It is worth mentioning that there is only small gap between optimal responses to inflation and exchange rate volatility. These excessively large values maybe due to the presence of critical inter-temporal variables in a highly inertial policy environment (unity smoothing coefficient). In the subsequent efforts, ϕ_g was fixed at its estimated point to avoid such scaling effect.

Table 5.1: Optimal monetary policy coefficients

Policy coefficients	Estd.	Weights (λ_y, λ_R)[4]					
		(1,1)	(1, 0.5)	(0.5,1)	(0.5,0.5)	(0,1)	(1,0)
Inflation	1.629	0.042	0.005	0.187	0.125	3.98	-0.038
Output	0.356	2.279	2.361	2.074	2.234	0.223	2.45
Norminal exchange rate	0.222	0.061	-0.089	0.380	0.144	0.813	-0.262
Interest rate	0.523	0.79	0.757	0.812	0.745	1	0.717
Output growth	2.013	-	-	-	-	-	-
Loss		0.024	0.0019	0.0021	0.0016	0.00076	0.00145

Our weight settings consistently show high degree of persistence of interest rate, ranging from 0.71 to the extreme value at 1 (when zero weight is assigned on output). This inertia is, however, much weaker than findings in other developed economies context. Output stabilization remains with the highest priority regardless of the weight assigned on it. Only at extreme scenario when output are removed from loss function, feedback from interest rate is then shifted to inflation and currency depreciation; response to output variability is held close to estimated Taylor rule for Vietnam economy.

There is sign of the inherited inflation - output stabilization trade-off present in this model; the heavier the relative attention on output fluctuation, the smaller policy reaction on nominal sector is advised. Analogous pattern can be seen for Taylor coefficients on exchange rate volatility and the concerns against interest rate variance. It stems from model adoption of uncovered interest rate parity hypothesis, where expected currency depreciation is derived directly from policy rates relativity in foreign and home economy.

In any setting, it is optimal to condition on nominal currency fluctuation by a responsive manner. Depending on the loss function It could either draw equal feedback from interest rate in compared to CPI inflation variations, or stand out at even higher than observed level in Vietnam economy. This outcome works against the "exchange rate disconnect" puzzles and findings by Lubik & Schorfheide (2003) and Justinniano & Preston (2010), despite large resemblance in methodology between this paper and the latter. Strong interaction between interest and currency depreciation can be explained within the model construction as well as idiosyncratic features of the investigated economy. Contamination from volatility of exchange is linked with variability in real sector in via its impacts on trading activities. Vietnamese traders' profits is sensitive to any movement exchange rate due to local currency price setting practice. By locating both importers and exporters

[4] Relative weights on output stabilization are in turn 1, 2, 0.5, 1, 0, 0

inside home country, this model opens gateway for exchange rate fluctuation to directly enter profit function and influence local entities' decision on prices and outputs, which directly constitutes aggregate macro variables. In an alternative setting which features a foreign retailer that distributes export goods in world market, the exchange rate risks would be absorbed at dock by the retailer before passing through to home price level (Devereux & Engel, 2004). Structural characteristics of Vietnam imposed on the model economy amplifies further the magnitude of influence from exchange rate volatility. In the total domestic CPI inflation $\hat{\pi}_t = \zeta\hat{\pi}_t^H + (1-\zeta)\pi_t^F$, a much heavier share accommodated by import price inflation for the case of Vietnam means movements in the import sector could exacerbate more severely stability of aggregate domestic fundamentals. Weak home-bias obstructs participation in the supply chain; meanwhile relatively low monopolistic power in exporting couple with excessively heavy burden of price updating would substantially deteriorate production if price is forcibly updated due to exchange rate volatility. Existence of a durable "connect" among exchange rate and macro fundamentals in Vietnam is thus implied.

