MRes dissertation

How do capital controls and macroprudential policy interact with monetary policy in a small open economy?

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Abstract

In this paper, I focus on how macroprudential or capital control policy complements monetary policy of small open economies in the face of foreign interest rate shock. I build the base model followed by Aoki et al. (2018) and simulate the impulse response to the foreign interest rate shock and compare the two policies in terms of welfare. The results show that macroeconomic variables under low interest rate environment are more volatile than under high interest rate when the foreign interest rate shock is transmitted to SOEs. It implies that low interest rate environment is more vulnerable to recession than high interest rate environment. I also find that both macroprudential policy and capital control can help to mitigate the influence of foreign interest rate shock but capital control is a better instrument than macroprudential policy in terms of welfare.

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1 Introduction

After the global financial crisis (GFC), small open economies (SOEs) with high external dependence have been greatly affected by global factors, not only in the real sector but also in the financial sector. Monetary policy decisions in major countries such as the United States can have a significant impact on the changes of the market interest rates and exchange rates in SOEs through a wide variety of channels. Since the GFC, the low interest rate trend has been prolonged due to the zero interest rate policy of major countries such as the US, ECB, and Japan and the yield searching behavior of global investors has expanded to the emerging market economies. As a result, SOEs' financial markets became financial integration and the influence of global factors on SOEs' financial markets has increased compared to before the financial crisis (Ahmed and Zlate (2014) and Forbes and Warnock (2012)). One of evidence to support this is that the size of cross-border financial asset holdings has significantly increased over the past 20 years. As shown in table 1, the external financial debt of major countries increased from 3.6 times (Sweden) to 7.1 times (Australia) from 2000 to 2020. As well as major countries, Korea, a small open economy, increased about 6.7 times from $223.1 billion in 2000 to $1496.7 billion in 2020. As such, as the international integration of financial markets expands, the monetary policy of major economies has become a stronger impact on capital in-and-outflows, as well as the interest rates differential and exchange rates in small open economies.

The expansion of the influence of global factors can significantly affect

Table 1: External Financial Liabilities for Selected Countries

(billions of dollars)

	2000	2005	2010	2015	2020
Australia	441.0	982.1	2,088.9	2,296.3	3,116.3
Korea, Rep. of	223.1	512.0	826.4	939.5	1,496.7
Norway	159.3	413.5	830.7	788.3	980.5
Sweden	499.3	853.2	1,453.4	1,460.8	1,821.3
Thailand	114.0	147.5	305.0	381.8	550.1
United States	9,178.6	15,214.9	24,279.6	30,892.2	46,267.6

Source: International Investment Position, IMF

each country's foreign exchange rate and monetary policy decision which is relevant to the trilemma-dilemma debate. According to the trilemma hypothesis, a country cannot achieve three policy goals simultaneously: stable exchange rate, free international capital mobility and monetary policy autonomy at achieving domestic goals. That is, to achieve two of these three policy goals, one must be abandoned. Thus, if the trilemma is established, the independence of monetary policy can be ensured by giving up currency stability through the adoption of a flexible exchange rate regime. On the other hands, Rey (2015) suggests the dilemma hypothesis that whenever capital is freely mobile, the global financial cycle constrains domestic monetary policy regardless of the exchange rate regime.

The SOEs such as Korea seek to achieve the two goals of free capital mobility and independent monetary policy while absorbing external shocks through exchange rate fluctuations. If the trilemma is established, an independent monetary policy is possible in principle for economies that adopt floating exchange rates regime. For example, even if the US policy interest rate rises, the flexible exchange rate system made the yields of Korea and the US of government bonds be the same, so capital outflow from Korea to the US does not occur and the domestic monetary policy can be implemented according to internal circumstances. However, if the influence of global factors on the domestic financial market is excessive, it will be difficult to sufficiently absorb the impact of external shocks by only changing the exchange rate. Furthermore, the effectiveness of domestic monetary policy may be weakened (Bruno and Shin (2015) and Turner (2014).) There is a question as to whether a fully floating exchange rate system can be operated in SOEs in reality. In the case of many SOEs, since their own currency is not denominated in the international financial market, they are financed through a global currency such as the dollar, which is inevitably affected by the external environment (so-called original sin). If the exchange rate excessively fluctuates, the value of external debt will be able to change substantially. Thus it will have a negative impact on the real economy. As a result, many SOEs have incentives to operate monetary policy that focuses on the exchange rate to stabilize the external economy rather than the domestic economy. To stabilize the exchange rate against external factors, the policy rate must eventually be changed according to the exchange rate. Therefore, the argument that independent monetary policies cannot be implemented in SOEs even if they actually adopt a flexible exchange rate regime has became more persuasive after the GFC.

In this context, as the financial integration accelerates, there is also an argument that independent monetary policy is impossible without capital control or macroprudential policy. In other words, the independence of monetary policy in SOEs is weakening regardless of the exchange rate regime and the improvement of independence is possible through the management of capital movement. For example, as liquidity became plentiful after quantitative easing in the US, international investment banks invested heavily in financial instruments in the EMEs. Then, the central banks in the EMEs lost control of long-term interest rates. Even if the central banks intend to tighten the economy through the policy rates, long-term interest rates are not determined by the central bank, but by international capital, so there is practically no independence of monetary policy. Therefore, long-term interest rates, which have a greater influence on the real economy than short-term interest rates, respond more sensitively to global financial conditions. In other words, it means that the transmission process from the policy rate to long-term interest rates in SOEs is deteriorated, and the influence of monetary policy on the domestic economy undermines. Thus it is difficult to ensuure the independence of monetary policy if the flow of funds is not controlled.

If there exist some tools that can absorb foreign shocks such as capital in- and out-flows, monetary policy will be able to focus solely on domestic shocks. The alternatives to support monetary policy is capital control and macroprudential policy. Rey (2015) argues that under the circumstance that foreign capital flows lead to asset price bubbles, excess credit creation, and financial instability, capital controls or some tool of active capital account management is necessary in many countries and mentions "independent monetary policies are possible if and only if the capital account is managed." IMF (2012) states that capital liberalization is not always desirable for all countries, but that capital flow management measures, including capital control, can be utilized limitedly if the rapid influx of capital increases financial system instability.

In this paper, I focus on how macroprudential policy and capital control complements monetary policy of SOEs in the face of foreign interest rate shock. Specifically, the research questions are as follows:

1. Is the impact of foreign interest rate shock under low interest rate environment greater than that under high interest rate environment? If the low-interest rate trend is defined as after the GFC, and the high-interest rate trend is defined as before the GFC, it enables to compare whether the impact of the foreign rate shock on macroeconomics variables has changed before and after the GFC.

2. Can macroprudential or capital control policy mitigate the shock of foreign interest rate shock? In other words, if these two policies mitigate the fluctuation of macroeconomic variables caused by the foreign interest rate shock, the domestic monetary policy can focus on the internal conditions. It implies that managing the capital movement can help improve the independence of monetary policy.

3. If both two policies are effective to mitigate the foreign interest rate shock, which is the better policy to complement monetary policy? In terms of welfare, I can compare between the effect of capital control and macroprudential policy.

Specifically, I employ New Keynesian with a open economy framework based on Aoki et al. (2018) (henceforth ABK) to examine the interaction between these two policies and monetary policy in SOEs. The ABK framework incorporates a banking sector into a small open economy model. This banking sector plays a significant role in the model in that the impact of foreign shock on macroeconomic variables can be amplified. Introducing the banking sector is suitable for the small open economy model considering that the share of banks in the financial sector is larger in emerging economies than that in advanced economies (Kitano and Takaku, 2020). Moreover, it enables to analyze the effect of capital control and macroprudential policy by taxing on foreign borrowing or banking capital.

