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Financial Frictions in the Small Open Economy*

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Abstract

This paper introduces a global banking system in a small open economy DSGE model with financial frictions. The model features global relative price adjustments with incomplete asset market. Three main findings stand out. Firstly, foreign financial shocks capture negative spillovers from foreign country in a global financial crisis. We show that country differences in the severity of the shocks depend on the degree of trade openness and banking system stability. Secondly, credit policy could be more powerful than monetary policy to alleviate foreign financial shocks since an expansionary monetary policy and alternative policy rules are not a sufficient tool in the global financial crisis. In particular, credit policy based on international credit spread outperforms credit policy based on domestic credit spread since the latter leads to “excess smoothness” in the real exchange rate. Lastly, foreign credit policy has a negligible influence on domestic welfare so that the small open economy can effectively reduce welfare losses only if the central bank in the economy injects credit.

Keywords: Small open economy, Financial frictions, Global banking system, Credit policy, Monetary policy

JEL Classification Numbers: E44, E52, F41

1 Introduction

The recent U.S. financial crisis featured significant disruption of financial intermediaries and cross-border spillovers. The meltdown of the shadow banking system due to the collapse of the U.S. housing market bubble and loose regulatory policies deteriorated the entire financial system and the world economy. Thus, a new generation of DSGE models incorporate frictions in financial intermediaries¹ such as Cúrdia & Woodford (2016), Gertler & Karadi (2011), Gertler & Kiyotaki (2010, 2015) and Gertler et al. (2012).

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¹Previous literature incorporates the linkages between the financial sector and the real economy in otherwise conventional New Keynesian DSGE models for both closed and open economies, developed by Bernanke et al. (1999), Kiyotaki & Moore

There have been a few attempts to incorporate frictions in financial intermediaries in an open economy framework such as Kollmann et al. (2011) and Dedola et al. (2013). This literature shows how country specific shocks lead to financial and macroeconomic interconnections across countries. However, in order to examine two large countries, the literature assumes a symmetric two country framework and does not embed important features of the open economy such as global relative prices (the terms of trade and the real exchange rate) and incomplete asset market structure. In addition, they analyse cross-border capital flows between banks and non-banks and thus they do not embed a global banking system: banks lend funds to both domestic and foreign firms but banks in one country do not lend to banks in another country. However, as shown in Kalemli-Ozcan et al. (2013) and Bruno & Shin (2014), cross-border capital flows through the global banking system account for a large proportion of total cross-border debt flows² and they are a critical determinant of macroeconomic synchronization. Global bank loans significantly alter the balance sheets of domestic banks, which boost the economy by lending more funds to domestic firms in normal times but trigger a financial crisis by suddenly withdrawing loans. This paper is also related to Aoki et al. (2016). Aoki et al. (2016) develop a small open economy model with financial intermediaries and analyse the transmission mechanism of foreign (interest rate) shocks through the fluctuation of the real exchange rate. However, there is no scope for the mechanism through the fluctuation of the real exchange rate in the global banking system, financial market imperfections and risk sharing condition.

In order to capture cross-border capital flows through the banking sector across countries, the model in this paper introduces a global banking system into a small open economy DSGE model and analyses how the source of funds (deposits and global bank loans) changes in response to financial and capital quality shocks. In a closed economy DSGE model with financial frictions, where banks are constrained in obtaining funds from households, a financial crisis affects the economy through a financial accelerator mechanism. We identify that in our open economy model, global bank loans generate an additional channel. Domestic banks in the small open economy can obtain additional funds from global banks and this in turn, exposes to the currency risk which influences the real cost of global bank loans, making the economy more vulnerable in response to the shocks.

(1997), Gertler et al. (2007), Faia (2010), Christiano et al. (2011) and many others. In this literature, the financial frictions arise from constraints on nonfinancial borrowers. Since the cost of external finance hinges on the balance sheet of the borrowers, the deterioration of the balance sheet from external shocks leads to a lower demand for capital, investment and output, leading to a fall in asset prices.

²According to BIS banking statistics, while cross-border claims of banks on global banks account for around three eighth in total cross-border liabilities, those of banks on non-banks only account for one eighth in total cross-border liabilities.

Since small open economies are vulnerable to global financial and non-financial conditions, our model embeds small open economy features in a tractable way. The response of the terms of trade and the real exchange rate allows us to investigate changes in trade and the current account. Also, allowing different degree of trade openness and banking system stability offers sources of heterogeneous dynamics of small open economies. In particular, our model features an incomplete asset market structure in line with empirical evidence on the lack of risk sharing (i.e the Backus & Smith (1993) puzzle)³ in terms of both international government bonds and the global bank loans market thereby allowing imperfect risk sharing in consumption. By embedding price stickiness and financial frictions, monetary and credit policy plays a role in our model.

We document the effects of financial and capital quality shocks in the domestic and foreign countries and then, look at the role of credit policy based on domestic and international credit spread, and an expansionary monetary policy⁴ to combat the financial crisis. Three main findings stand out. Firstly, foreign financial shocks capture cross-border spillovers in the small open economy rather than foreign capital quality shocks. In particular, the shocks broadly mimic a global financial crisis in the small open economy as defined by Calvo et al. (2006), Mendoza (2010) and Gourinchas & Obstfeld (2012): (a) contractions of output and investment, (b) decline in the net worth and asset prices, (c) a fall in CPI inflation, (d) reversals of international capital flows in terms of an increase in net exports and drops of global bank loans, (e) a depreciation of the terms of trade and the real exchange rate. Also, we show that country differences in the severity of the shocks depend on the degree of trade openness and banking system stability.

Secondly, while credit policy is powerful in response to foreign financial shocks by injecting credit flows to intermediate firms, the expansionary monetary policy and alternative monetary policy rules are not sufficient to alleviate the global financial crisis. In particular, credit policy based on international credit spread outperforms credit policy based on domestic credit spread since the latter leads to “excess smoothness” in the exchange rate and interrupts a role of the real exchange rate as a foreign financial shock absorber. A feedback rule with international credit spread additionally eliminates global relative price effects in the risk

³Namely, the correlation between relative consumption and the real exchange rate tends to be low or even negative in the data rather than close to one. Recently, macroeconomists have therefore begun to consider incomplete asset markets which are subject to volatile capital flows (Schmitt-Grohé & Uribe (2003), Tuladhar (2003), Benigno & Benigno (2003), Corsetti et al. (2008) and De Paoli (2009)). While the interest rate risk premium of holding foreign assets arises from the current account balance in Tuladhar (2003), it arises from the aggregate net foreign asset position of the country in De Paoli (2009). Benigno (2009) analyzes the impact of steady state net debt positions and finds that asymmetries in the steady state net debt position lead to macroeconomic volatility.

⁴In the financial crisis, central banks in small open economies tend to reduce the nominal interest rate by deviating from conventional Taylor interest rate rule in order to recover the economies. Thus, in this paper, we examine a role of an expansionary monetary policy defined as a monetary policy that further reduces the nominal interest rate by deviating from conventional Taylor interest rate rule.

sharing and allows an appreciation of the real exchange rate, reducing the real cost of global bank loans and increasing global bank loans. This in turn, increases consumption, price of assets, investment and output further. The global banking channel dominates a trade channel which reduces net exports and output in response to the appreciation.

Lastly, foreign credit policy has a negligible influence on domestic welfare in the crisis without domestic credit policy. While foreign credit policy increases net exports, consumption and output, it also increases capital outflows, the real cost of global bank loans, and volatilities of CPI inflation and capital prices due mainly to a depreciation of the real exchange rate. This implies that for given domestic credit policy, foreign credit policy functions as financial market distortions, widening a welfare gap between international credit policy rules with and without foreign credit policy. Thus, the small open economy can effectively reduce welfare losses only if the central bank in the economy conducts its own credit policy.

The paper is organized as follows: Section 2 describes the key macroeconomic variables in the global financial crisis. In Section 3, we describe the model including the incomplete asset market structure and the global banking system. Section 4 presents quantitative results. We analysis the impact of disturbances to the small open economy and the large economy to the agency cost and the quality of intermediary assets and show how the disturbances in both economies could influence the small open economy. Then, we evaluate the extent to which credit policy and the expansionary monetary policy to alleviate the financial crisis. Finally, our concluding remarks are presented in section 5.

2 Stylised Facts of the Global Financial Crisis

Our primary focus is on the experience of small open economies spilled over from a global financial crisis so that we show main US, Korean and Canadian variables during 2008q3-2012q3 in Figure 1. Korea and Canada have one of the most open goods and financial markets in the world and small open economies which are unable to influence the foreign interest rate, output and prices but also vulnerable goods and financial markets due to volatile capital flows and foreign currency risk. Also, since two economies have different degree of trade openness and banking system stability⁵, the movement comparison of main macroeconomic variables in different countries offers sources of heterogeneous dynamics of each economy in the global

⁵According to bank Z-score which captures the probability of default of a country's banking system, the score of Canada (i.e., Z-score: 15.1) is approximately two times higher than that of Korea (i.e., Z-score: 7) during 1994-2014. A higher value of Z-score indicates greater banking system stability. As for the degree of trade openness, Canada has more open goods market having the import/GDP ratio of 0.4 than Korea having the ratio of 0.3 for the same period.

