



IMPACT OF GLOBAL LOW INTEREST RATES TO THE CAPITAL FLOWS AND FINANCIAL VULNERABILITY OF SMALL OPEN ECONOMIES



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ABSTRACT

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In this paper, we develop a dynamic stochastic general equilibrium (DSGE) model with financial frictions, to explore how the exogenous global low-interest-rate shock affect the small open economies, and study the effects of two macroprudential policies for protecting the external sector and financial system. We find that, when there are negative world interest rate shocks to ultra-low levels, small open economies will experience capital inflow surge, amplified domestic business cycles and increased financial leverage, leading to accumulation of financial vulnerability. However, the liability-side macroprudential policy depending on foreign debt leverage is effective in smoothing the fluctuations of economic variables. The other asset-side macroprudential policy depending on bank's total asset expansion works in a similar but less effective way. The research results support that it is reasonable for emerging economies to adopt macroprudential policies in the current low-interest-rate environment, and the liability-side macroprudential policy linking with foreign debt leverage is more effective.

Contribution/ Originality: This study contributes to the existing literature by developing a dynamic stochastic general equilibrium (DSGE) model with financial frictions, to explore how the exogenous global low-interest-rate shock affect the small open economies, and study the effects of two macroprudential policies for protecting the external sector and financial system.

1. INTRODUCTION

The Global Financial Crisis (GFC) and the slow recovery from its aftermath promoted ultra-loose monetary policies among central banks over the past decade. Many central banks in advanced economies quickly lowered policy interest rates to zero or near zero levels, to restart growth and combat persistent deflationary risks. Ten years later after the GFC, with the current sluggish world economy, many central banks started to lower interest rates again¹ and some even used unconventional monetary policies (UMPs), pushing policy interest rates even into negative territory. Moreover, together with persistent macroeconomic headwinds since the GFC (like demographic

¹ In the year of 2019, more than 30 central banks started to lower policy interest rates, including Ghana, India, Azerbaijan, Ukraine, Kazakhstan, Malaysia, Sri Lanka, Philippines, Iceland, Chile, Australia, Russia, South Africa, Saudi Arabia, UAE, Bahrain, South Korea, Indonesia, US, Brazil, Egypt, New Zealand, Thailand, Hong Kong, Mexico, Paraguay, Denmark, ECB, China.

changes leading to decline in consumption, shortage of safe assets leading to global saving glut and depressing safe returns, and many economies have been with secular stagnation for quite a long time ((Bernanke, 2005; Caballero, 2018; Summers, 2014)) both the nominal and real interest rates are at historical lows across advanced economies (Del Negro, Giannone, Giannoni, & Tambalotti, 2019). Countries elsewhere were faced by spillovers from extremely easy global liquidity conditions and attendant volatile capital flows and financial stability risks² in a world with increasingly integrated financial markets. The spillover impacts of global low interest rates have raised serious concerns for countries elsewhere. The ensuing cross-border large and volatile capital inflows and its resulting financial vulnerability have created challenges to policy makers. Analysis of the impact of global low interest rates on the capital flows and financial vulnerability will be helpful for giving advice to policy makers to manage volatile capital flow movements and develop precautionary instruments to guarantee financial stability.

This paper is relative to several strands of literature. Global interest rates, mainly refer to interest rates of large advanced economies (especially the US), have long been a key factor leading to extreme capital flow movements and risks. The relationship between interest rates of advanced economies and capital flow movements of countries elsewhere, have been well studied in the empirical literature (Forbes & Warnock, 2012; Ghosh, Qureshi, Kim, & Zalduendo, 2014; Yang, Shi, Wang, & Jing, 2019). The interest rates of advanced economies usually have a significant negative relationship with capital inflows to EMEs. In contrast to existing extensive empirical literature, the main contribution of this paper is that we build an open economy DSGE model of small open economies, to further explore the dynamic influence of the current exogenous global low-interest-rate shocks to capital flows, domestic business cycles and financial vulnerability of small open economies.

This paper is also related to open economy DSGE analysis, which is widely used in analyzing the impact of exogenous shocks and policy analysis. After the GFC, researchers started to introduce financial frictions into financial intermediaries to make previous DSGE models more reality (Gertler & Kiyotaki, 2010). In this paper, we develop a small open economy model with financial frictions based on the models proposed by Gertler and Kiyotaki (2010) and Kitano and Takaku (2017). Existence of financial frictions means that bankers have incentives to divert assets and it is easier for bankers to divert foreign borrowing compared to domestic deposits. Another contribution of this paper is that, via introducing a variant of the banking sector, we refine the DSGE models to capture some form of financial fragility to foreign or global economy shocks (Adrian & Shin, 2009; Ghilardi & Peiris, 2016): the fraction of divertible assets by bankers is time varying, and related to the changes in the exogenous global interest rate.

Another related strand of literature focuses on capital controls and macroprudential policies. Many countries have implemented various capital control and macroprudential instruments to deal with the extreme capital flow movements, economic fluctuations and financial vulnerability risks from external shocks³. Different kinds of instruments and their effectiveness have been well studied in previous literature (De Paoli & Lipinska, 2013; Farhi & Werning, 2014; Liu & Spiegel, 2015; Ostry, Ghosh, & Korinek, 2012; Schmitt-Grohé & Uribe, 2016). This paper examines the effectiveness of macroprudential policies in dealing with exogenous global low-interest-rate shocks and compares two different instruments. The two macroprudential policy instruments considered in this paper include a liability-side macroprudential policy instrument depending on bank's foreign debt leverage⁴, and an asset-side instrument depending on bank's total asset expansion. More specifically, the liability-side macroprudential policy instrument depends on the proportion of bank's foreign debt in total asset, and the asset-side one depends on

² See (Independent Evaluation Office, 2019) for details.

³ See Forbes, Fratzscher, Kostka, and Straub (2016) and Magud, Reinhart, and Rogoff (2018) for details.

⁴ This is also viewed as a capital control instrument limiting real exchange rate appreciation in cyclical upturns. As this instrument also limits excessive (foreign) borrowing, it is viewed as a liability-side macroprudential policy in this paper (Gurmain, 2017). We don't further discuss the relationship between capital controls and macroprudential policies in this paper.

the bank's asset expansion. The results show that macroprudential policies are effective in limiting the world interest rate shock and the foreign-liability-related macroprudential policy is more effective than the other one for the net capital inflows, domestic business cycle amplification and financial leverage are much smaller during the scenario.

The remainder of this paper is arranged as follows. In Section 2, we present a small open economy DSGE model with macroprudential policies, and we calibrate the parameters. In Section 3, we present the main results of this paper. Specifically, we examine the shocks of global low interest rates to the small open economies with and without macroprudential policies. Then we examine the validity of the results using the real data from small open economies in Section 4. Section 5 concludes this paper.