The main results that I find are as follows:

1. In the case of foreign interest rate shock, the fluctuation of macroeconomic variables in the low interest rate circumstance is greater than in the high interest rate circumstance. In other words, It implies that low interest rate environment is more vulnerable to recession than high interest rate environment.

2. Both capital control and macroprudential policy appear to mitigate the impact of foreign interest rate shock. This can be interpreted that the central bank of SOEs focuses more on the domestic condition such as stabilization of inflation and GDP gap rather than the external condition such as fluctuation of exchange rate.

3. From the point of view of social welfare, capital control is a better instrument than macroprudential policy. Therefore, it is effective to use capital control for dealing with the event of foreign interest rate shock.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the model based on DSGE framework. Section 4 provides the results under several scenarios. Section 5 concludes and discusses implication of the findings.

2 Literature review

Before the GFC, the literatures show that foreign factors do not have a significant influence on the transmission of monetary policy and its effectiveness. Boivin and Giannoni (2008) examines the relationship between international forces and the US macroeconomic variables by using factor augmented VAR and suggests that in the case of the United States, global forces do not have play significant role in the monetary policy mechanism. Woodford (2007) concludes that international finance integration has little effect on monetary policy through the NK model with an open economy. However, after the GFC, due to the advent of zero interest rate policy (ZIRP) in major economies, many EMEs experienced changes of unprecedented magnitude in capital flows. Economists raised doubts as to whether EMEs could control the spillover of major countries' interest rate shocks only by adopting floating exchange rates regime. Rey (2015) argues the dilemma theory that large capital movement after the financial crisis make it difficult to ensure monetary independence regardless of exchange rate regime. Bruno and Shin (2015) and Turner (2014) also mention that the spillover of long term interest rate caused by the monetary policy of advanded countries cannot be prevented solely by flexible exchange rates. Obstfeld (2015) reports that the synchronization of long-term interest rates is experienced in countries with a flexible exchange rate regime as well as countries with a fixed exchange rate regime.

In addition, policymakers and economists argue that some tools such as capital controls and macroprudential regulations need to mitigate the vulnerability of EMEs to external shock (Rey (2015) and IMF (2012)). Moreover, waves in capital flows have generated a strand of literature focused on the role of capital controls and macroprudential policy. Jeanne and Korinek (2010) and Bianchi (2011) find that capital control or macroprudential policy can be welfare improving by reducing the likelihood of "Sudden Stops" crises. Fahri and Werning (2012) employ the NK model with a small open economy to examine the optimal capital control in fixed and floating exchange rate regime. With fixed exchange rates, capital control has an important role to ensure the monetary independence. In addition, in floating exchange rates, it mitigates the depreciation of exchange rate and the drop in consumption and outflow of capital. Kitano and Takaku (2017) set the small open economy with financial friction between domestic banks and foreign investors and find that capital control is effective in the presence of borrowing denominated by foreign currency. De Paoli (2013) also argues that capital control is beneficial for economy by welfare analysis based on the second-order perturbation methods. Korinek and Sandri (2016) compare the effectiveness of macroprudential policy and capital control in the small open economy model with the financial constraint on borrowers and conclude that macroprudential policy reduces the indebtedness of leveraged borrowers whereas capital controls induce more precautionary behavior for both borrower and savers.

Another strand of literature focuses on the effect of using capital control and macroprudential policy combined with monetary policy. David and Presno (2017) examine the relationship between capital control and independence of monetary policy in a flexible exchange rate regime and find that capital control can help central bank more focus on domestic variables.

Unsal (2013) analyzes the relationship between macroprudential policy and monetary policy using the open economy model and argues that macroprudential policy can complement the monetary policy under the capital inflow and macroprudential policy is more effective than capital control. On the other hand, Nispi Landi (2020) and Kitano and Takaku (2020) shows that the welfare-improving effect of capital control is larger than that of macroprudential policy under the foreign interest rate shock in EMEs.

3 Model

To analyze how to interact macroprudential policy and capital control with monetary policy, I build base model followed by ABK (2018) framework. This model is the conventional New Keyenesian model in a small open economy with financial intermediaries (banking sector). It includes the balance sheet channel which plays a role to amplify the effedct of the external shock. To compare the effect of two intstruments, I additionally denote macroprudential policy as tax on banks' lending and capital control as tax on foreign borrowing[1]. In addition, I assume that a central bank follows the augmented Taylor rule considering foreign interest rate as well as inflation, output gap (Daivd and Presno (2017)). The economy is populated by households (workers and bankers), a final goods producer, a continuum of intermediate goods producers and policy makers (government and central bank) that sets capital control, macroprudential policy and monetary policy. I describe the problem of each agent in turn.

[1]The ABK model does not distinguish between macroprudential policy and capital control.

3.1 Producers

3.1.1 Final goods sector

It is assumed that the final goods producer purchases intermediate goods $y_{i,t}$, $i \in [0,1]$ from the intermediate goods market at a price $P_{i,t}$ and produces final goods under perfect competition according to a constant returns to scale, as shown in equation (1)

$$Y_i = \left(\int_0^1 y_{it}^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}} \tag{1}$$

where $\eta > 1$. Then the final goods producer faces the profit maximization problem in (2) subject to (1)

$$\max_{y_{i,t}} \left[P_t Y_t - \int_0^1 p_{it} y_{it} di \right] \tag{2}$$

Solving the first order condition, it derives the demand curve of intermediate goods i as equation (3)

$$y_{it} = \left(\frac{P_t}{p_{it}} \right)^{-\eta} Y_t \tag{3}$$

Combining equation (1) and (3), aggregate price index P_t can be expressed as

$$P_t = \left(\int_0^1 p_{it}^{1-\eta} di \right)^{\frac{1}{1-\eta}}$$

3.1.2 Intermediate goods sector

It is assumed that the intermediate goods market is monopolistic competitive and each producer i inputs capital k'_{it}, imported material m_{it}, and labor l_{it} to produce differentiated intermediate goods y_{it} according to production function as follows

$$y_{it} = A_t \left(\frac{k'_{it}}{\alpha_K}\right)^{\alpha_K} \left(\frac{m_{it}}{\alpha_M}\right)^{\alpha_M} \left(\frac{l_{it}}{1-\alpha_K-\alpha_M}\right)^{1-\alpha_K-\alpha_M}$$

where α_K, α_M and $\alpha_K+\alpha_M \in (0,1)$, and A_t is aggregate productivity shock. Let Z_t, ϵ_t and w_t define the rental price of capital, the price of imported material and the wage rate in terms of final goods. Then the minimized unit cost function of production is derived as

$$m_t^C = \frac{1}{A_t} Z_t^{\alpha_K} \epsilon_t^{\alpha_M} w_t^{1-\alpha_K-\alpha_M} \tag{4}$$