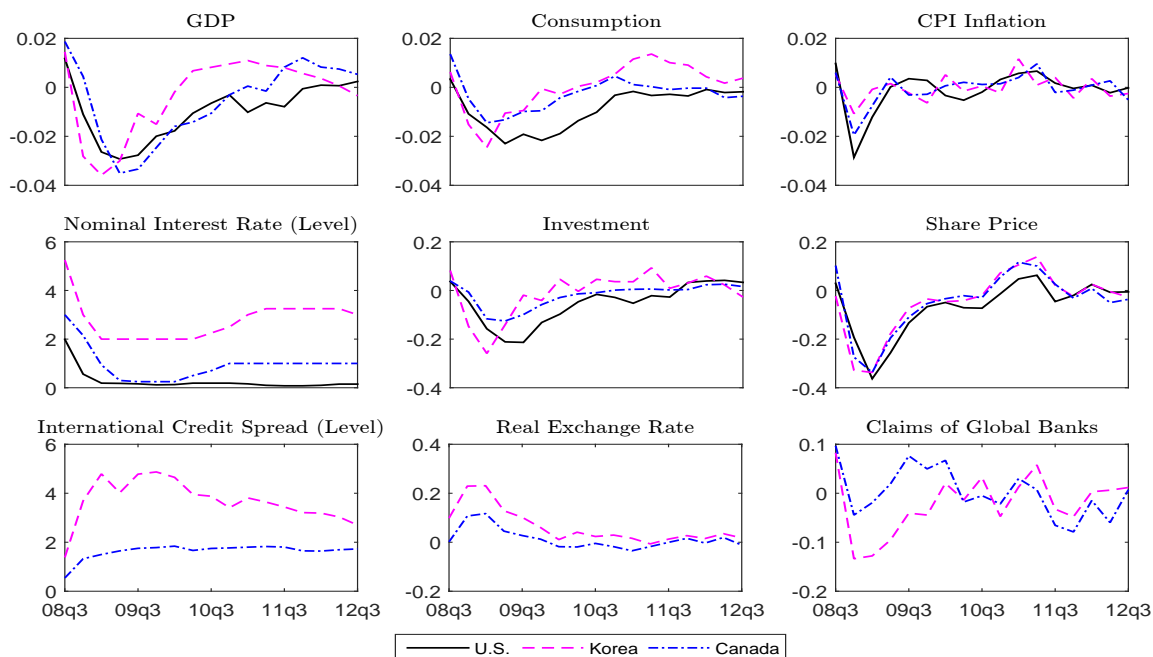


Figure 1: U.S., Korea and Canada

NOTE: While the nominal interest rate (overnight call rate (Korea and Canada) and effective federal funds rate (U.S.)) and international credit spread (between Libor and the yields on AA rated corporate bonds for Korea (the business prime rate for Canada)) are the annualized, other variables are expressed in log de-trended and estimated from 1994q4 to 2014q3. Following Christiano et al. (2011), stock prices (stock price index (Korea and Canada) and Dow Jones index (U.S.)), scaled by the GDP deflator are included. An increase in the real effective exchange rate indicates depreciation of the Korean and Canadian currencies against a broad basket of currencies. Source: The Bank of Korea, Statistics Canada, Federal Reserve Economic Data and BIS Statistics.

financial crisis.

Financial liberalisation, started in the 1990s relaxed restrictions on foreign loans and entry of financial institution and led to a substantial increase in cross-border borrowing from global banks, largely in the form of short-term debt. The stock of consolidated claims of global banks on both Korea and Canada accounted for about 30% of GDP in 2008q3. The global financial crisis started in the US and featured significant disruption of financial intermediaries and the global banking system. A depreciation of the real exchange rate raised the real cost of global bank loans and confidence of global banks was rapidly eroded in the financial crisis. Thus, Korean and Canadian banks were unable to roll over their short-term debt and foreign capital suddenly outflowed. Also, the banks attempted to reduce leverage by selling their assets and reducing loans to firms. The international credit spread sharply increased during the first two quarters, raising the cost of capital and this in turn reduced investment and output. Correspondingly, real

GDP, consumption, CPI inflation, investment and the claims of global banks decreased. Since the Canadian economy has more stable banking system, the financial channel had less severe influences on international credit spread, cross-border borrowing and investment. However, the economy has more open goods market so that lower foreign demand for Canadian goods coupled with lower price of imports reduced CPI inflation further and generated a symmetric fall in output. In order to recover the economy, the central banks of the small open economies aggressively reduced the nominal interest rate. Over the period given, variables show strong positive inter-country correlation.

3 Model

We develop a small open economy DSGE model with financial frictions and a global banking system. The baseline framework follows Benigno & Benigno (2003), Gali & Monacelli (2005) and Benigno (2009). Financial frictions and the global banking system are added following the approach of Gertler & Kiyotaki (2010, 2015) and Gertler & Karadi (2011). We extend the baseline DSGE model by embedding an incomplete asset market structure in the model presented in subsection 3.1-3.3 and introducing the global banking system between domestic and global banks presented in subsection 3.4.

3.1 Households

The world is composed of two countries, the home and the foreign country labelled by f . Households on the subinterval $[0, n]$ live in the home country and households on the subinterval $[n, 1]$ live in the foreign country. In order to specify the small open economy, a home bias is introduced. Since we assume that the home country is a small economy that is unable to influence the foreign economy, the foreign economy is analogous to a closed economy

Each domestic household contains a large number of individuals. It supplies labour, makes deposits in domestic banks, and holds both domestic currency denominated bonds and foreign currency denominated bonds. Domestic government bonds and deposits in domestic banks are perfect substitutes. Following Gertler & Karadi (2011), within the household, a fraction $1-e$ of individuals are workers and a fraction e are bankers. While workers supply labour and earn wages, bankers manage the bank and transfer bank dividends to the household. Each household consumes final goods from domestic and foreign countries, and consumption risk is perfectly pooled within the household.

The intertemporal utility of a representative household in the home economy is given by

$$\sum_{t=0}^{\infty} \beta^t U(C_t, L_t) \quad (1)$$

where per-period utility is

$$U(C_t, L_t) = \frac{(C_t - hC_{t-1})^{1-\rho}}{1-\rho} - \mathfrak{R} \frac{L_t^{1+\varphi}}{1+\varphi} \quad (2)$$

where ρ is the coefficient of relative risk aversion, h is the habit persistence parameter and φ is the inverse of the Frisch elasticity of labour supply. Aggregate consumption of a representative home (foreign) household is given by

$$C_t = \left[\lambda^{\frac{1}{\eta}} (C_{h,t})^{\frac{\eta-1}{\eta}} + (1-\lambda)^{\frac{1}{\eta}} (C_{f,t})^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}; \quad C_t^f = \left[\lambda^{\frac{1}{\eta^f}} (C_{f,t}^f)^{\frac{\eta^f-1}{\eta^f}} + (1-\lambda^f)^{\frac{1}{\eta^f}} (C_{h,t}^f)^{\frac{\eta^f-1}{\eta^f}} \right]^{\frac{\eta^f}{\eta^f-1}} \quad (3)$$

where $C_{h,t}$ ($C_{f,t}^f$) is the consumption of home (foreign) tradable goods and $C_{f,t}$ ($C_{h,t}^f$) is the consumption of foreign (home) tradable goods. Households have a home bias that implies, *ceteris paribus*, that they prefer to consume domestically produced goods. Following Sutherland (2005), $(1-\lambda) = \alpha(1-n)$ is the weight on imported goods, reflecting the relative size of home country n and the degree of openness α . Since a small open economy is characterised by $n \rightarrow 0$, $(1-\alpha)$ represents the degree of home bias in preferences. η (η^f) is the elasticity of substitution between home tradable goods and foreign tradable goods. For simplicity, we assume the same elasticity of substitution between different varieties across countries. The foreign weight on imports is defined as $(1-\lambda^f) = n\alpha$.

We assume that the law of one price holds: $P_{f,t} = X_t P_{f,t}^f$ and $P_{h,t} = X_t P_{h,t}^f$ where $P_{f,t}$ ($P_{h,t}$) is the price of imports (domestic goods) denominated in home currency, X_t is the nominal exchange rate and $P_{f,t}^f$ ($P_{h,t}^f$) is the price of foreign goods (exports) denominated in foreign currency.