2. THE RBC-DSGE MODEL WITH MACROPRUDENTIAL POLICIES FOR SMALL OPEN ECONOMIES

To explore the impact of global low interest rates, we build a real business cycle dynamic stochastic general equilibrium model (RBC-DSGE model) of a small open economy, with the world interest rate as an exogenous variable. The framework of our model is presented as follows Figure 1.

The model consists of households, banks, non-financial firms (goods producers and capital producers), and the government. This is a model with infinite periods and only intra-temporal trade. We assume there is a representative household, who consumes domestic and foreign goods, and provides labor to goods producers and deposits to banks. Banks raise funds from domestic households and foreign borrowing, and provide loans to domestic capital producers. Capital producers raise funds from banks to buy domestic goods (from goods producers) and foreign goods as inputs, producing new capitals and sell them to goods producers. Each goods producer produces output using an identical constant return to scale (CRS) Cobb-Douglas production function with capital and labor as inputs. Goods producers buy the capital from capital producers and pay wages to the labor provided by households. We assume that the capital, which could be viewed as intermediate goods for producing final goods, is not mobile, but labor is perfectly mobile across firms and countries. To deal with foreign shocks from global low interest rates, the government imposes macroprudential policies by imposing taxes on the banks' excessive asset and foreign debt.

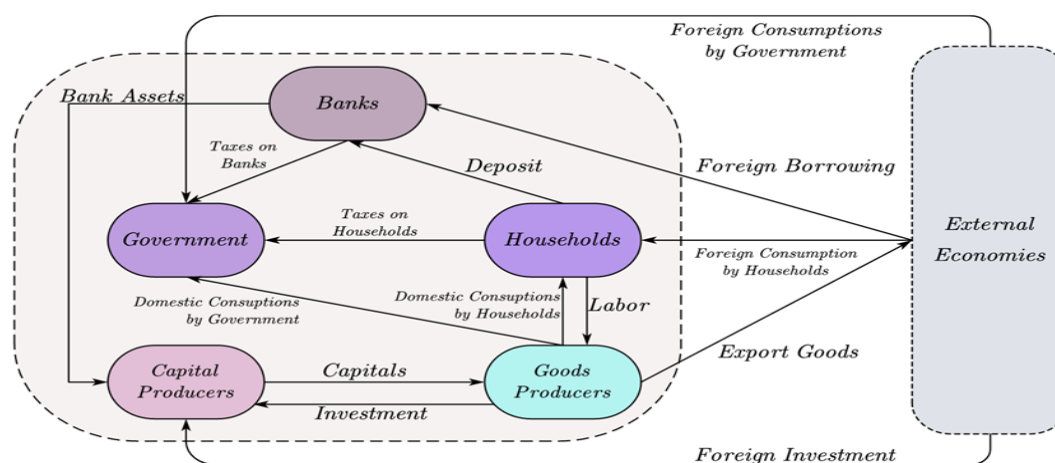


Figure-1. The framework of the model.

2.1. Households

Following Kitano and Takaku (2017) there is an infinite lived representative household with GHH utility preference⁵. the households maximize the following expected lifetime utility:

⁵ GHH preference has been widely adopted in many open economy models. See Mendoza (1991) and Neumeier and Perri (2005) for example.

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - \frac{\chi}{\varphi} L_t^\varphi)^{1-\gamma} - 1}{1-\gamma} \right] \quad (1)$$

where E_t is the expectation operator conditional on date t information, $\beta \in (0,1)$ is the discount factor for household's utility, C_t is a composite consumption index, L_t is the labor supply, χ is the relative utility weight of labor to consumption, $\gamma \in (0, \infty)$ is the inverse of intertemporal elasticity of substitution, and $\varphi \in (1, \infty)$ is the inverse Frisch elasticity of labor supply. The composite consumption index C_t is defined by:

$$C_t \equiv \left[(1-\nu)^{\frac{1}{1-\iota}} C_{H,t}^{\frac{1-\iota}{1-\iota}} + \nu^{\frac{1}{1-\iota}} C_{F,t}^{\frac{1-\iota}{1-\iota}} \right]^{\frac{1-\iota}{1-\iota}} \quad (2)$$

where $\iota \in (0, \infty)$ is the elasticity of substitution between domestic and imported goods, and $\nu \in (0,1)$ is the degree of trade openness (i.e., inverse degree of home bias). Given the consumption index C_t , the optimal expenditure allocation between domestic and imported goods is:

$$C_{H,t} = (1-\nu) \left(\frac{P_{H,t}}{P_t} \right)^{-\iota} C_t; \quad C_{F,t} = \nu \left(\frac{P_{F,t}}{P_t} \right)^{-\iota} C_t \quad (3)$$

where $C_{H,t}$ is consumption allocation on domestic goods, $C_{F,t}$ is consumption allocation on imported goods, $P_{H,t}$ is the domestic price level, $P_{F,t}$ is the import price level, and P_t is the consumer price index (CPI) defined by:

$$P_t \equiv \left[(1-\nu) P_{H,t}^{1-\iota} + \nu P_{F,t}^{1-\iota} \right]^{\frac{1}{1-\iota}} \quad (4)$$

Let W_t denote the real wage rate, $T_{h,t}$ lump-sum taxes, D_t the quantity of bank deposits made by households on date t , R_t the gross return on the deposits from $t-1$ to t , and Π_t net distributions from nonfinancial firms to households. Then the households will choose consumption, labor supply, and bank deposit to maximize his/her expected lifetime utility (1) subject to the flow of funds constraints:

$$C_t + D_t + T_{h,t} = R_t D_{t-1} + W_t L_t + \Pi_t \quad (5)$$

The first-order optimality conditions with respect to consumption, labor supply and deposit are given by

$$\left(C_t - \frac{\chi}{\varphi} L_t^\varphi \right)^{-\gamma} = \varrho_t \quad (6)$$

$$\chi L_t^{\varphi-1} = W_t \quad (7)$$

$$E_t[\Lambda_{t,t+1} R_{t+1}] = 1 \quad (8)$$

where Q_t is the Lagrangian multiplier associated to the constraint (5), and $\Lambda_{t,t+1} \equiv \beta \frac{Q_{t+1}}{Q_t}$ is the household's

stochastic discount factor from t to $t+1$.

2.2. Banks

In order to finance lending in each period, banks raise funds in both domestic and international markets.

We assume that, at the beginning of each period, banks accept deposits from domestic households and borrow money from foreign investors, and then lend to final goods producers. For each bank, the flow-of-funds constraint is given by:

$$Q_t s_t = n_t + d_t + e_t b_t \quad (9)$$

where Q_t is the market price of the bank's claim at date t , s_t is the volume of loans (banks' claim) to goods producers, n_t is the net worth, d_t is the stock of deposits from domestic households, e_t is the real exchange rate, and b_t is the quantity of foreign debt.