6 Conclusion

The key contribution of this paper is empirical evidence from developing economies to major arguments posed within New Keynesian economic framework regarding optimal monetary policy. On construction of monetary responses, it exhibits a strong emphasis of the Central Bank on variability of output growth in reality as well as in the stabilization-targeting policy problem. The results shown in this paper is also in favor of the policy mechanism that properly conditions on fluctuation of exchange rate. The economy characteristics that lead to this implications come in threefold. First, there is active and direct participation of local firms in international trade so that currency depreciation enters directly their profit function and affect production plan of home agents. In addition, weak market power and high magnitude of price stickiness exacerbates producers' revenue more deeply in the face of exchange rate uncertainty. Furthermore, larger share of tradable sector in the economy allows for the shocks in foreign economy and foreign currency denominated variables to transmit faster to local aggregate fundamentals. Exchange rate transmission channel is therefore more amplified.

The difference between multiple target Taylor-type interest setting rule versus other extreme monetary policy alternatives is that the policy maker does not especially wish to hard peg the currency. Instead, they take into account to the fluctuation and adjust their policy instruments to avoid excessive volatility of key macro economic fundamentals. Thus, this result should not be interpreted as advocating less flexible exchange rate mechanism, rather an implication on the role of foreign exchange related policy in a shock-prone, foreign reliant economy as Vietnam.

It is evident that incomplete exchange rate pass-through and open economy features in production sector are key determinants of the result yielded in this paper. However, the model have yet to take into account financial integration factor and other aspect of economy openness. This full fledged type of model is therefore left for future research.

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Appendix

A Optimal price setting

$$\max_{\{P_t^i(z)\}} E_t \sum_{j=0}^{\infty} D_{t,t+j} \Big\{ \frac{P_{t+j}^i(z)}{P_{t+j}} Q_{t+j}^i(z) - mc_{t+j} Q_{t+j}^i(z) - \frac{\Phi_i}{2} \left[\frac{P_{t+j}^i(z)}{P_{t+j-1}^i(z)} - 1 \right]^2 Q_t^i \Big\} \quad \text{(i=H,X)}$$

i) For domestic market, demand for each differentiated goods $Q_{t+j}^H(z) = \left[\frac{P_{t+j}^H(z)}{P_{t+j}^H}\right]^{-v} Q_{t+j}^H$ so the optimization problem becomes:

$$\max_{\{P_t^H(z)\}} E_t \sum_{j=0}^{\infty} D_{t,t+j} \Big\{ \frac{P_{t+j}^H(z)}{P_{t+j}} \left[\frac{P_{t+j}^H(z)}{P_{t+j}^H}\right]^{-v} Q_{t+j}^H - mc_{t+j} \left[\frac{P_{t+j}^H(z)}{P_{t+j}^H}\right]^{-v} Q_{t+j}^H - \frac{\Phi_H}{2} \left[\frac{P_{t+j}^H(z)}{P_{t+j-1}^H(z)} - 1 \right]^2 Q_t^H \Big\}$$

First order condition with respect to $P_{t+j}^H(z)$:

$$\begin{aligned} 0 = (1-v) \left[\frac{P_t^H(z)}{P_t^H}\right]^{-v} \frac{Q_t^F}{P_t} + v \left[\frac{P_t^H(z)}{P_t^H}\right]^{-v-1} \frac{Q_t^H}{P_t^H} \frac{MC_t}{P_t} \\ - \Phi_H \left[\frac{P_t^H(z)}{P_{t-1}^H(z)} - 1\right] \frac{Q_t^H}{P_{t-1}^H(z)} + \Phi_H E_t \Big\{ D_{t,t+1} \left[\frac{P_t^H(z)}{P_{t-1}^H(z)} - 1\right] \frac{P_{t+1}^H(z)}{P_t^H(z)} \frac{Q_{t+1}^H}{Q_t^H} \frac{Q_t^H}{P_t^H(z)} \Big\} \end{aligned}$$

In equilibrium, all firm behave similarly so $\frac{P_t^H(z)}{P_t^H} = 1$, FOC becomes:

$$\frac{P_t^H}{P_t} = \frac{v}{v-1} mc_t - \frac{\Phi_H}{v-1} (\pi_t^H - 1)\pi_t^H + \frac{\beta \Phi_H}{v-1} \left[\frac{U'_{C,t+1}}{U'_{C,t}} (\pi_{t+1}^H - 1) \pi_{t+1}^H \frac{Q_{t+1}^H}{Q_t^H} \right]$$

Symmetric equilibrium can be applied for tradable goods in a similar way to yield the pricing equations.