The optimal allocation of consumption between different countries yields the demand functions

$$C_{h,t} = \lambda \left(\frac{P_{h,t}}{P_t} \right)^{-\eta} C_t; \quad C_{f,t} = (1-\lambda) \left(\frac{P_{f,t}}{P_t} \right)^{-\eta} C_t \quad (4)$$

$$C_{f,t}^f = \lambda^f \left(\frac{P_{f,t}^f}{P_t^f} \right)^{-\eta} C_t^f; \quad C_{h,t}^f = (1-\lambda^f) \left(\frac{P_{h,t}^f}{P_t^f} \right)^{-\eta} C_t^f \quad (5)$$

The consumer price index (CPI) corresponding to the aggregate consumption in home and foreign coun-

try is given by

$$P_t = \left[\lambda (P_{h,t})^{1-\eta} + (1-\lambda) (P_{f,t})^{1-\eta} \right]^{\frac{1}{1-\eta}}; \quad P_t^f = \left[\lambda^f (P_{f,t}^f)^{1-\eta} + (1-\lambda^f) (P_{h,t}^f)^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad (6)$$

The household deposits funds in domestic banks and holds domestic and foreign government bonds. These are risk-free assets with a one-period maturity. For simplicity, we assume that while foreign government bonds are traded in both countries, domestic government bonds can only be traded in the domestic country so that foreign households can not hold domestic government bonds.

Following Schmitt-Grohé & Uribe (2003) and Benigno (2009), we introduce an incomplete asset market structure in terms of transaction costs⁶. Transactions in foreign currency denominated bonds issued by the foreign government, generate quadratic costs for the foreign government; specifically, quadratic costs are incurred from changing their assets away from the steady state. The foreign government pays these transaction costs to domestic households. The parameter τ measures the strength of these transaction costs. Thus, the real budget constraint of the representative domestic household is given by

$$B_{t+1} + D_{t+1} + Q_t B_{f,t+1} = W_t L_t + \Pi_t - T_t + R_{t-1} B_t + R_{t-1} D_t + Q_t R_{t-1}^f B_{f,t} + \frac{\tau Q_t}{2} (B_{f,t+1} - B_{f,t})^2 - C_t \quad (7)$$

The LHS of this expression reflects the real value of domestic government bonds, B_{t+1} , real deposits, D_{t+1} , and the real value (in terms of domestic currency) of foreign government bonds held by domestic households, $Q_t B_{f,t+1}$, where Q_t is the real exchange rate. Since both domestic government bonds and deposits are one period real riskless assets, they are perfect substitutes and pay the same gross real return, R_{t-1} from $t-1$ to t . The RHS reflects real labour income, $W_t L_t$, net profits from the ownership of bank, retail and capital producing firms, Π_t , lump sum taxes, T_t , the gross real interest from holdings of assets, transaction benefits arising from trade in foreign government bonds and consumption.

The corresponding budget constraint for the foreign representative household is

$$B_{f,t+1}^f + D_{t+1}^f = W_t^f L_t^f + \Pi_t^f - T_t^f + R_{t-1}^f B_{f,t}^f + R_{t-1}^f D_t^f - C_t^f \quad (8)$$

⁶Alternatively, we can impose a debt-elastic interest rate premium. Both incomplete asset market structures imply similar dynamics in log-linearized version. See for more details Schmitt-Grohé & Uribe (2003). In a standard small open economy model with incomplete international asset markets, purely temporary shocks can have a permanent effect on consumption and asset holdings due to the random walk properties as emphasised by Schmitt-Grohé & Uribe (2003) and Lubik (2007). In order to solve the unit-root problem and impose incomplete asset market structures in terms of both international bond markets and global banking sectors, we embed transaction costs.

where $B_{f,t+1}^f$ are foreign government bonds held by foreign households and denominated in foreign currency.

The optimal domestic households decision in terms of deposits, foreign government bonds and labour supply yields the first order conditions

$$E_t \beta \left(\frac{v_{t+1}}{v_t} \right) R_t = 1 \quad (9)$$

$$R_t [1 - \tau(B_{f,t+1} - B_f)] = R_t^f E_t \left(\frac{Q_{t+1}}{Q_t} \right) \quad (10)$$

$$v_t W_t = \Re L_t^p \quad (11)$$

where $v_t = (C_t - hC_{t-1})^{-\rho} - \beta h(C_{t+1} - hC_t)^{-\rho}$ is the marginal utility of consumption. Let variables with a ‘hat’ denote log deviations around steady state and these steady state values are denoted with letters without time scripts. Log linearizing (10) shows the deviation from real uncovered interest parity

$$\hat{R}_t = (\hat{R}_t^f + \chi \hat{B}_{f,t+1}) + E_t(\widehat{\Delta Q}_{t+1}) \quad (12)$$

where $\chi \equiv \tau B_f$ is the costs of adjusting bond holding. This equation implies that a higher effective foreign real interest rate or an expected depreciation of the real exchange rate will be reflected in a higher domestic interest rate.

3.2 The terms of trade, the real exchange rate and the risk sharing condition

The terms of trade is the relative price between exports and imports and it is defined as $S_t = P_{f,t}/P_{h,t}$. The real exchange rate between the domestic economy and country f is defined as $Q_t = X_t P_t^f / P_t$. Thus, Q_t is the relative price of goods between the domestic and foreign countries, expressed in domestic currency. Aggregating optimal domestic and foreign decisions yields the equilibrium risk-sharing condition

$$(\hat{v}_t - \hat{v}_{t+1}) - (\hat{v}_t^f - \hat{v}_{t+1}^f) = E_t(\widehat{\Delta Q}_{t+1}) + \chi \hat{B}_{f,t+1} \quad (13)$$

This equation implies imperfect risk sharing in the relative growth of the marginal utility of consumption due to deviations from PPP and to payments of transaction costs by the foreign government to domestic households. An expected real exchange depreciation raises the current (relative) real interest rate as shown in the UIP condition in (12). This in turn increases the growth of domestic consumption and reduces the

growth of the marginal utility⁷.

3.3 Government

Domestic and foreign governments issue one-period riskless bonds. Since we assume that domestic households can hold both domestic and foreign government bonds but that foreign households can hold only foreign government bonds, the real domestic government budget constraint can be expressed as

$$G_t + R_{t-1}B_t = T_t + B_{t+1} \quad (14)$$

where G_t is government expenditure. The real foreign government budget constraint is given by

$$G_t^f + R_{t-1}^f B_t^f = T_t^f + B_{t+1}^f - \frac{n\tau}{2(1-n)}(B_{f,t+1} - B_f)^2 \quad (15)$$

where $B_{t+1}^f = B_{f,t+1}^f + \frac{n}{1-n}B_{f,t+1}$ are the aggregate foreign government bonds held by domestic and foreign households. Since we assume the domestic economy is small, ($n \rightarrow 0$), transaction costs do not influence the foreign government budget constraint.

3.4 Banks

We assume two types of banks: domestic and global banks. Domestic banks on the subinterval $[0, n]$ are located in the home country and global banks on the subinterval $[n, 1]$ are located in the foreign country. In order to specify the small open economy, the relative size of the banks n is introduced.

Following Gertler & Kiyotaki (2010, 2015) and Gertler & Karadi (2011), we introduce an incentive constraint on bankers. We also assume that each banker becomes a worker with i.i.d. probability $1 - \sigma$ and survives as a banker with probability σ . Also, we assume that bankers can efficiently monitor intermediate firms and enforce their obligations. Thus, banks can frictionlessly lend available funds to intermediate firms and the firms pay state contingent debt.

⁷Extensive studies have analyzed imperfect risk sharing without habit persistence such as Benigno (2009), Corsetti et al. (2008) and De Paoli (2009). In complete financial markets, households purchase contingent claims traded internationally so that the marginal utility of consumption of both countries, weighted by the real exchange rate should be equalized, as noted by Backus & Smith (1993).

3.4.1 Domestic Banks

The domestic banks balance sheet is given by

$$H_t S_t^a = N_t + D_{t+1} + Q_t B_{i,t+1} \quad (16)$$

Domestic banks have three sources of funds: (a) deposits from domestic households, D_{t+1} , (b) borrowing from global banks, $Q_t B_{i,t+1}$ where $B_{i,t+1}$ are loans from global banks denominated in foreign currency (c) net worth, N_t . They use these funds to make loans to intermediate firms at the price of the loan H_t .

Due to the absence of frictions between intermediate firms and banks, domestic intermediate firms obtain loans from bank at the end of period t, $H_t S_t^a$ and repay, $R_{k,t+1} H_t S_t^a$ at the end of period t+1 where $R_{k,t+1}$ is the real gross return of the loans or assets.