Let R_t be the gross return on domestic deposit d_t from date $t-1$ to date t . Similarly, let $R_{b,t}$ be the gross return on foreign debt b_t in terms of domestic currency from date $t-1$ to date t , $R_{k,t}$ gross return on assets $Q_t s_t$ from date $t-1$ to t , and T_t^* the tax rate imposed by government on banks' assets or foreign debts in terms of domestic currency from date $t-1$ to date t . Then, the bank's net worth at date t is given by:

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - R_t d_{t-1} - R_{b,t} (1 + T_t^*) e_{t-1} b_{t-1}. \quad (10)$$

We also assume that the bank could bankrupt with probability $1 - \sigma$ ($0 < \sigma < 1$), and the bank maximizes the present value of future net worth discounted by the factors $\Lambda_{t,t+i}$, $i = 1, 2, \dots$. Thus, the value of bank at date t is given by:

$$V_t = E_t \sum_{i=1}^{\infty} (1 - \sigma) \sigma^{i-1} \Lambda_{t,t+i} n_{t+i}. \quad (11)$$

Similar to Gertler and Kiyotaki (2010) the bankers have incentives to divert a fraction θ_t of their assets. Divertible assets consist of total gross asset $Q_t s_t$ net a fraction ω of domestic deposit d_t for some $\omega \in [0,1]$. Different from previous studies, we assume that the fraction of divertible assets θ_t depends on the world gross interest rate R_t^* :

$$\theta_t = \theta \left[1 + \aleph \left(1 - \frac{R_t^*}{R^*} \right) + \frac{\aleph}{2} \left(\frac{R_t^*}{R^*} - 1 \right)^2 \right] \tag{12}$$

where \aleph measures the degree of home bias in banker's finance, and R^* is the steady-state value of R_t^* . As Adrian and Shin (2009) point out, during downturns of foreign economy, the small open economy is subject to the spillover effect of foreign recession. Then domestic bankers in small open economies are more likely to divert funds or divert more funds when the gross interest rate R_t^* is low. Thus, a sudden increase in θ_t due to a decline in R_t^* can be thought of capturing some form of one country's financial fragility to foreign or global economy shocks.

Because the fund suppliers recognize the bank's incentive to divert funds, they will not lend to the banks unless banks satisfy the following incentive constraint:

$$V_t \geq \theta_t (Q_t s_t - \omega d_t) \tag{13}$$

With $\omega = 1$, the bank is unable to divert any deposit from households. In this case, the domestic financing market operates frictionlessly. In contrast, with $\omega = 0$, domestic depositors are exactly like the foreign investors. Therefore, ω can be thought of as a degree of frictions in the financial market.

In the next, we will derive the aggregate relation of s_t , d_t and b_t . Here, we follow the same approach proposed by Kitano and Takaku (2017). Let $V_t(s_t, b_t, d_t)$ denote the maximum value of V_t defined in (11) given s_t , b_t and d_t . The Bellman equation for the bank's optimization problem at date t is given by

$$V_t(s_t, b_t, d_t) = E_t \Lambda_{t,t+1} \left\{ (1 - \sigma) n_{t+1} + \sigma \max_{s_{t+1}, b_{t+1}, d_{t+1}} V_{t+1}(s_{t+1}, b_{t+1}, d_{t+1}) \right\} \tag{14}$$

In order to solve this dynamic programming problem, we guess (and then verify) that function V_t is linear in s_t , b_t and d_t such that:

$$V_t(s_t, b_t, d_t) = \mathcal{V}_{s,t} s_t - \mathcal{V}_{b,t} b_t - \mathcal{V}_{d,t} d_t, \tag{15}$$

where $\mathcal{V}_{s,t}$, $\mathcal{V}_{b,t}$ and $\mathcal{V}_{d,t}$ are time-varying parameters that will be verified later. Note that these parameters are independent of individual bank's structure, and are supposed to be positive.

Let λ_t be the Lagrangian multiplier for the incentive constraint (13). Then, according to the conjectured form of V_t , the first-order optimality conditions for s_t , b_t and d_t are given by:

$$(1 + \lambda_t) \frac{\mathcal{V}_{s,t}}{Q_t} = \theta_t \lambda_t \tag{16}$$

$$(1 + \lambda_t) \mathcal{V}_{b,t} = 0 \tag{17}$$

$$(1 + \lambda_t) \mathcal{V}_{d,t} = \theta_t \omega \lambda_t \tag{18}$$

By substituting Equations 16-18 into Equation 13 and using Equation 9, we have

$$\left[\theta_t (1 - \omega) - \left(\frac{\mathcal{V}_{s,t}}{Q_t} - \mathcal{V}_{d,t} \right) \right] Q_t s_t \leq (\mathcal{V}_{d,t} - \theta_t \omega) n_t - \left[\theta_t \omega - \left(\mathcal{V}_{d,t} - \frac{\mathcal{V}_{b,t}}{e_t} \right) \right] e_t b_t \tag{19}$$

Combining Equations 16 and 18 gives us

$$\lambda_t = \frac{\frac{\mathcal{V}_{s,t}}{Q_t} - \mathcal{V}_{d,t}}{\theta_t (1 - \omega) - \left(\frac{\mathcal{V}_{s,t}}{Q_t} - \mathcal{V}_{d,t} \right)} \tag{20}$$

Similarly, it follows Equations 17 and 18 that

$$\mathcal{V}_{d,t} - \frac{\mathcal{V}_{b,t}}{e_t} = \frac{\theta_t \omega \lambda_t}{1 + \lambda_t} \tag{21}$$

Let $\mu_{s,t} \equiv \frac{\mathcal{V}_{s,t}}{Q_t} - \mathcal{V}_{d,t}$ and $\mu_{b,t} \equiv \mathcal{V}_{d,t} - \frac{\mathcal{V}_{b,t}}{e_t}$, then we have

$$\frac{\mu_{b,t}}{\mu_{s,t}} = \frac{\omega}{1 - \omega} \tag{22}$$

Then, Equation 19 implies

$$Q_t s_t \leq \phi_{s,t} n_t - \frac{\omega}{1 - \omega} e_t b_t \tag{23}$$

where

$$\phi_{s,t} \equiv \frac{\mathcal{V}_{d,t} - \theta_t \omega}{\theta_t (1 - \omega) - \mu_{s,t}} \tag{24}$$

Substituting the Equation 23 into the value function (15), we have

$$V(s_t, b_t, d_t) = (\mathcal{V}_{d,t} + \lambda_t (\mathcal{V}_{d,t} - \theta_t \omega)) n_t \tag{25}$$

Substituting Equation 25 for $t + 1$ into Bellman Equation 14 yields

$$\mathcal{V}_{s,t} s_t - \mathcal{V}_{b,t} b_t - \mathcal{V}_{d,t} d_t = E_t \Lambda_{t,t+1} \Omega_{t+1} n_{t+1}, \tag{26}$$

where

$$\Omega_t \equiv (1 - \sigma) + \sigma(\mathcal{V}_{d,t} + \lambda_t(\mathcal{V}_{d,t} - \theta_t \omega)) = (1 - \sigma) + \sigma(\mathcal{V}_{d,t} + \phi_{s,t} \mu_{s,t}) \tag{27}$$