To incorporate price rigidity into the model, I also assume that the intermediate goods producers pay additional cost in the style of Rotemberg (1982) in which firms face a quadratic cost of price adjustment. In other words, if the producers change the price in period t, it involves an adjustment cost $\frac{\kappa}{2}\left(\frac{p_{it}}{p_{it-1}}-1\right)^2$. Each differentiated intermediate goods producer i chooses p_{it}, y_{it} to maximize the expectation of discounted value of profit, subject to the production function (1) and the demand function (3):

$$E_0 \left\{ \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\left(\frac{p_{it}}{P_t} - m^C\right) y_{it} - \frac{\kappa}{2}\left(\frac{p_{it}}{p_{it-1}}-1\right)^2 Y_t \right] \right\}$$

where $\Lambda_{0,t}$ is the stochastic discount factor of the representative households and κ is the price stickiness parameter. Then the first order condition with respect to p_{it} under the symmetric equilibrium $p_{it} = P_t$ is derived as

$$(\pi_t - 1)\pi_t = \frac{1}{\kappa}(\eta m_t^C + 1 - \eta) + E_t \left[\Lambda_{t,t+1} \frac{Y_{t+1}}{Y_t} \pi_{t+1}(\pi_{t+1}-1) \right] \tag{5}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is one plus the inflation rate of the final goods. A usual New Keyenesian Philips curve can be derived via a log-linear approximation around a zero inflation steady state in which $\pi = \frac{\eta-1}{\eta} m^C = 1$

$$\hat{\pi}_t = \frac{\eta - 1}{\kappa} \widehat{m_t^C} + \beta E_t(\hat{\pi}_{t+1})$$

where $\hat{x}_t = (x_t - x)/x$ is the proportional deviation from the steady state value. Under the symmetric equilibrium, it can be induced as follows.

$$Y_t = A_t \left(\frac{K_{t-1}}{\alpha_K} \right)^{\alpha_K} \left(\frac{M_t}{\alpha_M} \right)^{\alpha_M} \left(\frac{L_t}{1 - \alpha_K - \alpha_M} \right)^{1-\alpha_K-\alpha_M} \tag{6}$$

where K_{t-1}, M_t and L_t are aggregate capital stock, imported materials and labor such as

$$K_{t-1} = \int_0^1 k'_{it} di, \;\; M_t = \int_0^1 m_{it} di, \;\; L_t = \int_0^1 l_{it} di$$

Note that the subscript of aggregate capital stock K is $t - 1$ not t, it implies that capital stock is accumulated by the end of the last period and then used for production of this period. The cost minimization implies

$$\frac{\epsilon_t M_t}{Z_t K_{t-1}} = \frac{\alpha_M}{\alpha_K} \tag{7}$$

$$\frac{w_t L_t}{Z_t K_{t-1}} = \frac{1 - \alpha_K - \alpha_M}{\alpha_K} \tag{8}$$

The law of motion for capital is given by

$$K_t = I_t + \lambda K_{t-1} \tag{9}$$

where $\lambda \in (0,1)$ is one minus constant depreciation rate and I_t is investment. The total investment cost equals $\left[1 + \frac{\kappa_I}{2}\left(\frac{I_t}{I} - 1\right)^2\right] I_t$ where the quadratic term is the additional production cost of supplying investment goods that occur when there is a difference between I_t and the non-stochastic steady state level I.

3.2 Households

Following Gertler and Karadi (2011) and Getler and Kiyotaki (2010), I formulate the households sector that involved the financial intermediaries (banks) as well as goods producers. The representative household consists of two types of members - bankers and workers, where the total population size is normalized to be unity. A banker remains a banker in the next period with probability σ or retires in the next period with probability $1-\sigma$. The retired bankers become workers and are replaced by the same number of workers who become new bankers. As a results, the proportion between the two types of members remains constant over time. The retired bankers take net worth as dividends and new bankers receive ξ fraction of total asset from households as initial funds.

Workers are able to own capital (equity) directly and also save deposits in banks. However, if they hold the ownership of capital, the additional management costs $\chi(K_t^h, K_t) = \frac{\varkappa^h}{\beta}\left(\frac{K_t^h}{K_t}\right)^2 K_t$ are incurred to receive the same payoff as bankers. $\varkappa^h$ is a parameter of direct finance cost that represents a disadvantage of workers relative to bankers in financing business. In case of savings, the deposit contract is nominal and short term and non-contingent.

Therefore, if workers deposit D_t^n in this period, they can receive $(1+i_t)D_t^n$ in the next period, where i_t represents the nominal interest rate on deposit.

On the other hand, workers cannot directly own foreign debt due to a lack of knowledge and ability. Therefore, all financial transactions between foreign and home agents are only possible through home banks. In addition, the financial transactions with foreign agents are denominated in foreign currency because the small open economy's currency of is not available in the rest of world. It implies that small open economy has to bear the risk of fluctuating foreign exchange rates.

The representative households solve the following maximization problem with respect to consumption C_t, labor supply L_t, direct capital ownership K_t^h, nominal bank deposit D_t.

$$E_0\left[\sum_{t=0}^{\infty}\beta^t ln\left(C_t - \frac{\zeta_0}{1+\zeta}L_t^{1+\zeta}\right)\right]$$

subject to the budget constraint

$$C_t + Q_t K_t^h + \chi(K_t^h) + D_t = w_t L_t + \Pi_t + (Z_t + \lambda Q_t)K_{t-1}^h + R_t D_{t-1}$$

where w_t is real wage Q_t is the equity price in terms of goods, D_t is the real value of deposit (D_t^n/P_t) and $R_t = \frac{1+i_{t-1}}{\pi_t}$ is the real interest rate on deposit from $t-1$ to t. β is the discount rate, ζ is the inverse of Frisch elasticity if labor supply and ζ_0 is the inverse of labor supply capacity in which these parameters satisfy $0 < \beta < 1$ and ζ, $\zeta_0 > 0$. Π_t is the real profits from production of differentiated goods and investment goods as well as banking as follows

$$\Pi_t = \int_0^1 \left[\left(\frac{p_{it}}{P_t} - m_t^c \right) y_{it} - \frac{\kappa}{2} \left(\frac{p_{it}}{P_t} - 1 \right)^2 Y_t \right] di + \left[Q_t - 1 - \frac{\kappa_I}{2} \left(\frac{I_t}{I} - 1 \right)^2 \right] I_t$$

$$+(1-\sigma)[(Z_t + \lambda Q_t) K_{t-1}^b - R_t D_{t-1} - \epsilon_t R_{t-1}^* D_{t-1}^*] - \xi (Z_t + \lambda Q_t) K_{t-1}^b$$

The first two terms are the profits from production of differentiated goods and investment goods and third term is the dividend for the retired bankers and fourth term is the start-up fund for the new bankers. The profits from final goods production can be ignored due to perfect competition.

The first of conditions for consumptions, labor, holding capital and deposit and investment can be derived as follows:

$$w_t = \zeta_0 L_t^{\zeta} \tag{10}$$

$$1 = E_t \left(\Lambda_{t,t+1} \frac{Z_{t+1} + \lambda Q_{t+1}}{Q_t + \varkappa^h \frac{K_t^h}{K_t}} \right) \quad where\ \Lambda_{t,\tau} = \beta^{\tau - t} \frac{C_t - \frac{\zeta_0}{1+\zeta} L_t^{1+\zeta}}{C_\tau - \frac{\zeta_0}{1+\zeta} L_\tau^{1+\zeta}} \tag{11}$$

$$1 = E_t (\Lambda_{t,t+1} R_{t+1}) \tag{12}$$

$$Q_t = 1 + \frac{\kappa_I}{2} \left(\frac{I_t}{I} - 1 \right)^2 + \left(\frac{I_t}{I} \right) \kappa_I \left(\frac{I_t}{I} - 1 \right) \tag{13}$$

3.3 Banks

The balance sheet of a bank is given by

$$Q_t k_t^b = d_t + n_t + \epsilon_t d_t^*$$

where n_t is the net worth, k_t^b is capital holding, d_t^* is the foreign debt and

$\epsilon_t$is the real exchange rate. That is, the bank's investment in capital is financed through the value of net worth, deposit from households, borrowing form foreign economy. Banks are exposed to the fluctuation of the exchange rate since they are holding foreign debt denominated foreign currency. If the domestic currency depreciates due to the foreign interest rate shock, the burden of foreign debt in domestic currency terms increases. It leads to decline the net worth and decrease the investment. Through the balance sheet channel, the exchange rate amplifies the effect of a foreign interest rate shock on the economy.