The banker's net worth or equity therefore evolves over time as

$$N_{t+1} = R_{k,t+1} H_t S_t^a - R_t D_{t+1} - R_{i,t} Q_{t+1} B_{i,t+1} \quad (17)$$

$$= [(R_{k,t+1} - R_t) H_t S_t^a + (R_t Q_t - R_{i,t} Q_{t+1}) B_{i,t+1} + R_t N_t] \quad (18)$$

We assume that a risk neutral banker gains utility from consumption of their accumulated net worth only when they cease to be a banker and become a worker. Thus, bankers maximize the expected present value of their net worth, given by

$$V_t = E_t \sum_{i=1}^{\infty} \beta^i (1 - \sigma) \sigma^{i-1} N_{t+i} \quad (19)$$

In order to limit bankers' ability to borrow funds from households, we assume the following moral hazard problem: the banker can divert a fraction κ_t of assets and transfer them to the household ⁸. If they do so, there is a forced bankruptcy and the creditors, domestic households and global banks seize the remaining portion, $1 - \kappa_t$ of assets. Following the approach of Aoki et al. (2016), we assume that the fraction of divertible assets depends on the sources of funds. In particular, we assume that it depends on global bankers' ability to divert global bank loans.

⁸In order to capture a loss of global financial market efficiency through a tightening of the leverage ratio as emphasized by Adrian & Shin (2008), Kiyotaki & Moore (2012), Perri & Quadrini (2011), Dedola & Lombardo (2012) and Dedola et al. (2013), we endogenize the agency cost parameters, κ_t .

$$k_t = k[1 + \varkappa \left(\frac{k_t^f}{k^f} - 1\right) + \frac{\varkappa}{2} \left(\frac{k_t^f}{k^f} - 1\right)^2] \quad (20)$$

where $\varkappa \equiv (1 - \rho^a)\Gamma$ measures the degree of home bias in banker's finance and consists of the degree of financial openness, $(1 - \rho^a)$ and banking system instability⁹, Γ . Thus, depositors and global banks will only supply funds if the banker has no incentive to divert funds, implying

$$V_t \geq \kappa_t H_t S_t^a \quad (21)$$

We can restate the expected present value of net worth at the end of period $t - 1$ recursively as

$$V_{t-1} = E_{t-1} \{ \beta(1 - \sigma)N_t + \beta\sigma \text{Max}[V_t(S_t^a, D_{t+1}, Q_t B_{i,t+1})] \} \quad (22)$$

From the definition of net worth in (17), we use the method of undetermined coefficients and guess that this value function is a linear function of assets, deposits and global bank funds.

$$V_t = V_{s,t} S_t^a - V_{b,t} D_{t+1} - V_{g,t} Q_t B_{i,t+1} \quad (23)$$

where $V_{s,t}$ is the marginal value from an additional unit of assets holding constant deposits and global bank funds and $V_{b,t}(V_{g,t})$ is the marginal cost of deposits (global bank funds). The banks choose S_t^a and $Q_t B_{i,t+1}$ in order to maximise $V_t(S_t^a, D_{t+1}, Q_t B_{i,t+1})$ subject to the incentive constraint and the bank's balance sheet constraint. The first order conditions with respect to S_t^a , $Q_t B_{i,t+1}$ and λ_t^a yield

$$\mu_t^a (1 + \lambda_t^a) = \lambda_t^a \kappa_t \quad (24)$$

$$V_{b,t} = V_{g,t} \quad (25)$$

$$H_t S_t^a \leq \frac{V_{b,t}}{(\kappa_t - \mu_t^a)} N_t \quad (26)$$

where λ_t^a is the Lagrangian multiplier with respect to the incentive constraint and $\mu_t^a = \frac{V_{s,t}}{H_t} - V_{b,t}$.

⁹The degree of banking system instability can be regarded as the degree of confidence in the financial crisis: in the crisis (a trigger), depositors and global banks believe that domestic bankers in unstable banking system, are more attractive to divert funds to themselves. The relationship between financial crisis and banking system stability has extensively analysed by Beck et al. (2006), De Jonghe (2010), Fu et al. (2014) and many others.

Equations (24) and (25) imply that the marginal value of assets is greater than the marginal cost of borrowing when the incentive constraint is binding $\lambda_t > 0$ or $\mu_t^a > 0$. According to equation (25), deposits and global bank funds are perfect substitutes. If the incentive constraint is binding, equation (26) can be written as

$$H_t S_t^a = \phi_t N_t \quad (27)$$

where $\phi_t = \left[\frac{V_{b,t}}{(\kappa_t - \mu_t^a)} \right]$ is the maximum leverage ratio. As Adrian & Shin (2008) point out, during downturns of foreign economy, banks can not roll over their debt from global banks since the confidence of foreign depositors and global banks is rapidly eroded. A fall in the price of assets leads to a fall in the value of loans funded. Net worth declines even faster and thus, the leverage ratio increases initially. Banks attempt to reduce the leverage by selling their assets and reducing loans to firms. Due to lower asset prices induced by fire sales of assets, their balance sheet is further deteriorated. In particular, banks in the small open economy have greater risk since their borrowers are substantially exposed to the global economy, generating a symmetric loss of domestic financial market efficiency. Thus, a sudden increase in κ_t due to an increase in the fraction of divertible global bank loans can be thought of as capturing some form of banks' fragility spilled over from a downturn of the global economy.

Combining (16) and (27) yields

$$D_{t+1} + Q_t B_{i,t+1} = (\phi_t - 1) N_t \quad (28)$$

Holding net worth constant, an increase in the ability to divert funds, κ_t reduces aggregate borrowing. Thus, the moral hazard problem leads to an endogenous financial constraint. Also, this equation implies that additional funds from global banks raises the leverage ratio for a given net worth.

We introduce time varying relative weights on borrowings between home deposits and global bank funds. For a given incentive constraint and aggregate borrowings, domestic banks choose optimal allocation of funds. Aggregate borrowings can be written as

$$B_{t+1}^{all} = D_{t+1} + Q_t B_{i,t+1} \quad (29)$$

defining ρ_t^a as the (time-varying) share of domestic deposits in total borrowing by domestic banks, then $D_{t+1} = \rho_t^a B_{t+1}^{all}$ and $Q_t B_{i,t+1} = (1 - \rho_t^a) B_{t+1}^{all}$.

The demand of domestic banks for domestic deposits and borrowing from global bank funds can be

obtained by combining (16),(27) and (29)

$$D_{t+1} = \rho_t^a (\phi_t - 1) N_t \quad (30)$$

$$Q_t B_{i,t+1} = (1 - \rho_t^a) (\phi_t - 1) N_t \quad (31)$$

Holding constant net worth and relative weights, an increase in the ability to divert borrowing (a reduction of the leverage) restricts demand for each type of borrowing.

Since we assume constant government spending and net profits from the ownership, combining (7), (14) and (30) yields a market clearing condition for deposits. Then, by rearranging and log linearizing this condition around the steady state, the time varying relative weight on deposits can be written as

$$\begin{aligned} \hat{\rho}_t^a = & \frac{1}{\beta \mathfrak{v}} [B_f (\hat{B}_{f,t} + \hat{R}_{t-1}^f) + D (\hat{D}_t + \hat{R}_{t-1})] + \hat{Q}_t \left(\frac{B_f}{\beta \mathfrak{v}} - \frac{B_f}{\mathfrak{v}} \right) - \left(\frac{B_f}{\mathfrak{v}} \right) \hat{B}_{f,t+1} \\ & + \left[\frac{WL}{\mathfrak{v}} (\hat{W}_t + \hat{L}_t) - \left(\frac{C}{\mathfrak{v}} \right) \hat{C}_t \right] - [\hat{N}_t + \left(\frac{\rho^a S^a}{\mathfrak{v}} \right) \hat{\phi}_t] \end{aligned} \quad (32)$$

where $\mathfrak{v} = \rho^a (S^a - N) > 0$. For a given net worth and the leverage or the value of assets, an increase in income from labour supply and gross return of assets, or a reduction of spending on current foreign assets and consumption raises the relative weights on deposits. This implies that as shown in equation (25), since deposits and global bank funds are perfect substitutes as sources of borrowing, domestic banks use global bank loans in order to supplement insufficient demand for aggregate borrowings after obtaining funds from domestic households who impose the incentive constraints. Conversely, for given deposits, an increase in net worth and the leverage ratio raises demand for aggregate borrowing and thereby increasing (lowering) the relative weights on global bank loans (deposits).

We can rewrite the value function by combining (16), (23) and (25) as

$$V_t = \mu_t^a H_t S_t^a + V_{b,t} N_t \quad (33)$$

Then, we can verify the linear value implied by the undetermined coefficients solution

$$R_t = R_{i,t} E_t \left(\frac{Q_{t+1}}{Q_t} \right) \quad (34)$$

$$V_{b,t} = E_t (\beta \Omega_{t+1}) R_t \quad (35)$$

$$\mu_t^a = E_t[\beta\Omega_{t+1}(R_{k,t+1} - R_t)] \quad (36)$$

where $\Omega_{t+1} = [(1 - \sigma) + \sigma(\mu_{t+1}^a\phi_{t+1} + V_{b,t+1})]$ is the present value of marginal net worth. From equation (34), a higher debt adjusted global bank interest rate and the real exchange rate depreciation is compensated by higher deposit rate. This also implies uncovered interest parity between deposits and global bank funds. According to equation (35), the marginal cost of deposits is the augmented stochastic discounted real deposit interest rate. Analogously, μ_{t+1}^a is the augmented stochastic discounted excess return to capital. Without the incentive constraint or financial frictions, bankers will borrow funds until the return to capital is equal to the deposit rate in the perfect capital market, $E_t(\beta\Omega_{t+1})R_{k,t+1} = E_t(\beta\Omega_{t+1})R_t$.