Applying the method of undetermined coefficient to Equation 26, we have

$$\mathcal{V}_{s,t} = R_{k,t+1} E_t \Lambda_{t,t+1} \Omega_{t+1} Q_t, \tag{28}$$

$$\mathcal{V}_{b,t} = R_{b,t+1} (1 + T_{t+1}^*) e_t E_t \Lambda_{t,t+1} \Omega_{t+1}, \tag{29}$$

$$\mathcal{V}_{d,t} = R_{t+1} E_t \Lambda_{t,t+1} \Omega_{t+1} = \frac{R_{t+1}}{R_{b,t+1}(1+T_{t+1}^*)e_t} \mathcal{V}_{b,t} \tag{30}$$

Since the parameters $\phi_{s,t}$ is independent of individual bank's structure, we can aggregate Equation 23 across banks:

$$Q_t S_t = \phi_{s,t} N_t - \frac{\omega}{1-\omega} e_t B_t \tag{31}$$

where capital letters indicate corresponding aggregate variables. Using aggregate version of Equations 9 gives us

$$D_t = Q_t S_t - N_t - e_t B_t \tag{32}$$

Following from (24), we have

$$\phi_{s,t} = Q_t \frac{S_t}{N_t} + \frac{\omega}{1-\omega} e_t \frac{B_t}{N_t} \tag{33}$$

When there are some bankers go bankruptcy and become households, we assume that the same number of households become bankers so that the portion of bankers in the economy is constant over time. This will simplify our model and we do not need to keep track of the distributions of household and banking sector. When the

households become bankers, they obtain a fraction $\frac{\xi}{1-\sigma}$ of fund from exiting bankers. And the evolution of N_t is

given by:

$$N_t = (\sigma + \xi) R_{k,t} Q_{t-1} S_{t-1} - \sigma R_{b,t} e_{t-1} B_{t-1} - \sigma R_t D_{t-1} \tag{34}$$

2.3. Goods Producers

The final goods producers operate in a fully competitive market and produces domestic goods using capital and labor according to the CRS Cobb-Douglas function:

$$Y_t = K_t^\alpha L_t^{1-\alpha} \tag{35}$$

where Y_t is total output, K_t is the capital, and L_t is the labor. Since we assume that labor supply is perfectly mobile, the first-order optimality condition for labor supply leads to:

$$W_t = (1 - \alpha) \frac{P_{H,t} Y_t}{P_t L_t} \tag{36}$$

It follows that the gross profit per unit of capital is then given by:

$$\frac{Y_t - W_t L_t}{K_t} = \left[1 - (1 - \alpha) \frac{P_{H,t}}{P_t} \right] \frac{Y_t}{K_t} \tag{37}$$

In a fully competitive market, the firms earn zero profits. Then the gross return on the capital from date t to $t + 1$ must satisfy:

$$R_{k,t+1} = \frac{\left[1 - (1 - \alpha) \frac{P_{H,t+1}}{P_{t+1}} \right] \frac{Y_{t+1}}{K_{t+1}} + Q_{t+1} (1 - \delta)}{Q_t} \tag{38}$$

where δ is the depreciation rate of the capital.

2.4. Capital Producers

Capital producers acquire new capitals from final domestic and foreign goods, and subject to adjustment costs.

Similar to C_t , we define new capitals by:

$$I_t \equiv \left[(1 - \nu)^{\frac{1}{\eta}} I_{H,t}^{\frac{1-\eta}{\eta}} + \nu^{\frac{1}{\eta}} I_{F,t}^{\frac{1-\eta}{\eta}} \right]^{\frac{\eta}{1-\eta}} \tag{39}$$

Then, the optimal capital acquisitions on domestic and foreign goods are given by

$$1. \quad I_{H,t} = (1 - \nu) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} I_t \quad \text{and} \quad I_{F,t} = \nu \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} I_t \tag{40}$$

respectively. The optimization problem of a capital producer is to choose $I_{t+i}, i = 0, 1, \dots$, such that the present value of future profits is maximized:

$$\max_{I_{t+i}} E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \left\{ Q_{t+i} I_{t+i} - \left[1 + f \left(\frac{I_{t+i}}{I_{t+i-1}} \right) I_{t+i} \right] \right\} \tag{41}$$

where $f(x) = \frac{\eta}{2} (x - 1)^2$ is the adjustment cost function satisfying $f(1) = 0, f'(1) = 0$ and $f''(x) > 0$ so that the aggregate output of the capital producers is decreasing returns to scale in the short run and is constant returns to scale in the long run, and $\eta > 0$ is the inverse elasticity of net investment to the price of capital. The first-order optimality condition for I_t then gives us:

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right). \quad (42)$$

As we have assumed in Section 2.1, the profits, if there is any, are redistributed to households in lump sum.

2.5. Government

Government imposes taxes on the foreign debt and households, and spend on domestic and foreign goods. The government's budget constraint is given by:

$$G_t = T_t^* R_{b,t} e_{t-1} B_{t-1} + T_{h,t} \quad (43)$$

where $G_t \equiv \left[(1-v) \frac{1}{i} G_{H,t}^{\frac{i-1}{i}} + v \frac{1}{i} G_{F,t}^{\frac{i-1}{i}} \right]^{\frac{i}{i-1}}$ is the government composite consumption index, $G_{H,t}$ is the government spending on domestic goods and $G_{F,t}$ is the government spending on foreign goods. Similar to C_t , the optimal government spending allocation is given by

$$G_{H,t} = (1-v) \left(\frac{P_{H,t}}{P_t}\right)^{-i} G_t \text{ and } G_{F,t} = v \left(\frac{P_{F,t}}{P_t}\right)^{-i} G_t \quad (44)$$

We assume that G_t is fixed at its steady-state level G . Therefore the government spending on domestic and foreign goods are constants for every period. The reason we make this assumption is that the purpose of this paper is to study the effects of external shocks on a small open economy's capital flows, such as foreign debt. Thus, fixing G_t at a constant level is helpful in making such effects distinguishing.

We first consider a simple rule for liability-side macroprudential policy related to excessive foreign debt, given by:

$$T_t^* = \tau \left[\log\left(\frac{e_{t-1} B_{t-1}}{Q_{t-1} S_{t-1}}\right) - \log\left(\frac{eB}{QS}\right) \right] \quad (45)$$

where $\frac{eB}{QS}$ is the steady-state value of $\frac{e_t B_t}{Q_t S_t}$, and $\tau > 0$ is the parameter for tax level. This rule indicates that the government raises (reduces) tax rate on foreign borrowing when the fraction of foreign borrowing in assets increases (decreases). The purpose of this rule is to discourage the banks relying heavily on the foreign borrowing.

This could effectively reduce the likelihood of a surge in capital inflows when the foreign rate $R_{b,t}$ is low and a sudden stop when $R_{b,t}$ is high, and could also limit the related real exchange fluctuations.