ii) For export goods, the posted price is denominated in foreign currency ($P_t^{X*}(z)$), exporter shall convert back to equivalent local currency price $P_t^X(z) = e_t P_t^{X*}(z)$ to solve his profit maximization target, which now presented in pure local currency denominated variables:

$$\max_{\{P_t^X(z)\}} E_t \sum_{j=0}^{\infty} D_{t,t+j} \Big\{ \frac{P_{t+j}^X(z)}{e_t P_{t+j}} \left[\frac{P_{t+j}^X(z)}{P_{t+j}^X}\right]^{-\gamma} Q_{t+j}^X - mc_{t+j} \left[\frac{P_{t+j}^X(z)}{P_{t+j}^X}\right]^{-\gamma} Q_{t+j}^X - \frac{\Phi_X}{2} \left[\frac{P_{t+j}^X(z)}{P_{t+j-1}^X(z)} - 1 \right]^2 Q_t^X \Big\}$$

For the importers, their marginal cost is expressed entirely by product of exchange rate and world price. The optimal price setting equation is therefore analogous to that of non-tradable goods, except the marginal cost is now replaced by importers' $mc_t = e_t P_t^*(z)$.

B Log-linearized system

The empirical analysis with Bayesian technique requires the system of equations characterizing model equilibrium to be expressed in a linear Gaussian form readily for Kalman filter technique. In this paper, optimal decision rule of endogenous variables are thus log-linearized around a non-stochastic steady state. The new system features all three core elements of New Keynesian model: i) an IS equation governs relation between consumption and interest rate, ii) a New Keynesian Phillip Curve (NKPC) characterizing inflation and real variables, iii) a monetary policy rule, together with other identities.

The adapted IS equation is obtained by log-linearizing household optimality's Euler Equation:

$$\frac{-\sigma}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \frac{\sigma}{1-h}(\hat{c}_{t+1} - h\hat{c}_t) = \omega_{t+1} - \omega_t + \hat{R}_t - E_t\hat{\pi}_{t+1}$$

$$\hat{c}_t = \frac{1}{1+h}\hat{c}_{t+1} + \frac{h}{1+h}\hat{c}_{t-1} - \frac{1-h}{\sigma+\sigma h}\hat{R}_t + \frac{1-h}{\sigma+\sigma h}E_t\hat{\pi}_{t+1} + \frac{1-h}{\sigma+\sigma h}E_t(\omega_t - \omega_{t+1})$$

Another useful condition derived from household optimization is the uncovered interest rate parity that comes in linearized form:

$$\hat{R}_t - \hat{R}^*_t = \Delta\hat{e}_{t+1} + \hat{\Psi}_t = \Delta\hat{e}_{t+1} + \hat{\Phi}_{Rt} - \chi\hat{D}_t$$

NKPC is adopted by log-lineaizing firm optimal price setting equations.

$$\frac{1-\zeta}{\theta}(\hat{q}^F_t - \hat{q}^H_t) = \frac{v}{v-1}\hat{mc}_t - \frac{\Phi_H}{v-1}\hat{\pi}^H_t + \frac{\beta\Phi_H}{v-1}\left[\frac{-\sigma}{1-h}(\hat{c}_{t+1} - h\hat{c}_t) + \frac{\sigma}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \hat{\pi}^H_{t+1} + \hat{q}^H_{t+1} - \hat{q}^H_t\right]$$

$$T\hat{O}T^X_t = \frac{\gamma}{\gamma-1}\hat{mc}_t - \frac{\Phi_X}{v-1}\hat{\pi}^X_t + \frac{\beta\Phi_F}{v-1}\left[\frac{-\sigma}{1-h}(\hat{c}_{t+1} - h\hat{c}_t) + \frac{\sigma}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \hat{\pi}^X_{t+1} + \hat{q}^X_{t+1} - \hat{q}^X_t\right]$$

$$T\hat{O}T^F_t = \frac{v}{v-1}\hat{q}_t - \frac{\Phi_F}{v-1}\hat{\pi}^F_t + \frac{\beta\Phi_F}{v-1}\left[\frac{-\sigma}{1-h}(\hat{c}_{t+1} - h\hat{c}_t) + \frac{\sigma}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \hat{\pi}^F_{t+1} + \hat{q}^F_{t+1} - \hat{q}^F_t\right]$$