Aggregate net worth is the sum of the net worth of surviving bankers, $N_{s,t}$ and that of new bankers, $N_{n,t}$. Since the net worth of surviving bankers in the current period is a fraction, σ of the total net worth in the previous period, $N_{s,t} = \sigma Z_t N_{t-1}$ and the household transfers a fraction of assets to the new banker $N_{n,t} = \omega\phi_{t-1}N_{t-1}$, log linearizing aggregate net worth around the steady state gives

$$\hat{N}_t = (\sigma Z)\hat{N}_{s,t} + (1 - \sigma Z)\hat{N}_{n,t} \quad (37)$$

where $Z_t = \frac{N_t}{N_{t-1}} = [(R_{k,t} - R_{t-1})\phi_{t-1} + R_{t-1}]$ is the growth rate of net worth in period t

3.4.2 Global Banks

The global bank balance sheet is given by

$$H_t^f S_t^{fa} + B_{i,t+1}^f = N_t^f + D_{t+1}^f \quad (38)$$

A global banker's net worth evolves as

$$N_{t+1}^f = R_{k,t+1}^f H_t^f S_t^{fa} + R_{i,t} B_{i,t+1}^f - R_t^f D_{t+1}^f \quad (39)$$

We assume a global bank interest rate depends on the domestic banks' asset position, AP_t denominated in domestic currency: $\Xi_t = f(AP_t)$, with $f'(\cdot) > 0$. Global banks raise a premium as a fraction of foreign borrowing in total assets increase and require a premium above the riskless rate since they will not lend out funds for which the cost of borrowing is greater than the return of assets.

Thus, the global bank interest rate is determined by

$$R_{i,t} = R_t^f \Xi_t \quad (40)$$

Specifically, we assume $\Xi_t = e^{\Upsilon[(Q_t B_{i,t})/HS^a - QB_i/HS^a]}$ where $\Upsilon = \Upsilon^a(HS^a/QB_i)$ represent the degree of global banking sector imperfection. The log linearized global bank interest rate is given by

$$\hat{R}_{i,t} = \hat{R}_t^f + \Upsilon^a(\hat{Q}_t + \hat{B}_{i,t}) \quad (41)$$

By combining (34) and (41), we can show that the deviation from uncovered interest parity is also shown in terms of global banking sector imperfection

$$\hat{R}_t = [\hat{R}_t^f + \Upsilon^a(\hat{Q}_t + \hat{B}_{i,t})] + E_t(\widehat{\Delta Q}_{t+1}) \quad (42)$$

This equation implies that a higher global banking interest rate or an expected depreciation of the real exchange rate will be reflected in a higher domestic interest rate. Thus, Υ^a can be interpreted as the degree of deviation from uncovered interest parity.

Analogous to domestic bankers, the global banker faces the incentive constraint

$$V_t^f \geq \kappa_t^f (H_t^f S_t^{fa} + B_{i,t+1}^f) \quad (43)$$

We guess that the value function is a linear function of assets and deposits.

$$V_t^f = V_{s,t}^f S_t^{fa} + V_{i,t}^f B_{i,t+1}^f - V_{b,t}^f D_{t+1}^f \quad (44)$$

where $V_{s,t}^f$ and $V_{i,t}^f$ is the marginal value of loans to foreign intermediate firms and domestic banks and $V_{b,t}^f$ is the marginal cost of deposits.

The global banks choose S_t^{fa} and D_{t+1}^f in order to maximise the value function subject to the incentive constraint and the bank's balance sheet constraint. The first order conditions in terms of S_t^{fa} , D_{t+1}^f and λ_t^a yield

$$\frac{V_{s,t}^f}{H_t^f} = V_{i,t}^f \quad (45)$$

$$H_t^f S_t^{fa} + B_{i,t+1}^f = \phi_t^f N_t^f \quad (46)$$

where $\phi_t^f = \left[\frac{V_{b,t}^f}{(\kappa_t^f - \mu_t^{fa})} \right]$ is the maximum leverage ratio and we assume that stochastic foreign agency cost parameter follows an AR(1) process in logs, $\hat{\kappa}_t^f = \rho_k^f \hat{\kappa}_{t-1}^f + \varepsilon_{k,t}^f$.

The global banking asset clearing condition is given by

$$nB_{i,t+1} = (1-n)B_{i,t+1}^f \quad (47)$$

Due to a small open economy specification where n tends to zero, log linearizing (46) around the steady state yields

$$\hat{H}_t^f + \hat{S}_t^{fa} = \hat{\phi}_t^f + \hat{N}_t^f \quad (48)$$

Thus, a global banking asset market clearing condition coupled with the small open economy specification ensures that domestic banks in the small open economy can not influence global banks while the converse is not true.

We can rewrite the value function by combining (38),(44) and (45) as

$$V_t^f = \mu_t^{fa} (H_t^f S_t^{fa} + B_{i,t+1}^f) + V_{b,t}^f N_t^f \quad (49)$$

Then, we can verify the assumed linear value function by combining the conjectured value function with the Bellman equation

$$V_{b,t}^f = E_t(\beta \Omega_{t+1}^f) R_t^f \quad (50)$$

$$\mu_t^{fa} = E_t[\beta \Omega_{t+1}^f (R_{k,t+1}^f - R_t^f)] \quad (51)$$

A debt elastic global bank interest rate and the incentive constraint ensure excess returns on global bank loans over deposits, $E_t(\beta \Omega_{t+1}^f) R_{i,t} \geq E_t(\beta \Omega_{t+1}^f) R_t^f$. Without financial imperfections, the global bank rate is always equal to the foreign deposit rate.

The composition of aggregate net worth for global bankers is analogous to domestic banks.

3.5 The Goods Sector

The capital and intermediate goods sectors consist of a continuum of homogeneous firms. Domestic capital producing (intermediate) firms on the subinterval $[0, n]$ are located in the home country and foreign capital

producing (intermediate) firms on the subinterval $[n, 1]$ are located in the foreign country.

3.5.1 The Capital Goods Sector

Competitive capital producing firms produce new capital, I_t using final outputs and sell to intermediate firms at the price H_t . Following Christiano et al. (2005), producing new capital incurs investment adjustment costs which depends on the growth rate of investment, $f(\frac{I_t}{I_{t-1}})I_t$.

A capital producing firm maximizes the present value of discounted profits

$$E_t \sum_{t=0}^{\infty} \beta^t \{H_t I_t - [1 + f(\frac{I_t}{I_{t-1}})]I_t\} \quad (52)$$

Following Dedola et al. (2013), we assume the functional form for the investment adjustment costs to be, $f(\frac{I_t}{I_{t-1}}) \equiv \frac{\eta_i}{2} (\frac{I_t}{I_{t-1}} - 1)^2$ where η_i is the inverse elasticity of investment with respect to the price of capital.

The optimal decision of investment yields the capital supply function.

$$\hat{I}_t = (\frac{1}{1+\beta}) (\frac{1}{\eta_i} \hat{H}_t + \hat{I}_{t-1} + \beta \hat{I}_{t+1}) \quad (53)$$

Tobin's Q relation shows the positive relation between current investment and the price of capital goods.

The aggregate capital stock at the end of period t , S_t^a comprises new investment and the undepreciated capital stock.

$$S_t^a = (1 - \delta)K_t + I_t \quad (54)$$

where δ is the rate of depreciation and K_t is the capital stock after production.

Following Gertler et al. (2012), we introduce capital quality shocks.

$$K_{t+1} = \Psi_{t+1} S_t^a \quad (55)$$

3.5.2 The Intermediate Goods Sector

The production function of a representative domestic intermediate firm is

$$Y_{m,t} = A_t K_t^{\alpha^p} L_t^{1-\alpha^p} \quad (56)$$

where $Y_{m,t}$ is intermediate output and α^p is effective capital share. A_t is an intermediate sector total factor productivity shock.

The real profit of the intermediate firm is given by

$$Profit_{m,t} = P_{m,t}Y_{m,t} + H_t(1 - \delta)K_t - R_{k,t}H_{t-1}S_{t-1}^a - W_tL_t \quad (57)$$

The intermediate firm sells intermediate goods, $P_{m,t}Y_{m,t}$ where $P_{m,t}$ is the real price of intermediate goods, and undepreciated capital to retail firms, $H_t(1 - \delta)K_t$. Also, the firm pays real wage, W_t to workers.