We also consider another rule for an asset-side macroprudential policy given by Aoki, Benigno, and Kiyotaki (2018)⁶

$$T_t^* = \tau (\log S_{t-1} - \log S) \quad (46)$$

⁶ Please see the following website for details:

http://personal.lse.ac.uk/BENIGNO/ABKBankModel3-24-2016_GB_revision.pdf

where S is the steady-state value of S_t . Here, the tax rate on banks is an increasing function of the percentage deviation of bank's asset from non-stochastic stationary steady state. Thus, government raises the tax rate when banks excessively expand its asset quantity, which leads to accelerated credit growth.

2.6. International Market

Because we are considering a small open economy, the home country will not affect the price level in the foreign countries. Therefore, we can assume that $P_{F,t} = P_t^*$, where P_t^* is the price index in the foreign country in terms of the domestic currency. The terms of trade q_t is then defined by:

$$q_t \equiv \frac{P_{F,t}}{P_{H,t}} = \frac{P_t^*}{P_{H,t}} \quad (47)$$

Following from the definition of P_t in (4), we further define $g(q_t)$ by:

$$g(q_t) \equiv \frac{P_t}{P_{H,t}} = [(1 - \nu) + \nu q_t^{1-\iota}]^{\frac{1}{1-\iota}} \quad (48)$$

Combining the above definition for $g(q_t)$ and Equations 3, 40 and 44, we have:

$$C_{H,t} = (1 - \nu)g(q_t)^\iota C_t \quad (49)$$

$$I_{H,t} = (1 - \nu)g(q_t)^\iota I_t \quad (50)$$

and

$$G_{H,t} = (1 - \nu)g(q_t)^\iota G_t. \quad (51)$$

The real exchange rate is then given by

$$e_t \equiv \frac{P_t^*}{P_t} = \frac{q_t}{g(q_t)} \quad (52)$$

2.7. Market Clearing

In order to close the model, we require market clearing in goods, capital and labor.

First, aggregate output is divided between household consumption $C_{H,t}$, investment expenditures $I_{H,t}$, government domestic spending $G_{H,t}$ and exogenous demand EX_t for exports as follows

$$\begin{aligned} Y_t &= C_{H,t} + \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_{H,t} + G_{H,t} + q_t EX_t \\ &= (1 - \nu)g(q_t)^\iota (C_t + I_t + \Gamma_t + G_t) + q_t EX_t \end{aligned} \quad (53)$$

where $\Gamma_t = f\left(\frac{I_t}{I_{t-1}}\right)I_t$ is the adjustment cost.

The trade balance in terms of CPI is given by:

$$TB_t \equiv \frac{Y_t}{g(q_t)} - C_t - I_t - G_t - \Gamma_t. \tag{54}$$

And the evolution of foreign debt B_t in terms of foreign currency is given by

$$B_t = R_{b,t}^* B_{t-1} - \frac{TB_t}{\epsilon_t} \tag{55}$$

where $R_{b,t}^*$ is the bank's foreign borrowing rate from date $t - 1$ to date t . Then the current account is given by

$$CA_t \equiv B_{t-1} - B_t \tag{56}$$

and the relation between $R_{b,t}$ and $R_{b,t}^*$ is given by

$$R_{b,t} = \frac{\epsilon_t}{\epsilon_{t-1}} R_{b,t}^* \tag{57}$$

We assume that the bank's gross foreign borrowing rate $R_{b,t}^*$ is the sum of an exogenous world gross interest rate R_t^* and a country premium as follows

$$R_{b,t}^* = R_t^* + \psi \left\{ \exp \left[\frac{q_{t-1} B_{t-1}}{Y_{t-1}} - \frac{qB}{Y} \right] - 1 \right\} \tag{58}$$

where $\frac{qB}{Y}$ is the steady-state value of $\frac{q_t B_t}{Y_t}$, and $\psi > 0$ is the parameter for country-specific interest rate premium.

Note that the country premium increases with the fraction of foreign debt. This is adopted to guarantee the stationary of foreign debt. In addition, we assume that the logarithm of exogenous world gross interest rate R_t^* follows the AR(1) process:

$$\log R_t^* = (1 - \rho_{R^*}) \log R^* + \rho_{R^*} \log R_{t-1}^* + \epsilon_t^{R^*}, \epsilon_t^{R^*} \sim i.i.d. N(0, \sigma_{R^*}^2) \tag{59}$$

where R^* is the expected value of R_t^* and $\epsilon_t^{R^*}$ is the independent and identical shock following normal distribution with zero mean and standard deviation σ_{R^*} .

The funds for final goods producers to purchase capitals are financed from banks as follows

$$Q_t K_{t+1} = Q_t S_t \tag{60}$$

The capital accumulation is given by:

$$K_{t+1} = I_t + (1 - \delta)K_t \quad (61)$$

Finally, the condition that labor supply equals labor demand requires that

$$(1 - \alpha) \frac{P_{H,t} Y_t}{P_t L_t} = \chi L_t^{\varphi-1} \quad (62)$$

In all, (EX_t, R_t^*) follows an exogenous stochastic process. Five prices $(Q_t, R_{t+1}, R_{b,t+1}, R_{k,t+1}, P_{H,t}/P_t)$ and nine quantities $(Y_t, C_t, L_t, I_t, K_{t+1}, D_t, N_t, S_t, B_t)$ together with four shadow prices $(V_{s,t}, V_{b,t}, V_{d,t}, \lambda_t)$ are determined as a function of the state variables $(K_t, C_{t-1}, I_{t-1}, D_{t-1}, R_t, R_t^*, B_{t-1}, EX_t)$ by the sequence of eighteen equations: the first-order optimality conditions for households, banks and nonfinancial firms (8, 20, 21, 28, 29, 30, 31, 34, 35, 38, 42, 55), and the market clearing conditions for goods, capital, exchange rate and labor (32, 53, 57, 60, 61, 62).

2.8. Calibration

We choose the parameters based on existing literatures and calibration. The values of parameters are summarized in Table 1. For the parameters for households, we set the discount factor β to 0.98 and the inverse intertemporal elasticity of substitution γ to 2 as in Aguiar and Gopinath (2007). The curvature on labor φ is 1.455 as in Mendoza (1991). The relative utility weight of labor χ is set to 3.092 such that the labor supply is 0.2 in the steady state.

For the parameters for banks, we follow the methods used by Gertler and Karadi (2011). σ is set to make the bank's life to be eight years, the index for financial friction ω is set to 0.25 in the benchmark case, and the parameters θ_t and ξ are set to 0.606 and 8.258×10^{-4} , respectively, such that the spread between R_b and R is 100 basis point per year and the leverage ratio is 4 in the steady state.

The parameters for non-financial producers are set according to Gertler and Kiyotaki (2010). The effective capital share α , the capital depreciation δ and the inverse elasticity of net investment to the price of capital are set to 0.330, 0.0025 and 1.5, respectively.