From here, we explore some useful expression and definitions. The official term-of-trade (TOT) defined as the ratio of export prices to import prices, can be interpreted as the amount of import goods an economy can purchase per unit of export goods. For internal use, we conveniently denote TOT^X_t as the relative price between export and total CPI, and TOT^F_t is the same expression for the case of import price.

$$T\hat{O}T^F_t - T\hat{O}T^F_{t-1} = \hat{\pi}^F_t - \hat{\pi}^F_{t-1}$$

and

$$T\hat{O}T^X_t - T\hat{O}T^X_{t-1} = \hat{\pi}^X_t - \hat{\pi}^X_{t-1} - \Delta\hat{e}_t$$

Apart from consumption appears due to inter-temporal utility discount, real variables appear in the equations include export $\hat{q}^X_t$, import $\hat{q}^F_t$ and non-tradable goods $\hat{q}^H_t$. Log-linearized expressions base on earlier functional derived in the firm's problem brings us the forms:

$$\hat{q}^F - t = -\theta(\hat{p}_t^F - \hat{p}) + \hat{z}_t = \frac{-\theta}{\zeta} T\hat{O}T_t^F + \hat{q}_t^F$$
$$\hat{q}_t^X = -\eta(\hat{p}_t^X - \hat{e}_t - \hat{p}_t^*) + \hat{z}_t^* = -\eta(T\hat{O}T_t^X - q) + \hat{z}_t^*$$

$q = \frac{e_t P_t^*}{P_t}$ is defined as real exchange rate. Log-linearizing around steady state yields:

$$\hat{q}_t = \hat{e}_t + \hat{p_t^*} - \hat{p}_t \quad \text{and} \quad \hat{q}_t - \hat{q}_{t-1} = \Delta\hat{e}_t + \hat{\pi}_t^* - \hat{\pi}_t$$

The two goods market clearing conditions gives the expression for national accounting identity:

$$\hat{z}_t = \hat{c}_t = \zeta\hat{q}_t^H + (1-\zeta)\hat{q}_t^F = \zeta(\hat{y}_t - \hat{q}_t^X) + (1-\zeta)\hat{q}_t^F$$
$$\hat{y}_t = \frac{1}{\zeta}\hat{c}_t + \hat{q}_t^X + \frac{\zeta - 1}{\zeta}\hat{q}_t^F$$

The marginal cost is given by $\hat{mc}_t = \varphi\hat{y}_t + \frac{\sigma}{1-h}(\hat{c}_t - \hat{c}_{t-1}) - (\varphi + 1)\hat{a}_t - \frac{1-\zeta}{\theta}(\hat{q}_t^F - \hat{q}_t^H)$.

Debt evolves according to: $\hat{D}_t - \frac{1}{\beta}\hat{D}_{t-1} = \frac{\zeta-1}{\zeta}\hat{q}_t^F - \hat{q}^X$.

Again, the model is closed by Taylor rule:

$$\hat{R}_t = \rho_R\hat{R}_{t-1} + (1-\rho_R)(\phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t + \phi_g\Delta\hat{y}_t + \phi_e\Delta\hat{e}_t) + \epsilon_{Rt}$$