The firm chooses labour inputs and capital in order to maximize real profit subject to the production function.

$$\frac{(1 - \alpha^p)P_{m,t}Y_{m,t}}{L_t} = W_t \quad (58)$$

$$R_{k,t} = \frac{\Psi_t}{H_{t-1}}[M_t + H_t(1 - \delta)] \quad (59)$$

where $M_t = \frac{\alpha^p Y_{m,t} P_{m,t}}{K_t}$ is the gross production profit.

3.5.3 Retail Goods Sector

We assume monopolistic retail firms in order to introduce sticky prices. Retailers purchase intermediate goods from intermediate firms and costlessly diversify them. Then, it sells to households, government and capital producing firms.

Final total domestic output, Y_t is a CES composite of a continuum of retail goods.

$$Y_t = \left[\left(\frac{1}{n}\right)^\frac{1}{\varepsilon} \int_0^n Y_{h,t}(r)^\frac{\varepsilon - 1}{\varepsilon} dr \right]^\frac{\varepsilon}{\varepsilon - 1} \quad (60)$$

where $Y_{h,t}(r)$ is the output of retailer r and ε is the elasticity of substitution between goods from the same country. The cost minimizing decision of final output users leads to the demand function

$$Y_{h,t}(r) = \left(\frac{1}{n}\right) \left(\frac{P_{h,t}(r)}{P_{h,t}}\right)^{-\varepsilon} Y_t \quad (61)$$

A randomly selected proportion $1 - \theta$ of retail firms sets new price, $\bar{P}_{h,t}$ each period while a fraction θ partially index to lagged domestic inflation following Christiano et al. (2005). Since firms who can set a new price in period t do not know when they will next be able to reset their price, they maximize the expected

present value of discounted profits, given by

$$E_t \sum_{i=0}^{\infty} (\beta\theta)^i [Y_{h,t+i}(r) \frac{\bar{P}_{h,t}}{P_{h,t+i}} \prod_{k=1}^i \pi_{h,t+k-1}^{\zeta} - TC_{h,t+i}(Y_{h,t+i}(r))] \quad (62)$$

subject to the sequence of demand functions

$$Y_{h,t+i}(r) \leq \left(\frac{1}{n}\right) \left(\frac{\bar{P}_{h,t}}{P_{h,t+i}}\right)^{-\varepsilon} Y_{t+i} \quad (63)$$

where $TC_{h,t+i}(Y_{h,t+i}(r))$ is the real total cost induced by purchasing intermediate goods. The first order condition yields

$$E_t \sum_{i=0}^{\infty} (\beta\theta)^i \left[\frac{\bar{P}_{h,t}}{P_{h,t+i} P_{h,t-1}} \prod_{k=1}^i \pi_{h,t+k-1}^{\zeta} - \Theta \frac{P_{m,t+i}}{P_{h,t-1}} \right] Y_{h,t+i}(r) = 0 \quad (64)$$

where $\Theta = \frac{\varepsilon}{\varepsilon - 1}$ is the markup of price over marginal cost in steady-state and ζ measures indexation to past inflation. Real marginal cost is simply equal to the real price of intermediate goods.

The domestic price index is given by $P_{h,t} = [\theta(\pi_{h,t-1}^{\zeta} P_{h,t-1})^{1-\varepsilon} + (1-\theta)\bar{P}_{h,t}^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}}$, which, when log linearized around the steady state yields $\hat{\pi}_{h,t} = (1-\theta)(\bar{P}_{h,t} - \hat{P}_{h,t-1}) + \theta\zeta\hat{\pi}_{h,t-1}$. Combining this with the log linearized optimal price setting strategy, we obtain the marginal cost based New Keynesian Philips curve expressed in terms of domestic inflation

$$\hat{\pi}_{h,t} = \frac{\zeta}{1+\zeta\beta} \hat{\pi}_{h,t-1} + \frac{\beta}{1+\zeta\beta} E_t(\hat{\pi}_{h,t+1}) + \frac{1}{1+\zeta\beta} \varpi \hat{P}_{m,t} \quad (65)$$

where $\varpi = \frac{(1-\beta\theta)(1-\theta)}{\theta}$. The log linearized CPI index in equation (6) is

$$\hat{\pi}_t = \lambda \hat{\pi}_{h,t} + (1-\lambda) \hat{\pi}_{f,t} \quad (66)$$

Thus, CPI inflation is a function of past and expected future domestic inflation, the price of intermediate goods and imports.

3.6 Resource Constraint, Net Exports and Monetary Policy

Final domestic output consists of consumption of domestic goods in both countries¹⁰, investment expenditures and government consumption.

$$Y_t = C_{h,t} + C_{h,t}^f + [1 + f(\frac{I_t}{I_{t-1}})]I_t + G_t \quad (67)$$

Domestic net exports, NX_t are defined as

$$NX_t = C_{h,t}^f - (\frac{P_{f,t}}{P_{h,t}})C_{f,t} \quad (68)$$

We assume that policy makers follow a Taylor-type interest rate rule. Let i_t be the nominal interest rate which link to the real interest rate by the Fisher equation, $\hat{i}_t = \hat{R}_t + E_t(\hat{P}_{t+1} - \hat{P}_t)$.

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1 - \rho_i)(\rho_\pi \hat{\pi}_t + \rho_y \hat{Y}_t) + \varepsilon_{m,t} \quad (69)$$

where ρ_i represents the degree of interest rate smoothing and $\varepsilon_{m,t}$ is an exogenous shock to monetary policy.

3.7 Credit Policy

Following Gertler & Karadi (2011) and Gertler et al. (2012), we assume that the central bank implements credit policy by purchasing domestic private securities in a financial crisis. In addition to a feedback rule according to domestic credit spread $\zeta_{d,t}$, we introduce an alternative feedback rule according to international credit spread $\zeta_{i,t}$ since the financial crisis in a small open economy can be characterised by an increase in both domestic and international credit spread

$$\zeta_{d,t} = \zeta + \vartheta[E_t(R_{k,t+1} - R_t) - (R_k - R)]; \quad \zeta_{i,t} = \zeta + \vartheta[E_t(R_{k,t+1} - R_{i,t}) - (R_k - R_i)] \quad (70)$$

where ζ is the steady state fraction of assets intermediated by the central bank and ϑ is the value of the feedback coefficient. While the feedback rule according to domestic credit spread eliminates financial imperfections, the latter additionally eliminates global relative price effects which influence the real interest rate and consumption. As implied by the UIP, the risk sharing and perfect capital market conditions, the perfect risk sharing without global relative price effects can be achieved by targeting international credit spread. As in Gertler et al. (2012), we also introduce quadratic costs to credit policy and have government

¹⁰Consumption clearing condition in open economies, can be shown as $C_t = C_{h,t} + C_{f,t}$ and thus, consumption is not directly presented in the resource constraint.

expenditures as

$$G_t = G + \tau_1 H_t S_{g,t}^a + \tau_2 (H_t S_{g,t}^a)^2 \quad (71)$$

where $S_{g,t}^a = \zeta_t S_t^a$ denotes assets intermediated by the central bank and $\zeta_t \in \{\zeta_{d,t}, \zeta_{i,t}\}$. Assets intermediated by the central bank are not constrained. With credit policy and efficiency costs, the consolidated government and central bank budget constraint can be rewritten as

$$G_t + R_{t-1} B_t + H_t S_{g,t}^a = T_t + B_{t+1} + R_{k,t} H_{t-1} S_{g,t-1}^a \quad (72)$$

4 Model Analysis

4.1 Parameterization

We choose fairly conventional values of parameters as set out in Table 1. β is set equal to 0.99 and thus in steady state $\beta = 1/R$ which implies a riskless steady state real annual return of approximately 4%. Following Benigno (2009), the costs of adjusting bond holding is set as $\chi = 0.012$. The elasticity of substitution between home and foreign tradable goods and between same category are set as $\eta = 1.5$ and $\varepsilon = 4.167$ respectively. This calibration assumes common values of the risk aversion, $\rho = 1$ and the inverse Frisch labour supply elasticity $\varphi = 0.276$. The government share of GDP is set to $G/Y = 0.2$. The probability of not being able to set a new price is set equal to 0.75 which implies an average of four periods between price adjustment. The capital share in production and depreciation rate are set as $\alpha^p = 0.33$ and $\delta = 0.025$. Since the efficiency costs of credit policy are likely to be less than 10 basis points per year as Gertler et al. (2012) point out, the costs are set as $\tau_1 = 0.000125$ and $\tau_2 = 0.0012$. Following García-Cicco et al. (2010), the degree of global banking sector imperfection is set such that in the steady state, a 1% increase in global bank debt as a share of assets raises the spread between global bank interest rate and foreign riskless rate by around 0.5% which implies $\Upsilon = 2.22$. We choose conventional Taylor rule parameters for the inflation coefficient $\rho_\pi = 1.5$ and the output coefficient $\rho_y = 0.125$.