For the parameters related to government and open economy, the steady-state level of fraction of government expenditure $\frac{G}{Y}$ is set to 0.2 (Kitano & Takaku, 2017) and the steady-state value of portion of foreign debt to output is set to 0.4 (Devereux, Lane, & Xu, 2006). The tax level related to macroprudential policies (or we may call capital control level) τ is set to 0.05 for the benchmark case. The elasticity of substitution between domestic and imported

goods ι is set to 1.5 according to Ravenna and Natalucci (2008). Following Cook (2004) the degree of openness ν is set to 0.28. The parameter for country-specific risk premium ψ is set to 0.03, that lies between 0.0075 in Unsal (2011) and 0.05 in Akinci and Queralto (2014). The persistence and the standard deviation of the foreign interest rate shock, ρ_{R^*} and σ_{R^*} , are set to 0.98 and 0.0025, respectively.

Table-1. Parameter calibration.

Households		
β	0.980	Utility discount rate
γ	2.000	Inverse of intertemporal elasticity of substitution
φ	1.455	Curvature parameter on labor
χ	3.092	Relative utility weight of labor
Banks		
σ	0.875	Survival rate of bankers
θ	0.606	Fraction of divertible assets
κ	0.349	Degree of home bias in finance
ω	0.250	Financial friction index
ξ	8.258×10^{-4}	Transfer to entering bankers
Final goods producers		
α	0.330	Effective capital share
δ	0.0025	Capital depreciation rate
Capital goods producers		
η	1.500	Inverse elasticity of net investment to the price of capital
Government		
τ	0.05	Tax rate level of macroprudential policies (Capital control level)
G/Y	0.200	Steady-state fraction of government expenditure
B/Y	0.400	Steady-state fraction of foreign debt
Open economy		
ι	1.500	Elasticity of substitution between domestic and imported goods
ν	0.280	Inverse degree of home bias or degree of openness
ψ	0.030	Country-specific interest rate premium
ρ_{R^*}	0.980	Persistence of foreign interest rate
σ_{R^*}	0.0025	Standard deviation of foreign interest rate

3. SIMULATION RESULTS OF THE IMPACT OF GLOBAL LOW INTEREST RATES

In the RBC-DSGE model for a small open economy in Section 2, the world interest rate is the exogenous variable and the domestic macroeconomic and external-sector variables are the endogenous variables. Based on this framework, in this section, we explore the impact of global low interest rates to small open economies though simulating a negative world interest rate shock. Specifically, we study how the small open economy responses to the unexpected decline in world interest rates.

3.1. Impulse Responses of Main Variables to Negative Shocks on Global Interest Rates without Macroprudential Policies

We first make a simulation with an unanticipated average annual 100 basis points decrease in exogenous global interest rate, which matches the current predictions that the US will probably reduce the interest rate of total 100 basis points through this year to fight the world economic contraction⁷. As shown in Figure 2, an exogenous decline in the world interest rate decreases the foreign borrowing cost R_b of small open economies, and this leads to a deterioration of the current account, which means increasing net capital inflows to small open economies. As a result, the foreign debt B of small open economies accumulates and the real exchange rate e appreciates. The increasing foreign debt leads to an increase in bank's asset S and producer's capital K . The increase in capital raises up the output Y and investment I , which causes the capital price Q increases. However, the bank's net worth $N = QS - D - eB$ does not change significantly, which implies that the bank's leverage ratio increases due to the surge in capital inflows. Therefore, exogenous decline in foreign interest rates amplified the domestic business cycle (Y, I and R_k) through bank's higher leverage ratio, and the financial vulnerability accumulates.

3.2. Impulse Responses of Main Variables to Negative Shocks on Global Interest Rates with Macroprudential Policies

Based on the simulation results of the DSGE model with macroprudential policies, we examine the effectiveness of macroprudential policies and compare two different instruments. The impulse responses of main variables to a decrease in global interest rates with and without macroprudential policies are shown in Figure 3. The black solid, red dash and blue dotted lines in Figure 3 are the cases with the liability-side macroprudential policy with a focus on foreign borrowing (45), the asset-side macroprudential policy, (46) and no macroprudential policy with $\tau = 0$, respectively.

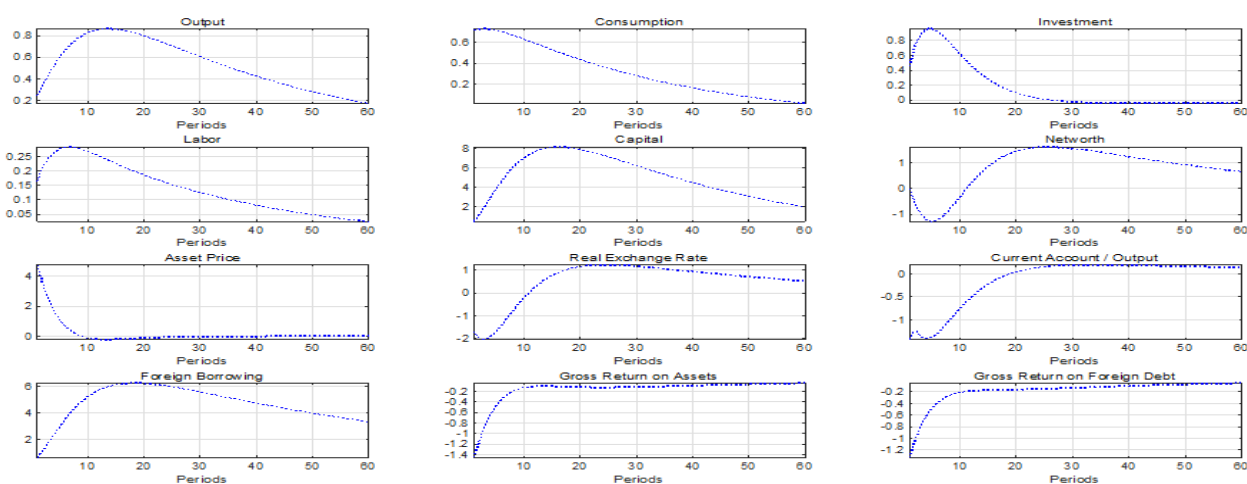


Figure-2. Impulse responses to negative world interest rate shock without macroprudential policies.

Source: Authors' calculation in MATLAB.