C Impulse Response Functions

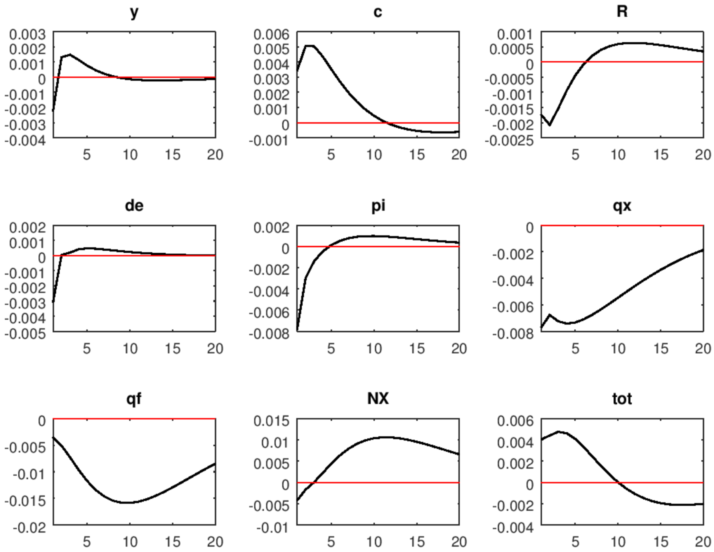

Figure A0.1: Impulse response to technology shock

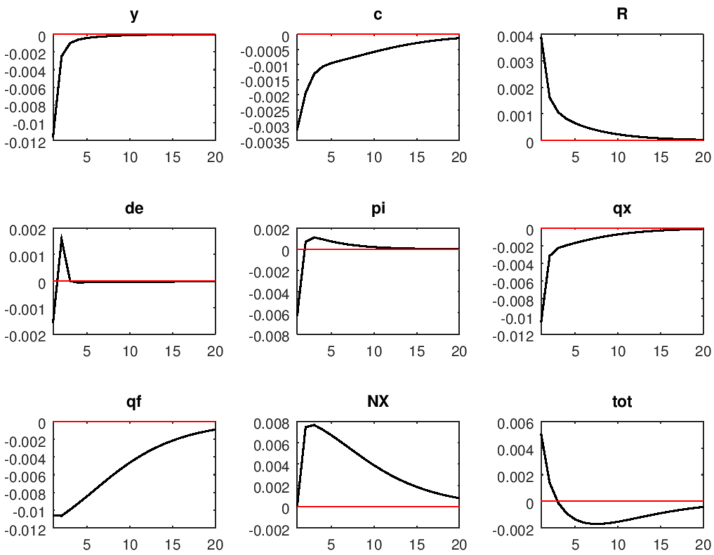

Figure A0.2: Impulse response to monetary policy innovation

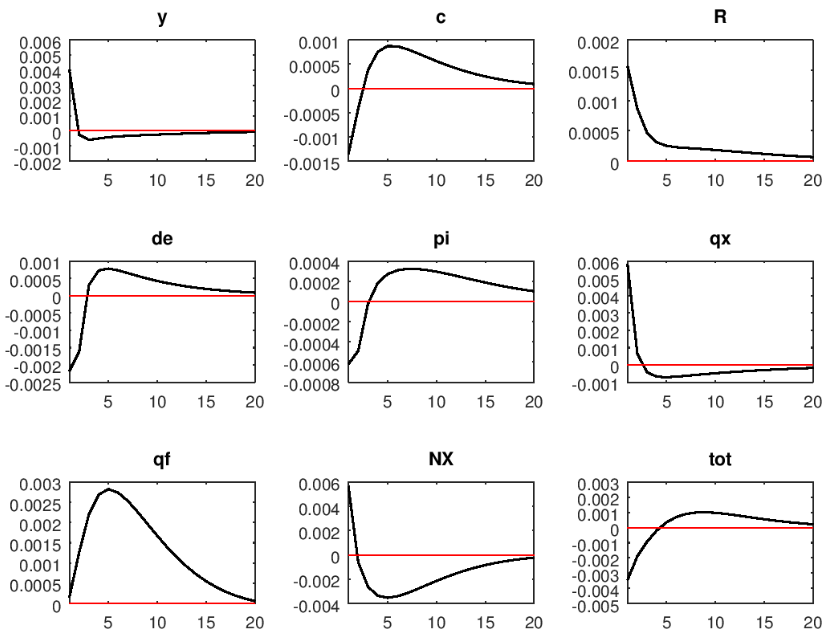