Furthermore, I assume that borrowing from foreign economy is subject to the following additional costs:

$$\chi^b(\epsilon_t d_t^*, Q_t k_t^b) = \frac{\varkappa^b}{2} x_t^2 Q_t k_t^b$$

where $x = \frac{\epsilon_t d_t^*}{Q_t k_t^b}$ and $\varkappa^b$ is a parameter of management cost for foreign borrowing. As the proportion of assets financed by foreign borrowing x increases, borrowing costs increase. Therefore, despite the relatively cheaper borrowing costs due to low interest rates in foreign economy, the existence of the management costs induce that banks cannot continue to increase the proportion of foreign borrowing. Considering the management costs and macroprudential regulation and capital control on the bank's balance sheet, the following flow of funds constraint of a bank can be derived

$$\left[1 + \tau_t^K + \frac{\varkappa^b}{2} x_t^2\right] Q_t k_t^b = (1 + \tau_t^N) n_t + d_t + (1 - \tau_t^{D*}) \epsilon_t d_t^*$$

where τ_t^K and τ_t^{D*} are the tax rate on capital holding and foreign debt respectively and τ_t^N is the subsidy rate on net worth. The bank's net worth evolves as the difference between earnings on assets and payments on debt

$$n_t = (Z_t + \lambda Q_t)k_{t-1}^b - R_t d_{t-1} - \epsilon_t R_{t-1}^* d_{t-1}^* \tag{14}$$

where R_t^* is real foreign interest rate from $t-1$ to t. It can be also nominal interest rate because there is no inflation in foreign economy. The net worth of a new banker is given by

$$n_t^{new} = \xi(Z_t + \lambda Q_t)K_{t-1}$$

Given that a banker manages a bank until retirement and receives a bank's net worth as a dividend upon retirement, the bank maximizes the expected present value of future dividend as

$$V_t = E_t\left[\sum_{t=0}^{\infty} \Lambda_{t,t+j}\sigma^{j-1}(1-\sigma)n_{t+j}\right]$$

where n_{t+j} is net worth (dividend) of the bank when a bank retires at $t+j$ and $\Lambda_{t,t+j}$ is stochastic discount factor of the representative household.

To limit on the bank's ability to raise funds, I introduce the moral hazard problem as ABK (2018) model. A banker can decide whether to manage a bank honestly or divert assets for personal use. If operated honestly, the payoffs will be realized in the next period. However, if a banker diverts assets, a bank become bankrupt. This induces an incentive constraint:

$$V_t \geq \Theta(x_t)Q_t k_t \tag{15}$$

where Θ is the divertable fraction of assets as follows:

$$\Theta(x_t) = \theta_0 exp(-\theta x_t)$$

where $x_t = \frac{\epsilon_t d_t^*}{Q_t k_t}$ is the fraction of assets financed by foreign borrowing and θ and θ_0 are both positive. The parameter θ represents the extent to which foreign lenders improve the corporate governance of domestic bankers and θ_0 represents a severity of the bank moral hazard. The left-hand side of (15) represents the gains from operating honestly and the right-hand side of (15) represents the gains from diverting. Thus the incentive constraint, in which the left-hand side must be greater than or equal to the right-hand side, must be satisfied in order that the rational creditors supplies funds to the bank.

Each bank chooses the capital holding k_t, domestic deposit d_t and foreign debt d_t^* to maximize the value function as

$$V_t = E_t\{\Lambda_{t,t+1}[(1-\sigma)n_{t+1} + \sigma V_{t+1}]\}$$

subject to the balance sheet constraint (14) and the incentive constraint (15).

Denote ψ_t as Tobin's Q ratio of the bank. It can be expressed in terms of value function.

$$\psi_t \equiv \frac{V_t}{n_t} = E_t\left[\Lambda_{t,t+1}(1-\sigma+\sigma\psi_{t+1})\frac{n_{t+1}}{n_t}\right]$$

Denote $\phi_t = \frac{Q_t k_t}{n_t}$ as the the leverage multiple. From the balance sheet condition and the flow of funds constraint,

$$\frac{n_{t+1}}{n_t} = \frac{Z_{t+1} + \lambda Q_{t+1}}{Q_t}\frac{Q_t k_t}{n_t} - R_{t+1}\frac{d_t}{n_t} - R_t^* \frac{\epsilon_{t+1}}{\epsilon_t}\frac{\epsilon_t d_t^*}{n_t}$$

$$= \left[\frac{Z_{t+1} + \lambda Q_{t+1}}{Q_t} - (1+\tau_t^K)R_{t+1}\right]\phi_t + \left[(1-\tau_T^{D^*})R_{t+1} - \frac{\epsilon_{t+1}R_t^*}{\epsilon_t}\right]x_t\phi_t$$

$$+ \left(1 + \tau_t^N - \frac{\varkappa^b}{2}x_t^2\phi_t\right)R_{t+1}$$

Then the bank chooses ϕ_t and x_t to maximize Tobin's Q ratio

$$\psi_t = \max_{\phi_t, x_t}\left[\mu_t\phi_t + \mu_t^*\phi_t x_t + \left(1 + \tau_t^N - \frac{\varkappa^b}{2}x_t^2\phi_t\right)\nu_t\right]$$

subject to the incentive constraint

$$\psi_t \geq \Theta(x_t)\phi_t = \theta_0 exp(-\theta x_t)\phi_t$$

where

$$\mu_t = E_t\left\{\Omega_{t+1}\left[\frac{Z_{t+1} + \lambda Q_{t+1}}{Q_t} - (1+\tau_t^K)R_{t+1}\right]\right\} \tag{16}$$

$$\mu_t^* = E_t\left\{\Omega_{t+1}\left[(1-\tau^{D^*})R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t}R_t^*\right]\right\} \tag{17}$$

$$\nu_t = E_t\left\{\Omega_{t+1}R_{t+1}\right\} \tag{18}$$

$$\Omega_{t+1} = \Lambda_{t,t+1}(1 - \sigma + \sigma\psi_{t+1})$$

It can be interpreted that Ω_{t+1} is the stochastic discount factor of the banker, μ_t is the excess return on capital over domestic deposit, μ_t^* is the cost advantage of foreign currency debt over domestic deposit, and ν_t is the marginal cost of deposit. I assume that μ_t and μ_t^* are strictly positive. Considering that the incentive constraint is binding, the first of condition can be derived as

$$\phi_t = \frac{(1+\tau_t^N)\nu_t}{\Theta(x_t) + \frac{\varkappa^b}{2}x_t^2\nu_t - (\mu_t + \mu^* x_t)} \tag{19}$$

$$\psi_t = \Theta(x_t)\phi_t \tag{20}$$

$$x_t = \frac{\mu_t^*}{\varkappa^b \nu_t} - \frac{1}{\theta} + \sqrt{\left(\frac{\mu_t^*}{\varkappa^b \nu_t}\right)^2 + \left(\frac{1}{\theta}\right)^2 + 2\frac{\mu_t}{\varkappa^b \nu_t}} = x\left(\frac{\mu_t^*}{\nu_t}, \frac{\mu_t}{\nu_t}\right) \tag{21}$$

It implies that ϕ_t is decreasing in the moral hazard parameter θ_0 and increasing in $\frac{\mu_t}{\nu_t}$, $\frac{\mu_t^*}{\nu_t}$ and x_t is increasing in $\frac{\mu_t}{\nu_t}$, $\frac{\mu_t^*}{\nu_t}$. Intuitively, if the cost advantage of foreign debt relative to domestic deposit and/or the excess return of capital over domestic deposit are large, the bank raise the leverage as well as funds from the foreign economy.