⁷ Please see details in the following website: <https://www.bloomberg.com/news/articles/2020-03-01/fed-ready-to-cut-rates-despite-doubt-they-can-fix-virus-fallout>

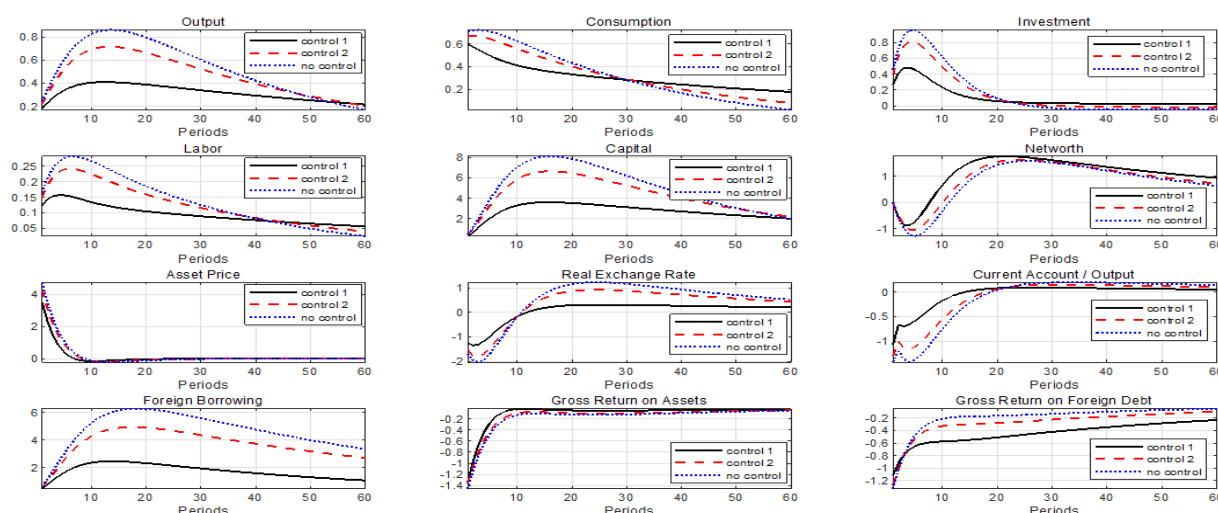


Figure-3. Impulse responses to negative world interest rate shock. Controls 1 and 2 correspond to the liability-side macroprudential policy limiting excessive foreign borrowing(45) and the asset-side macroprudential policy with a focus on domestic bank's asset expansion(46), respectively.

Now we commence to compare the cases with and without macroprudential policies in Figure 3. We can see

that the effects of an exogenous decrease in foreign interest rates on Y, C, I, L, K, CA and B are larger when there are no macroprudential policies. Moreover, the economy with the liability-related macroprudential policy limiting excessive foreign debt (45) experiences smaller movements in real exchange rate, capital inflows, foreign debt and financial leverage than the economy with the asset-side macroprudential policy (46). Therefore, we can conclude that the liability-side macroprudential policy with a focus on foreign debt is more effective than the asset-side macroprudential policy with a focus on domestic asset expansion(this could also be viewed as credit growth) in avoiding large fluctuation caused by the sudden decline in the world interest rate of small open economies.

3.3. Impulse Responses of Main Variables under Larger Shocks

In this subsection, we examine the effects of different macroprudential policies under larger negative shocks on world interest rates. Specifically, we set the standard deviation twice as in the benchmark case. The impulse responses of main variables with and without macroprudential policies are summarized in Figure 4.

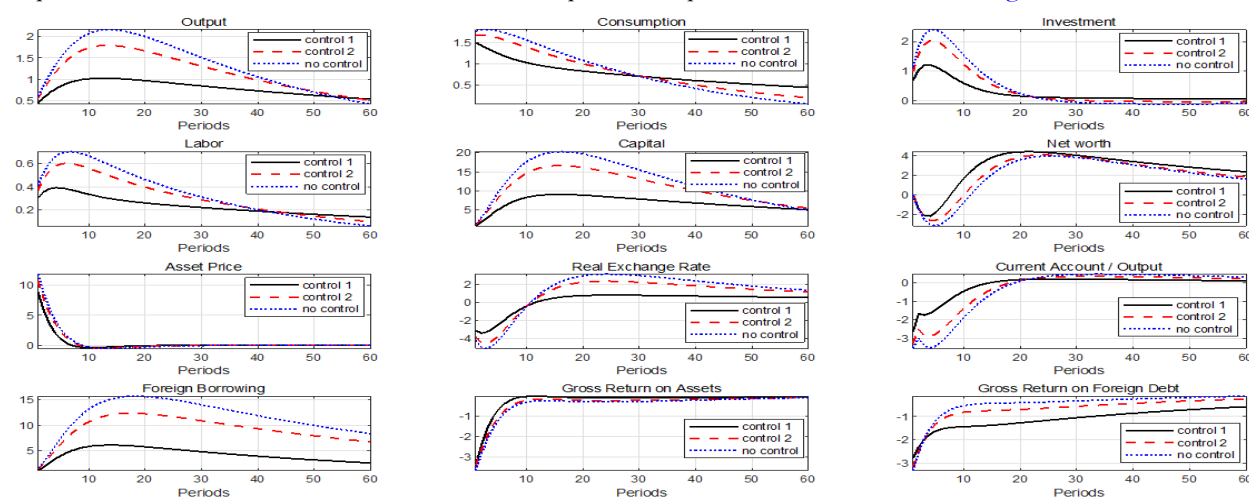


Figure-4. Impulse responses to larger negative world interest rate shock.

In Figure 4, we can see that the patterns of responses of main variables to the larger exogenous shocks are the same as those of benchmark case in Figure 3, except that the sizes of fluctuations are further amplified. For example,

the current account to output ratio worsens by about 2.5% due to large shocks rather than 1% in previous small shocks, which means the larger capital inflows under large global interest rate shock. Moreover, it is worth to pay attention to the large difference of foreign debt B with and without macroprudential policies in Figure 4. The foreign debt B increases 15% after eighteen periods under the large shocks if no macroprudential policy is applied, while the largest increase in B is less than 7% with the liability-side macroprudential policy (45). This result strongly supports the validity of the macroprudential policies adopted by EMEs in order to protect their financial system from risks of capital inflow surges and financial vulnerability accumulation due to global low interest rates.

4. MODEL VALIDATION IN REAL WORLD

To examine the validity of the model's conclusion in Section 3, we turn to check whether the previous real data of small open economies is consistent with the model during a shock of negative world interest rate. The criteria for screening small open economies are as follows: (1) Whether a country is small or not is based on its percentage to the world GDP, and the threshold chosen in this paper is 3 percent. The US, China, Japan, Germany, France, UK, and India are chosen as large economies, which take more than 57 percent of the world GDP together. (2) Whether a country is open or not is based on the capital control database by Fernández, Klein, and Rebucci (2016). According to this database, countries will be identified as open if the values of capital control indicators are below 0.5⁸. Specifically, the following indicators are included in the identification process: overall restrictions index, average bond restrictions, average money market restrictions, average commercial credits restrictions, average financial credits restrictions. Based on WEO's GDP data in 2018 and restricted by data availability of capital control, 81 countries are chosen as small open economies, including 29 advanced economies, and 52 emerging and developing economies.