Figure A0.3: Impulse response to risk premium shock

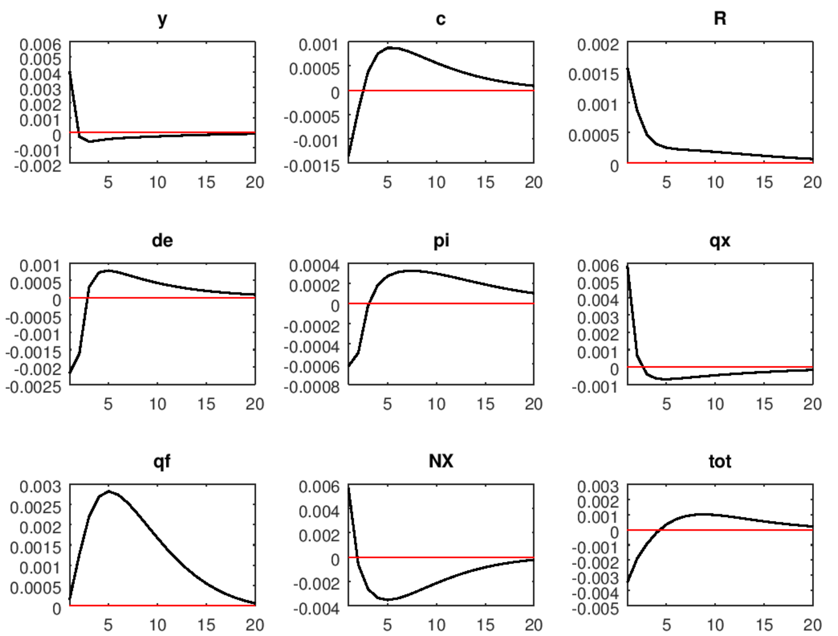

Figure A0.4: Impulse response to foreign interest rate shock

D Priors and Posteriors

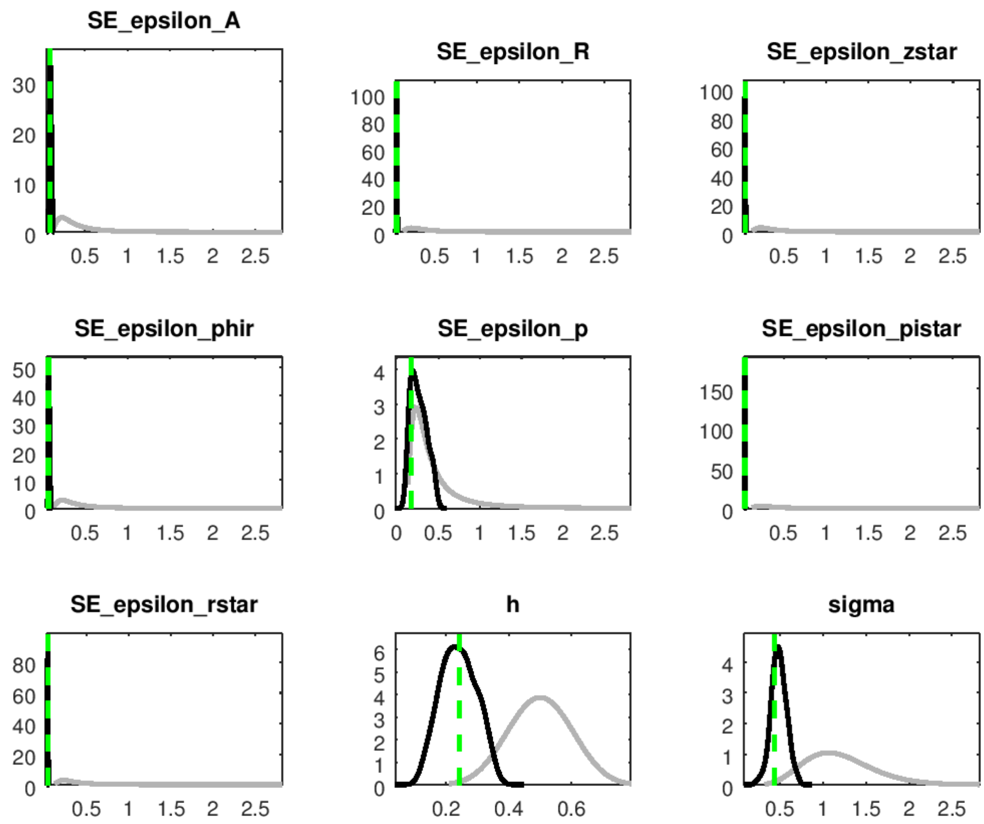

Figure A0.1: Priors and Posteriors Estimation (1)