3.4 Government

The government implements macroprudential policy and capital control as taxes on capital holding and foreign borrowing of banks and returns the tax revenue to banks as a subsidy for their net worth. Let τ_t^K denotes the tax rate on capital holding, $\tau_t^{D^*}$ denotes the tax rate on foreign debt and τ_t^N denotes the subsidy rate on net worth. The government budget constraint is given by

$$\tau_t^N N_t = \tau_t^K Q_t K_t^b + \tau_t^{D^*} \epsilon_t D_t^* \tag{22}$$

where N_t, K_t^b and D_t^* are aggregate net worth, capital holding and foreign debt of total banks. Macroprudential policy and capital controls are described by

$$\tau_t^K = \omega_K \left[log \left(\frac{Q_{t-1}K_{t-1}}{QK} \right) \right]$$

$$\tau_t^{D^*} = \omega_{D^*} \left[log \left(\frac{\epsilon_{t-1}D_{t-1}^*}{\epsilon D^*} \right) \right]$$

where QK and ϵD^* are the value of Q_tK_t and $\epsilon_t D_t^*$ in the steady state respectively. The macroprudential policy means that if the amount of capital holding of the banks increases, the government raises tax rate on the capital holding and the capital control means that if the amount of foreign borrowing of the banks increases, the government raises tax rate on the foreign borrowing.

3.5 Central Bank

The monetary policy follows the augmented Taylor rule as in Davis and Presno (2017) in which the central bank adjusts the policy rate considering foreign interest rate as well as inflation and output gap. This is to reflect that the monetary policy in advanced economies drives the monetary policy rate in the emerging market economies as shown by Kim (2014) and Hofmann and Takáts (2015)

$$i_t - i = \rho_i(i_{t-1} - i) + (1 - \rho_i)\left[\omega_\pi(\pi_t - \pi) + \omega_y(Y_t - Y) + \omega_{i^*}(i_t^* - i^*)\right] \quad (23)$$

where i, i^*, π are the value of domestic and foreign nominal interest rate and inflation in steady state. I assume that the policy rate equals to the deposit interest rate as in Christiano et al. (2010) and Curidia and Woodford (2009).

3.6 Foreign Economy

I focus on the small open economy which means all foreign economic variables such as output Y^*, price P^* and nominal interest rate R^* are given. The first two are assumed to be constant over time, while the foreign rate follows an autoregressive stochastic process.

$$Y_t^* = Y^* = 1$$

$$P_t^* = P^* = 1$$

$$R_t^* = (1 - \rho_R^*)R^* + \rho_R^* R_{t-1}^* + \upsilon_t^{R^*}$$

where R^* is the steady-state level of the foreign interest rate and $\upsilon_t^{R^*}$ is an exogenous shock driving business cycle fluctuations in the small open economy as follows

$$\upsilon_t^{R^*} \sim N(0, \sigma_{R^*}^2)$$

Foreign households decide export demand in small open economy according to the following function

$$EX_t = \left(\frac{P_t}{e_t P_t^*} \right)^{-\varphi} Y_t^* = \epsilon_t^{\varphi} Y_t^* \tag{24}$$

where e_t and $\epsilon_t \equiv (e_t P_t^* / P_t)$ are the nominal and real exchange rates. The export demand for foreign households increases when the real exchange rate depreciates.

3.7 Market Equilibrium

Output consists of consumption, investment and its adjustment cost, export, the cost of changing price, managing capital from households, raising funds from foreign economy as

$$Y_t = C_t + \left[1 + \Phi\left(\frac{I_t}{I}\right)\right] I_t + EX_t + \frac{\kappa}{2}(\pi_t - 1)^2 Y_t + \chi^h(K_t^h, K_t) + \chi^b(\epsilon_t D_t^*, Q_t K_t^b) \tag{25}$$

Net output which equals to final expenditure is

$$Y_t^{net} = Y_t - \epsilon_t M_t - \frac{\kappa}{2}(\pi_t - 1)^2 Y_t - \chi^h(K_t^h, K_t) - \chi^b(\epsilon_t D_t^*, Q_t K_t^b)$$

Net foreign debt consists of net import and the repayment of foreign debt from the previous period

$$D_t^* = M_t - \frac{1}{\epsilon_t} EX_t + R_{t-1}^* D_{t-1}^* \tag{26}$$

The aggregate net worth of banks is the sum of the net worth of operating bank and the start-up fund of new banker as

$$N_t = \sigma\left[(Z_t + \lambda Q_t) K_{t-1}^b - R_t D_{t-1} - \epsilon_t R_{t-1}^* D_{t-1}^*\right] + \xi(Z_t + \lambda Q_t) K_{t-1} \tag{27}$$

The aggregate balance sheet of the bank is given by

$$Q_t K_t^b \left(1 + \frac{\varkappa^b}{2} x_t^2\right) = \left(1 + \frac{\varkappa^b}{2}\right) \phi_t N_t \tag{28}$$

$$= N_t + D_t + \epsilon_t D_t^* \tag{29}$$

$$x_t = \frac{\epsilon_t D_t^*}{Q_t K_t^b} \tag{30}$$

The equilibrium of capital holding is

$$K_t = K_t^b + K_t^h \tag{31}$$

The equilibrium is given by eight price variables (m_t^c, π_t, Z_t, w_t, i_t, ϵ_t, Q_t, τ_t^N), twelve quantity variables (Y_t, M_t, L_t, C_t, I_t, K_t, EX_t, N_t,K_t^b, K_t^h, D_t, D_t^*) and six bank variables (x_t, ψ_t, ϕ_t, ν_t, μ_t, μ_t^*) which satisfy twenty six equations (4-13, 16-31) given exogeouns stochastic process A_t,R_t^* and initial values for (K_{t-1}, K_{t-1}^b, D_{t-1}, $R_{t-1}^* D_{t-1}^*$,i_{t-1}, A_t, R_t^*)