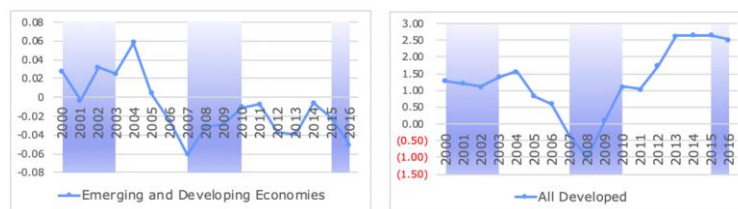


Figure-5. CA dynamics of emerging and developing economies, and advanced small open economies.

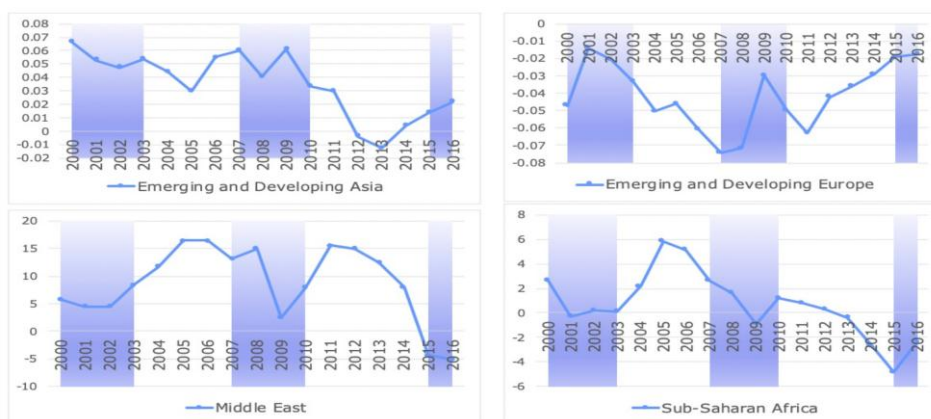


Figure-6. CA Dynamics of emerging and developing small open economies in different regions.

⁸ The values of the capital control database range from 0 to 1. Larger values represent more restrictions.

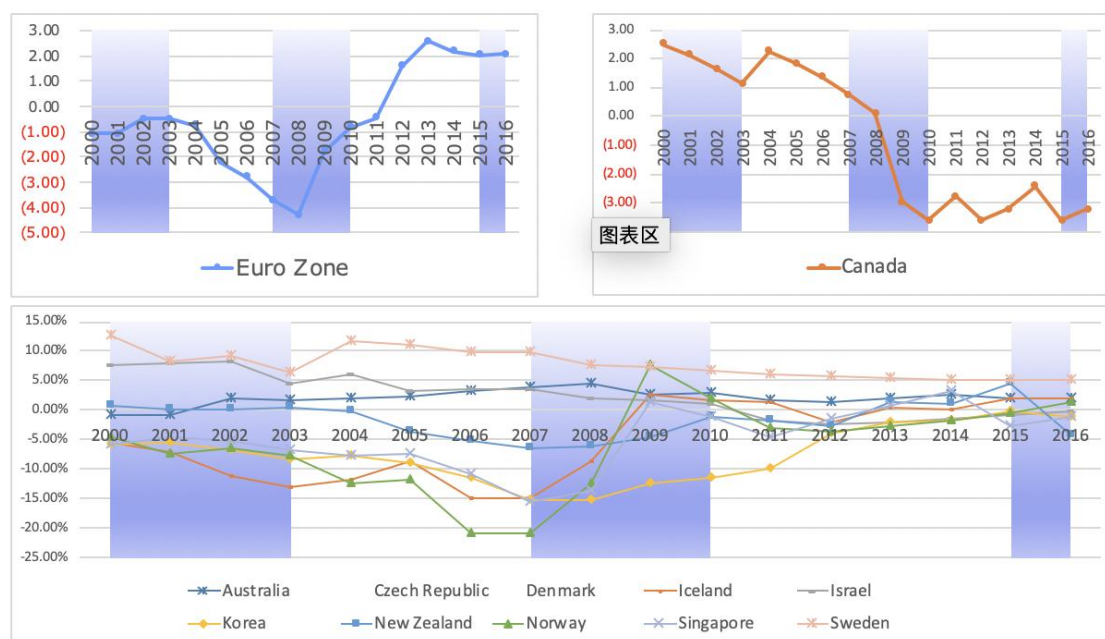


Figure-7. CA Dynamics of advanced economies in different regions.

From Figure 5 and 7, we can see that, in the post-GFC period, when there is a negative external world interest rate shock (the shadow area), the current account conditions of small open economies were deteriorated both in EMEs and advanced economies. As CA and net capital flows are the opposite sites of a mirror, deteriorated CA means net capital inflows surged in small open economies for both advanced economies and EMEs as a whole, when the negative global interest rate shock happened.

Regionally, after the external negative world interest rate shock during 2007-2010, emerging and developing Asia experienced increasing net capital inflows for almost 5 years during the global low interest rate period after global financial crisis. This situation reversed from the Fed's announcement of tapering its quantitative easing policy, after which the US Treasury yields surged. The increasing net capital inflows to emerging and developing Europe reversed earlier compared to the Asia due to the European Sovereign Debt Crisis. While capital inflows to Middle East, North Africa and Sub-Saharan Africa behaved in exactly the opposite way, for the current account conditions improved since the negative world interest rate shock and deteriorated sharply since 2014. This is possibly because the main factors affecting the capital inflows to these areas are commodity prices. The capital inflows to these areas declined with most of the commodity prices started to decline, and reversed for many commodity prices started to go up since 2016.

As for advanced economies, Euro Zone and other developed economies experienced capital outflows during the global low interest rate period since the external negative world interest rate shock, and the capital outflows continued to increase before 2013. This implies that capital flowed from Euro Zone and other developed economies to elsewhere during the global low interest rate period, and one possible explanation is that the interest rates in these economies are highly related to the US. While things are quite different for Canada, for Canada experienced continuous large net capital inflows during the global low interest rate period since the external negative world interest rate shock during 2007-2010.

5. CONCLUSIONS

In this paper, we have developed a RBC-DSGE model with financial frictions and different macroprudential policies for small open economies. The financial frictions are characterized by the time-varying divertible proportion of banks' assets and differences in divertibility of bankers in domestic and foreign debt. We then explore how the exogenous low world interest rate shocks affect the small open economies and study the effectiveness of

two macroprudential policies for protecting the external sector and financial system from the global low interest rate shocks. It turns out that the foreign debt, capital, output and financial leverage of small open economies increase while the current account to output ratio deteriorates (which means capital inflow surges) when the world interest rate experiences a negative shock. The sizes of economic fluctuations exaggerate under larger shocks on the world interest rate. We find that the liability-side macroprudential policy limiting excessive foreign borrowing is effective in smoothing the responses of economy variables but the asset-side one with a focus on banks' total assets expansion works in a less effective way. The real data of small open economies illustrates that the EMEs and advanced economies both experienced capital inflow surges when there was a negative world interest rate shock to ultra-low levels, which is consistent with the conclusion of the model. However, for the regional data, it is not always consistent with the model's conclusion.

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