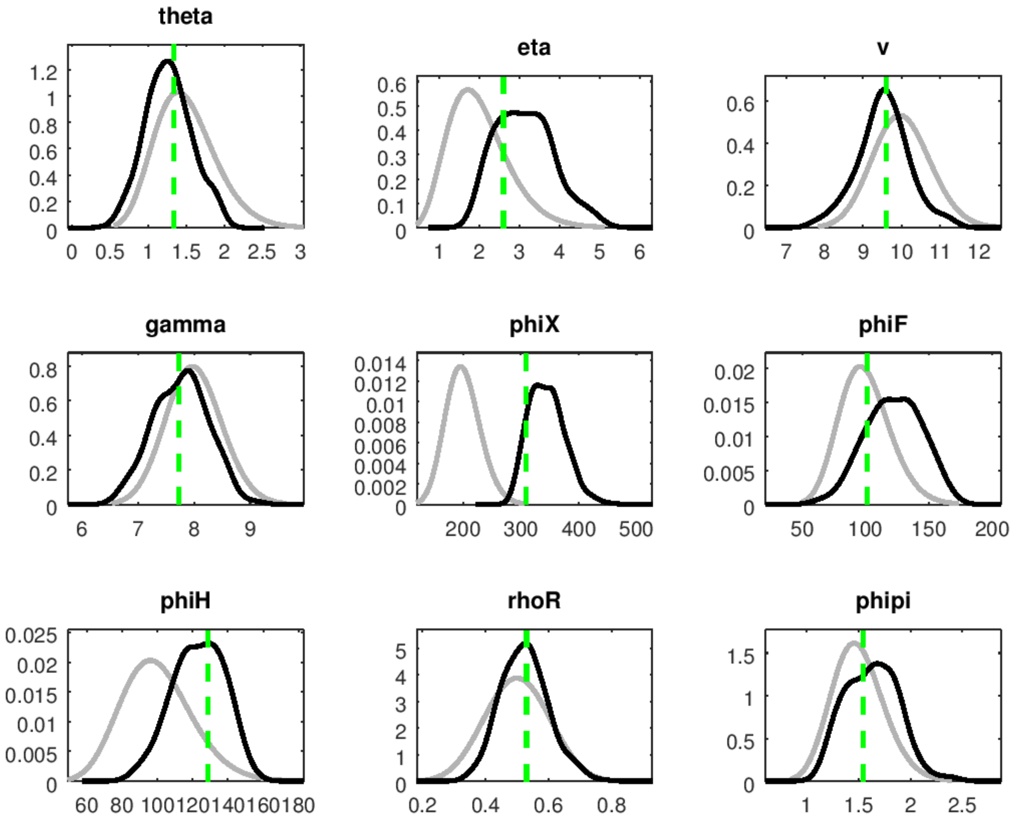

Figure A0.2: Priors and Posteriors Estimation (2)