4 Numerical Experiments

4.1 Parameters

In this model, I refer to the parameter values that fall generally in line with the literature related to DSGE open economy for emerging market. Basically, most parameter values are used from the ABK (2018). Table 2 summarizes the parameter values that I use in this analysis and table 3 reports the steady state values of the equilibrium. For the parameters related to households, the discount rate (β) is set to 0.985, the inverse of Frisch elasticity of labor supply (ζ) is 0.333, which is between 0.25 in Banerjee (2016) and 0.455 in Kitano and Takaku (2020) and the labor coefficient (ζ_0) 7.883, which is lower than 4.060 in in Kitano and Takaku (2020). For the parameters related producers, the cost share of capital and imported intermediate goods are set to 0.3, 0.18 respectively. The cost of adjusting price (κ) and adjusting investment goods production (κ_I) is 55.743 (as in Nispi Landi (2020)) and 0.67 respectively. The depreciation rate is 0.02. For the parameters related to banks, the bank survival rate is set to 0.94, which is lower than 0.96 (as in Kitano and Takaku (2020) and Christiano et al (2010)) and 0.972 (as in Gertler and Kiyotak (2010)) and the elasticity of leverage with respect to foreign borrowing (θ) is 0.1 which means the fraction that the banker can divert (Θ) deceases by 1% when the foreign borrowing increases by 10%. The fraction of transfering to new banker (ξ) is 0.0046 in which is higher than 0.0042 in Kitano and Takaku (2020). In addition, the steady state value of foreign interest rate (R^*) is set to 1.02 in annual by obtaining the average of 10-year US government bond after GFC (from 2009 to 2020). The steady state value of domestic interest rate is 1.04 in annual assuming that the sperad between the US and SOEs is 200bp[2]. The bank leverage multiple equals 4 and the foreign borrowing to bank asset ratio equals 0.25 in the steady state. In the baseline, the coefficients of Taylor rule (ω_{pi}, ω_y, ω_{i^*}) are 1.5, 0.1, 0.1. and the coefficient of interest rate smoothing (ρ_i) is 0.8. In baseline, the standard deviation of foreign shock (σ^*) is 1% in annualized rate.

[2] After GFC (2009-2020), the average of the US 10-year government bond yields is 2.35 and that of 10-year government bond yields for several SOEs (Korea, Mexico, New Zealand) is 4.19, that is, the spread is 184bp.

Table 2: Baseline parameters

	Description	Value
	Households	
β	discount rate	0.985
ζ	inverse of Frisch elasticity of labor supply	0.333
ζ_0	inverse fo labor supply	7.883
$\varkappa^h$	cost parameter of direct finance	0.0197
	Producers	
α_K	cost share of capital	0.3
α_M	cost share of imported intermediate goods	0.18
λ	1 - depreciation rate	0.98
η	elasticity of demand	9
κ	cost of adjusting price	55.743
κ_I	cost of adjusting investment goods production	0.67
φ	price elasticity of export demand	1
	Banks	
θ	elasticity of leverage wrt foreign borrowing	0.1
θ_0	divertable proportion of assets	0.399
σ	survival probablity	0.94
ξ	fraction of total assets brought by new banks	0.0046
κ^b	management cost for foreign borrowing	0.219
	Central Bank and Government	
ρ_i	Interest rate smoothing coefficient	0.8
ω_π, ω_y, ω_{R^*}	Taylor rule coefficients	1.5, 0.1, 0.1
ω_K, ω_{D^*}	macroprudential and capital control coefficients	0, 0

Table 3: Baseline steady state (Annual)

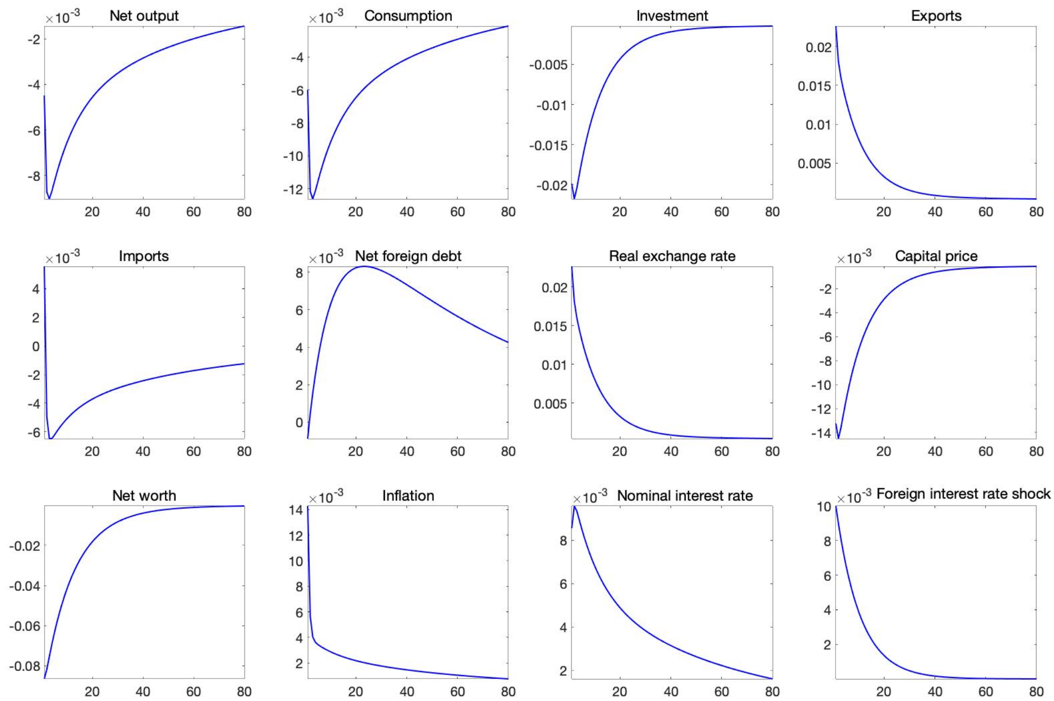
	Description	Value
Q	price of capital	1
π	inflation rate	1
R^*	foreign interest rate	1.02
R	domestic interest rate (=deposit interest rate)	1.04
ϕ	bank leverage multiple	4
x	foreign debt to bank asset ratio	0.25
χ^h	cost of direct finance of households	0.0148
χ^b	cost of foreign borrowing of banks	0.0141

4.2 Results

4.2.1 Baseline

In order to simulate impulse response functions, the model is solved using a first-order approximation around the steady state. Figure 1 represents the impulse response to the foreign interest rate shock by 1% in annual rate in the baseline. The y-axis in the graph means the changes from the steady state in quarterly except that the domestic and foreign interest rates and inflation rates are in annual. The positive foreign interest rate shock depreciates the real exchange rate and increases the volume of exports. This initially mitigates the decline in output and consumption. However, a depreciation of the real exchange rate has two effects. The first is that it increases the bank's real foreign debt burden and reduces its net worth. This also reduces the bank's credit supply, which in turn declines investment and consumption, leading to a recession. Second, a depreciation of real exchange rate increases inflation due to raising the price of imports. The central bank raises interest rates to stabilize inflation, but this has the result of exacerbating the recession. It is not easy for central bank to respond to stabilize inflation and recover the recession caused by the shock of foreign interest rates.