In terms of the financial sector parameters, following Gertler & Kiyotaki (2010, 2015), Gertler & Karadi (2011) and Dedola et al. (2013) among others, we choose the steady state leverage ratio and interest rate spread as $\phi = 4$ and $R_k - R = 0.0025$ which implies an average annual credit spread of 100 basis points. The survival rate of bankers is set $\sigma = 0.972$ which implies an average tenure of bankers is around 8 years. These

Table 1: Parameters

Households		
Discount rate	β	0.99
Risk aversion	ρ	1
Inverse Frisch elasticity of labour supply	φ	0.276
Habit parameter	h	0.815
Relative utility weight of labour	\mathfrak{R}	3.409
Costs of adjusting the bond holdings	χ	0.012
Degree of trade openness (unless specified otherwise)	α	0.3
Elast. of substitution $C_{h,t}$ and $C_{f,t}$	η	1.5
Elast. of substitution individual varieties	ε	4.167
Banks		
Steady state leverage	ϕ	4
Steady state premium	$R_k - R$	0.0025
Steady state relative share of deposits	ρ^d	0.7
Survival rate of bankers	σ	0.972
Divertible fraction	κ	0.3847
Starting up transfer	ω	0.0021
Degree of global banking sector imperfection	Υ	2.22
Degree of banking system instability (unless specified otherwise)	Γ	3.3
Efficiency costs of credit policy	$\tau_1(\tau_2)$	0.000125 (0.0012)
Intermediate good firms		
Effective capital share	α^p	0.33
Depreciation rate	δ	0.025
Persistence capital quality shock	ρ_ψ	0.66
Capital producing firms		
Inverse elasticity of net investment to the price of capital	η^i	1.728
Degree of price stickiness	θ	0.75
Government		
Government share of GDP	G/Y	0.2
Inflation coefficient of the Taylor rule	ρ_π	1.5
Output coefficient of the Taylor rule	ρ_y	0.125

target values help to pin down parameters for the divertible fraction $\kappa = 0.3847$ and the start up transfer $\omega = 0.0021$. The steady state relative share of deposits in total borrowings is assumed to be $\rho^a = 0.7$.

4.2 Impulse Response Analysis

We calibrate the size of foreign financial shocks (i.e., twenty six standard deviation shocks to stochastic agency cost parameter) in order to obtain broadly similar magnitude to a global financial crisis in the small open economies. Specifically, foreign financial shocks capture main features of the global financial crisis for both small and (large) foreign economies. In order to focus on the small open economy having different degree of trade openness and banking system stability, we do not show impulse responses for the foreign economy. For conventional experiment of capital quality shocks, we consider the impact of five standard deviation shocks to capital quality when both countries follow the Taylor-type interest rate rule. We then look at the role of domestic central bank's monetary and credit policy.

Figure 2 shows the behaviour of the small open economy in response to an unexpected increase in foreign agency cost. In order to explore country differences in response to the shocks, we set different parameter values in terms of the degree of trade openness and banking system instability (i.e., $\alpha = 0.3$ and $\Gamma = 3.3$ (calibrated for a small open economy with unstable banking system such as Korea) vs $\alpha = 0.4$ and $\Gamma = 2.7$ (calibrated for a small open economy with stable banking system and high degree of trade openness such as Canada)). Also, in order to explore the behaviour of a small open economy influenced only by indirect effects of the shocks, we show the impulse responses for the economy with $\Gamma = 0$. We assume that the shocks follow a first-order auto-correlation process that persist at the rate of 0.8 per quarter.

As for the economies with $\Gamma \neq 0$, The foreign financial shocks directly lowers supply of domestic banks' loans from global banks¹¹ thereby reducing funds to non-financial firms due to the incentive constraint. While global bank loans denominated in foreign currency decline at first, contracting credit flows through the balance sheet of domestic banks, deposits from domestic households slowly fall by nearly 10% with second round effects of lowered income of households and real interest rate. The shocks lead to a depreciation of the real exchange rate but it also lowers foreign aggregate demand, partially offsetting an increase in net exports and the impact of drop in global bank loans denominated in foreign currency. Since banks are leveraged, the impact of a decline in net worth is enhanced by the higher leverage ratio. Banks require intermediate firms to pay a higher risk premium over the riskless rate. This in turn, raises the cost of capital thereby contracting

¹¹Global bank loans are denominated in foreign currency in figures

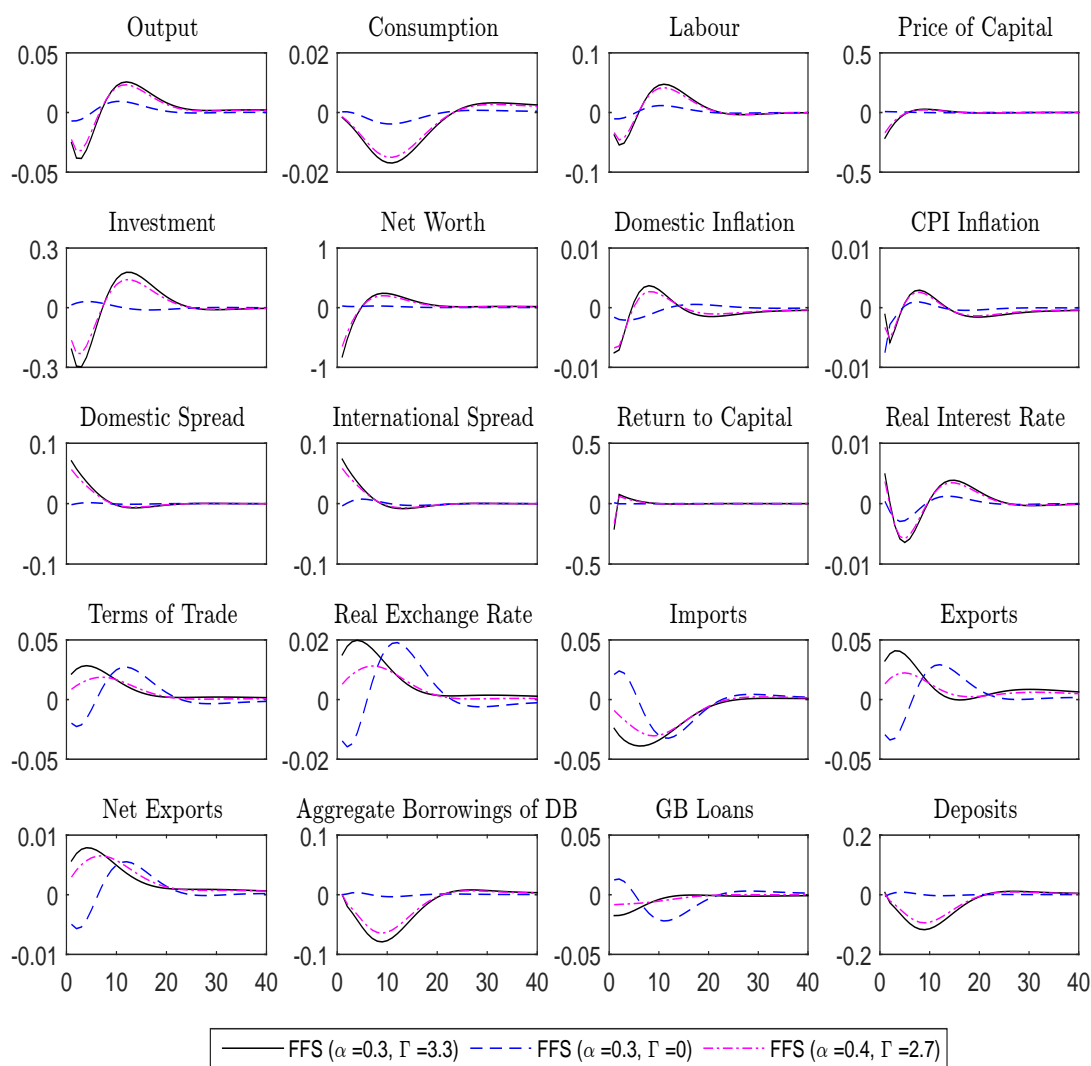


Figure 2: Impulse Responses to Financial Shocks under a Taylor-Type Interest Rate Rule

NOTE: FFS, DB and GB refer to foreign financial shocks, domestic bank and global bank, respectively.

investment and output. A fall in domestic inflation coupled with a fall in foreign inflation pulls down CPI inflation as small open economies experienced in the global financial crisis. The economy with greater trade openness is more influenced from lower foreign demand and price of imports so that CPI inflation is further reduced. A deterioration of global financial market efficiency generates amplified impact on the domestic economy through a sharp increase in the real cost of global bank loans, domestic and international credit spread, and a fall in asset prices. Thus, this reduces domestic labour, consumption and output. Since the economy with greater trade openness also has higher banking system stability, it has less severe influence on

consumption, credit spread, investment and price of capital. However, it suffers from lower foreign demand and a small increase in net exports and this in turn, generates a symmetric fall in output.