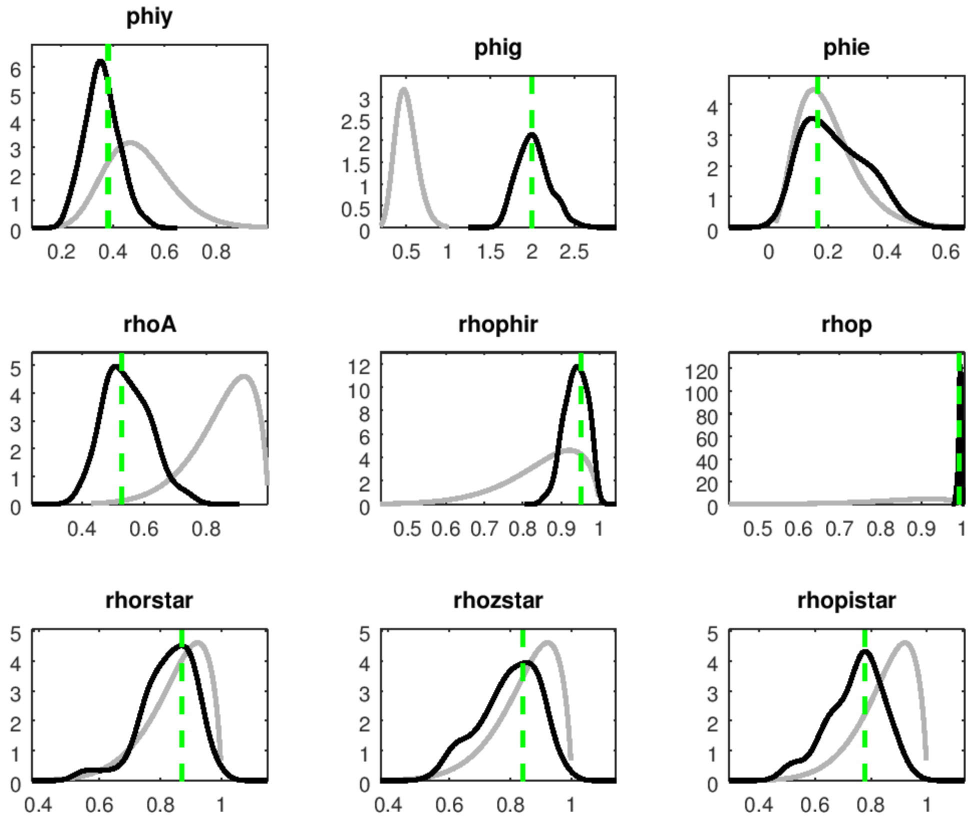

Figure A0.3: Priors and Posteriors Estimation (3)

E Identification

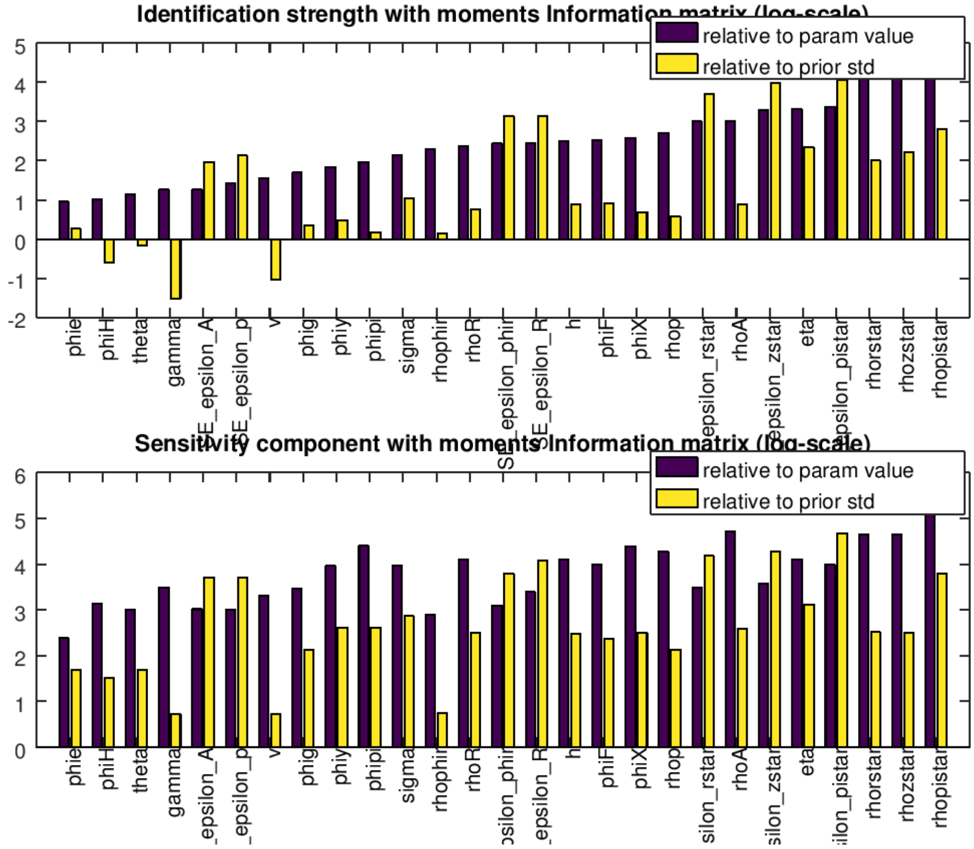

Figure A0.1: Identification strength of model parameters