Figure 1: Baseline impulse response to foreign interest rate by 1% without policy

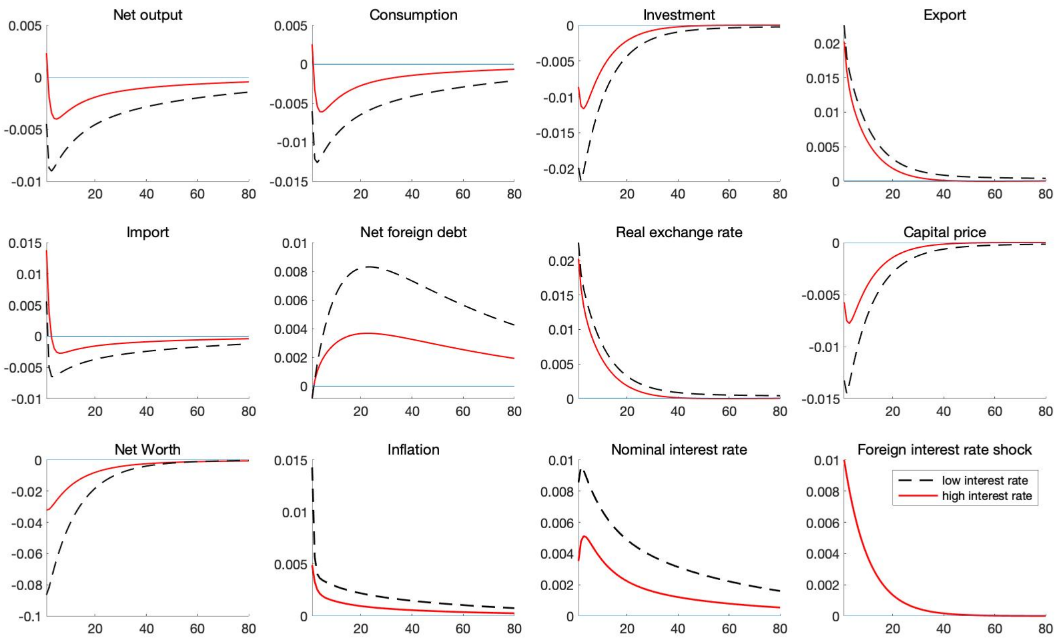


4.2.2 Impulse response under high and low interest rate environment

I simulate the impact of foreign interest rate shocks on the economy before and after the GFC. Since the GFC, most countries have kept low interest rates to respond to economic downturns. Taking this into account, I set the steady state interest rate level different from the baseline while keeping other variables the same. Specifically, I set the foreign interest rate as R^{*}=1.04 and the domestic interest rate as R=1.06, based on the average of the US 10-year government bond yields before the GFC (from 2003 to 2008), assuming that the spread between the US and SOEs is 200bp[3]. Figure 2 shows to compare the impulse response of 1% foreign interest rates shock under low and high interest rates. The solid line is the impulse response curve before the GFC (R^{*}=1.04, R=1.06), and the dashed line, which is tha baseline, is after the GFC (R^{*}=1.02, R=1.04). However, in the high interest rate environment, assuming before the GFC, not only the capital price and the bank's net worth fall less, the decline in consumption and investment is also small compared to the baseline. It implies that, under the foreign interest rate shock, low interest rate environment after the GFC is more vulnerable to recession than the high interest rate environment before the GFC.

[3]Before GFC (2003-2008), the average of the US 10-year government bond yields is 4.28 and that of 10-year government bond yields for several SOEs (Korea, Mexico, New Zealand) is 6.62, that is, the spread is 234bp.

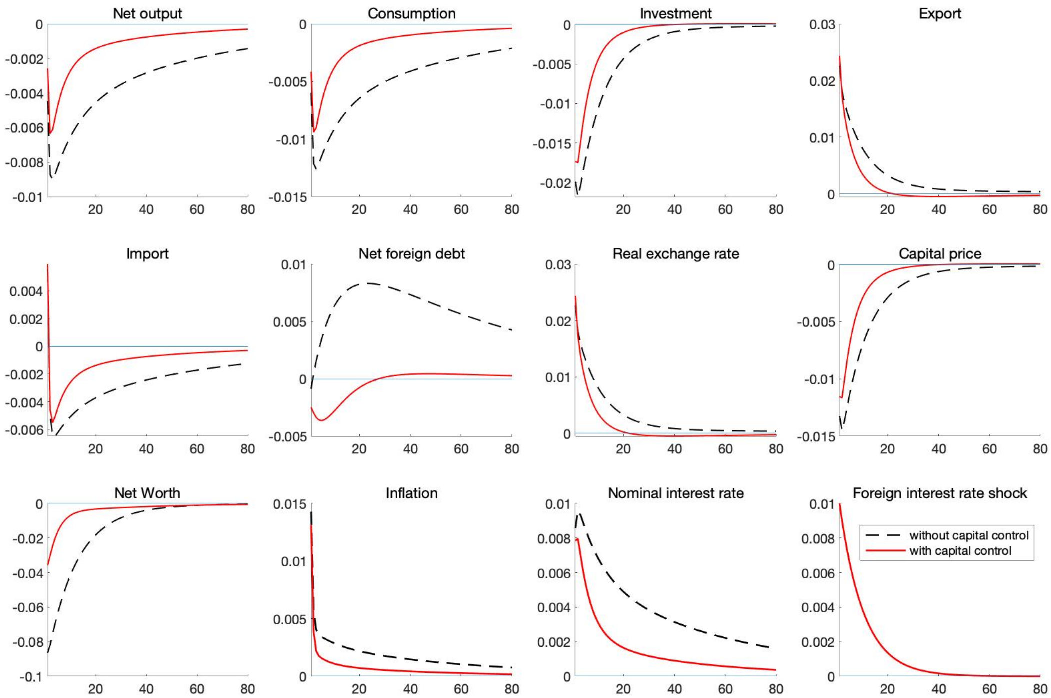
Figure 2: Impulse responses to the foreign interest rate shock by 1% under low and high interest rate environment (R^*=1.02 and 1.04)



4.2.3 Impulse response with and without capital control

In this section, I examine the effect of capital control in the event of a foreign interest rate shock. In other words, I compare the impulse response of foreign interest rate shock under the circumstance with and without capital control to identify whether there is an advantage of capital control. The capital control coefficient (ω_{D^*}) is adjusted to 0.2 for the circumstance with capital control and 0 without capital control. In both situations, the coefficients of Taylor rule are the same. Figure 3 shows the impulse response to the foreign interest rate shock of the economy. The solid line represents the impulse response curve when capital controls are present, and the dashed line is the baseline (without capital control). As mentioned before, capital control means the form of tax rate, which is the increasing function of the deviation of foreign borrowing from steady state. It can alleviate the effect of currency depreciation. Thus, under capital control, inflation and capital prices move less than when there is no capital control. Therefore, consumption, aggregate output also move less. This means that economy with capital controls reduces the likelihood of a recession compared to economy without capital controls. Then, central bank can implement more aggressive monetary policy than in the absence of capital control. In other words, if monetary policy and capital control are implemented at the same time, it is possible to respond more effectively to the foreign interest rate shock.

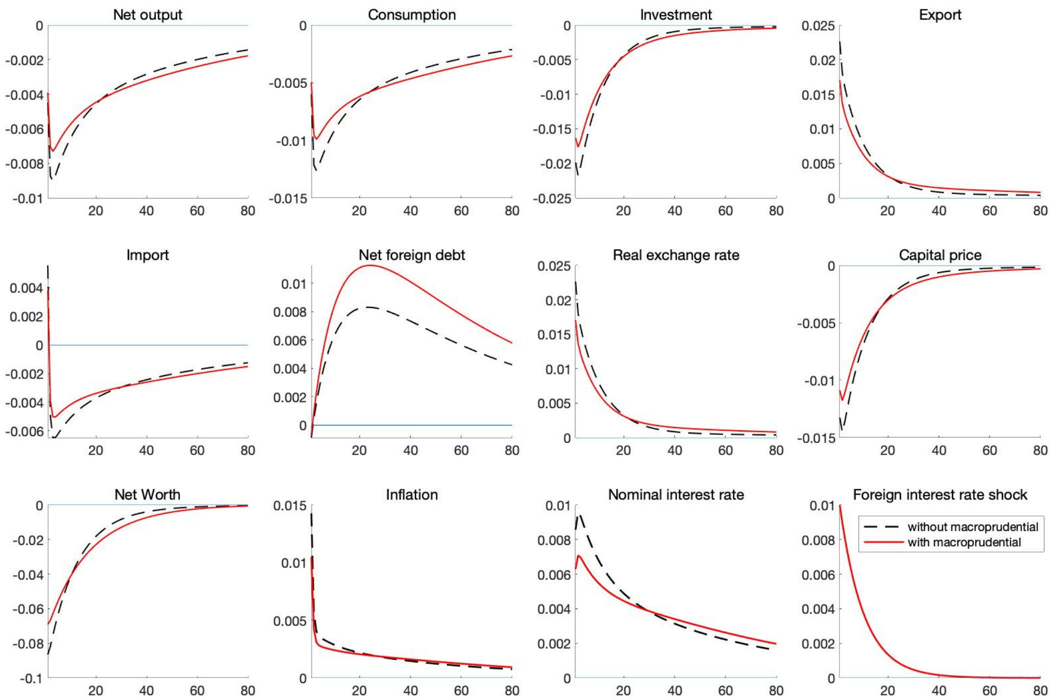
Figure 3: Impulse responses to the foreign interest rate shock by 1% with and without capital control ($\omega_{D^*} = 0$ and 0.2)



4.2.4 Impulse response with and without macroprudential policy

I also examine the effect of macroprudential policy under the foreign interest rate shock. In the same way as the previous section, I compare the impulse response of the foreign interest rate shock under the circumstance with and without macroprudential policy to identify the merit of this policy. The macroprudential policy coefficient (ω_K) is adjusted to 0.2 for the circumstance with macroprudential policy and 0 without macroprudential policy. In both situations, the coefficients of the Taylor rule are the same. Figure 4 represents the impulse response to the foreign interest rate shock of the economy. The solid line represents the impulse response curve when macroprudential policy is implemented, and the dashed line is the baseline. As the previous chapter, macroprudential policy defines the form of tax rate, which is the increasing function of the deviation of bank's asset holdings from steady state. Like capital control, it can mitigate the effect of currency depreciation but capital price and bank's net worth only slightly improve compared to when there is no macroprudential policy. As a result, consumption and aggregate output also improve slightly. In the end, macroprudential policy is not effective in preventing the possibility of recession caused by the foreign interest rate shock compared to capital control.

Figure 4: Impulse responses to the foreign interest rate shock by 1% with and without macroprudential policy (ω_K =0 and 0.2)



4.2.5 Welfare analysis

In the previous section, it is confirmed that both capital control and macroprudential policy are effective in responding to the foreign interest rate shock, even if there is a difference in degree. In this section, I quantitatively analyze how effective the two policies are. Thus I conduct the welfare analysis to examine the effect of capital control and macroprudential policy by taking a second order approximation of the model, as done in Schmitt-Grohé and Uribe (2004). It is commonly used for welfare analysis in many literatures. For policy evaluation, I compute the welfare level associated with a particular policy rule and compare it to that in a baseline case. I assume the welfare level is the conditional expected discounted utility of the representative household. The welfare associated with a particular value of capital control or macroprudential policy conditional on the non-stochastic steady states is defined as

$$\mathcal{W}_0 \equiv E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t) = E_0 \sum_{t=0}^{\infty} \beta^t U((1+\epsilon_i)C, L)$$

where C and L are the consumption and labor in the steady state. I can evaluate the welfare improving effect of capital control and macroprudential policy in the several scenarios by comparing the value of ϵ_i associated with the combination of (ω_{D^*},ω_π) and (ω_K, ω_π) to that in the baseline case.

Table 4 represents the welfare gain from different combinations of monetary policy and capital control. Each column denotes the alternative coefficients of capital control ω_{D^*}= 0 , 0.1 and 0.2 and each row denotes the alternative coefficients of Taylor rule ω_π= 1.25, 1.5 and 2.0. The number in the table is the change in welfare in terms of consumption equivalence relative to the baseline $\omega_{D^*}= 0$ and ω_π=1.5. It is confirmed that the coefficient of capital control $\omega_{D^*}= 0.2$ leads to welfare gains by 5.54% when the coefficient of Taylor rule ω_π is 1.5. There are also welfare gains from increasing the coefficient of Taylor rule ω_π from 1.5 to 2.0. The combination of $\omega_\pi = 1.5$and $\omega_{D^*}= 0.2$ gives the highest welfare in the table.

Table 4: Welfare effect from the different combination of monetary policy and capital control

ω_{D^*}/ω_π	1.25	1.5	2.0
0	-2.04%	0.00%	0.64%
0.1	4.46	4.63	4.73
0.2	5.45	5.54	5.61

Table 5 shows the welfare gain from different combinations of monetary policy and macroprudential policy. Each column denotes the alternative coefficients of maroprudential policy $\omega_K= 0$, 0.1 and 0.2 and each row denotes the alternative coefficients of Taylor rule $\omega_\pi= 1.25$, 1.5 and 2.0. The number in the table is the change in welfare in terms of consumption equivalence relative to the baseline $\omega_K= 0$ and ω_π=1.5. The welfare gains from having macroprudential policy of $\omega_K= 0.2$ is 0.82% when the coefficient of Taylor rule ω_π is 1.5. However, the welfare gains from the combination of macroprudential policy and monetary policy are smaller than that of capital control and monetary policy, even though the pattern of welfare effect is similar to Table 4.

Table 5: Welfare effect from the different combination of monetary policy and macroprudential policy

ω_K/ω_π	1.25	1.5	2.0
0	-2.04%	0.00%	0.64%
0.1	-0.92	0.64	0.97
0.2	0.00	0.82	0.82

The above results suggest that rather than macroprudential policy, capital control is a useful instrument to supplement monetary policy in the event of the foreign interest rate shock. Since capital control specifically targets the foreign borrowing, this well complements the monetary policy. On the other hand, macroprudential policy is less useful as it only reduces overall borrowing of the economy regardless of residency of lenders.

5 Conclusion

After the GFC, the monetary authorities in major economies implemented zero interest rate policy to recover the economy and many SOEs experienced changes of unprecedented magnitude in capital flows. This has contributed to accelerating the international financial integration. According to the Dilemma phenomenon, the global factor limits the independence of monetary policy under free capital movement regardless of the exchange regime. Economists think that capital control and macroprudential policy can improve the effectiveness of monetary policy in SOEs under the foreign interest rate shock. In this paper, I focus on how macroprudential or capital control policy complements monetary policy of small open economies in the face of foreign interest rate shock around the steady state. The research questions are as follows: First, under the low inflation environment, is the impact of foreign interest rate shock on SOEs greater than high interest rate environment? Second, Under the foreign interest rate shock, can macroprudential or capital control policy increase the effectiveness of domestic monetary policy? Third, if both two policies are effective to mitigate the foreign shock, which is the better policy to complement monetary policy? To deal with these questions, I build the base model followed by Aoki et al. (2018) and then simulate impulse response to foreign interest rate shock in several scenarios and compare the two policies in terms of welfare. The results show that macroeconomic variables under low interest rate environment are more volatile than under high interest rate when the foreign interest rate shock is transmitted to SOEs. It implies that low interest rate environment is more vulnerable to recession than high interest rate environment. I also find that both macroprudential policy or capital control can help to mitigate the influence of foreign interest rate shock but capital control is the better instrument than macroprudential policy in terms of welfare.

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