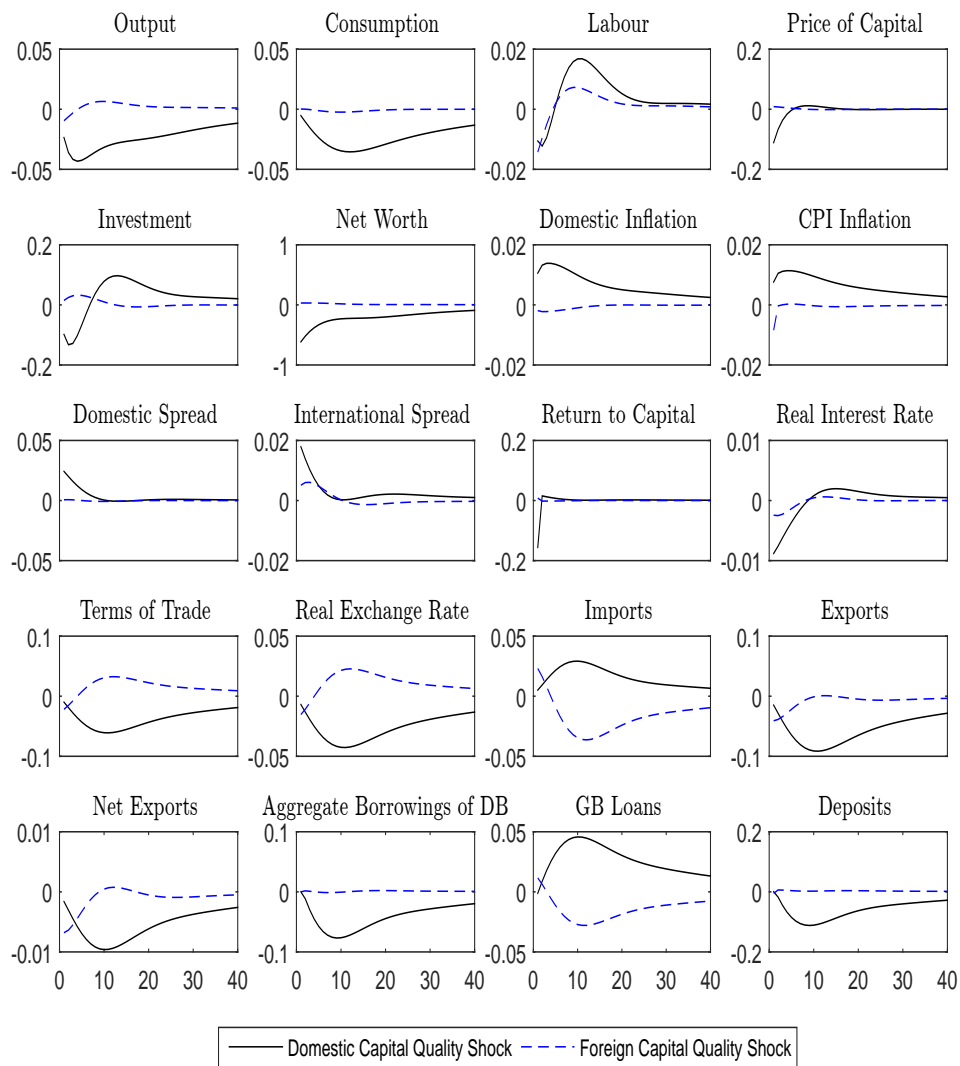


Figure 3: Impulse Responses to Capital Quality Shocks under a Taylor-Type Interest Rate Rule

NOTE: DB and GB refer to capital quality, small open economy, foreign economy, domestic bank and global bank, respectively.

Intermediate firms reduce demand for capital and labour, which depresses the production factor prices, real marginal costs and domestic inflation. Lower prices of domestic goods and a depreciation of the nominal exchange rate leads to a depreciation of the terms of trade and the real exchange rate, raising exports and depressing imports from the foreign country. Thus, depreciation of the terms of trade partially alleviates the

impact of the financial shock.

Turning to the economy influenced only by indirect effects of the shocks (i.e., $\Gamma = 0$), the foreign financial shocks have identical effects on the foreign economy. Thus, lower foreign inflation leads to appreciation of the terms of trade and the real exchange rate thereby increasing imports and reducing exports to foreign country. Along with lower foreign demand, this reduces net exports, production inputs, consumption and output. The lower risk adjusted global bank interest rate partially alleviates the deterioration of credit flows. However, the shocks have a limited impact on the balance sheet of domestic banks due mainly to the appreciation of the real exchange rate. This implies that the direct channels through the deterioration of global financial market efficiency plays a major role in the global financial crisis. Notice that the dynamics of the small open economy with different degree of trade openness and banking system stability in response to foreign financial shocks through the direct and indirect channels broadly mimic financial crisis in the small open economies spilled over from foreign country and capture key features of cross-border spillovers across countries.

Figure 3 shows the impact of negative domestic and foreign capital quality shocks on the small open economy with baseline calibrations. The shocks follow a first-order auto-correlation process that persist at the rate of 0.66 per quarter. Domestic capital quality shocks directly reduce the supply of domestic banks' loans from domestic households and global banks through the lower quantity of capital. In particular, deposit contractions of more than 10% may trigger bank runs. Intermediate firms reduce demand for capital and labour. In the second round, this further depresses asset values and domestic banks' net worth sharply declines by nearly 50%. Lower net worth generates analogous mechanisms as financial shocks. However, since capital quality shocks directly affect the capital accumulation equation and the production function, lower output coupled with lower wage incomes and labour moderately reduce real marginal cost. Due to a dominant role for forward-looking behaviour in the price setting, domestic and CPI inflation increase and this in turn leads to an appreciation of the terms of trade and the real exchange rate.

Foreign capital quality shocks appreciate the terms of trade and the real exchange rate thereby reducing net exports. Since foreign demand falls significantly, an appreciation of the terms of trade further reduces exports. Correspondingly output and demand for factor inputs falls. Lower prices of imports further pull down the overall price level and reduce the real interest rate, helping the small economy to be less susceptible to foreign capital quality shocks. An appreciation of the real exchange rate effectively reduces the real cost of global bank loans. This in turn increases credit flows through the domestic banks' balance sheet and

coupled with a decrease in foreign real interest rate, the global bank interest rate falls.

However, domestic and foreign capital quality shocks do not explain main features of the small open economy in the financial crisis and this in turn implies that negative spillovers from foreign countries occur through the foreign financial shocks.

4.3 Credit and Monetary Policy

In the global financial crisis from foreign financial shocks, the central bank may further reduce the nominal interest rate by deviating from the conventional Taylor interest rate rule (a 50 basis point decrease in $\varepsilon_{m,t}$) if the nominal interest does not reach the zero lower bound. Alternatively, the central bank may follow moderate credit policy rules ($\vartheta = 10$) by purchasing private assets along with conventional monetary policy.

Figure 4 and 5 represent the responses of key variables in response to foreign financial shocks¹² in the small open economy with different degree of trade openness and banking system stability. We investigate the role of the credit policy and the expansionary monetary policy in response to foreign financial shocks. Also, we show the effect of moderate foreign credit policy (i.e., $\vartheta^f = 10$) in order to explore international spillovers of foreign credit policy.

Domestic Credit policy offsets the impact of foreign financial shocks by directly injecting credit flows to intermediate firms so that foreign financial shocks can be effectively eliminated by credit policy. In particular, a feedback rule with international credit spread outperforms a rule with domestic credit spread since the former additionally eliminates global relative price effects in the risk sharing and allows an appreciation of the real exchange rate. This in turn reduces the real cost of global bank loans and increases consumption, price of assets, investment and output further. Foreign credit policy increases foreign aggregate demand and coupled with the depreciation of the real exchange rate, this raises domestic output and consumption mainly through the risk sharing condition and an increase in net exports. However, the depreciation also raises CPI inflation (a volatility of CPI inflation) and capital outflows due to an increase in the real cost of global bank loans. This in turn, reduces price of capital (increases a volatility of capital prices) and investment, and distorts domestic financial markets.

When there is an unexpected fall in the nominal interest rate, the small open economy recovers slowly from the shocks. A lower real interest rate increases consumption slowly with habit persistence but reduces

¹²We do not investigate the effects of credit and monetary policy in response to domestic or foreign capital quality shocks since the shocks do not capture main features of the global financial crisis in the small open economy. Instead, we focus on the role of (domestic and foreign) credit and monetary policy in response to foreign financial shocks.

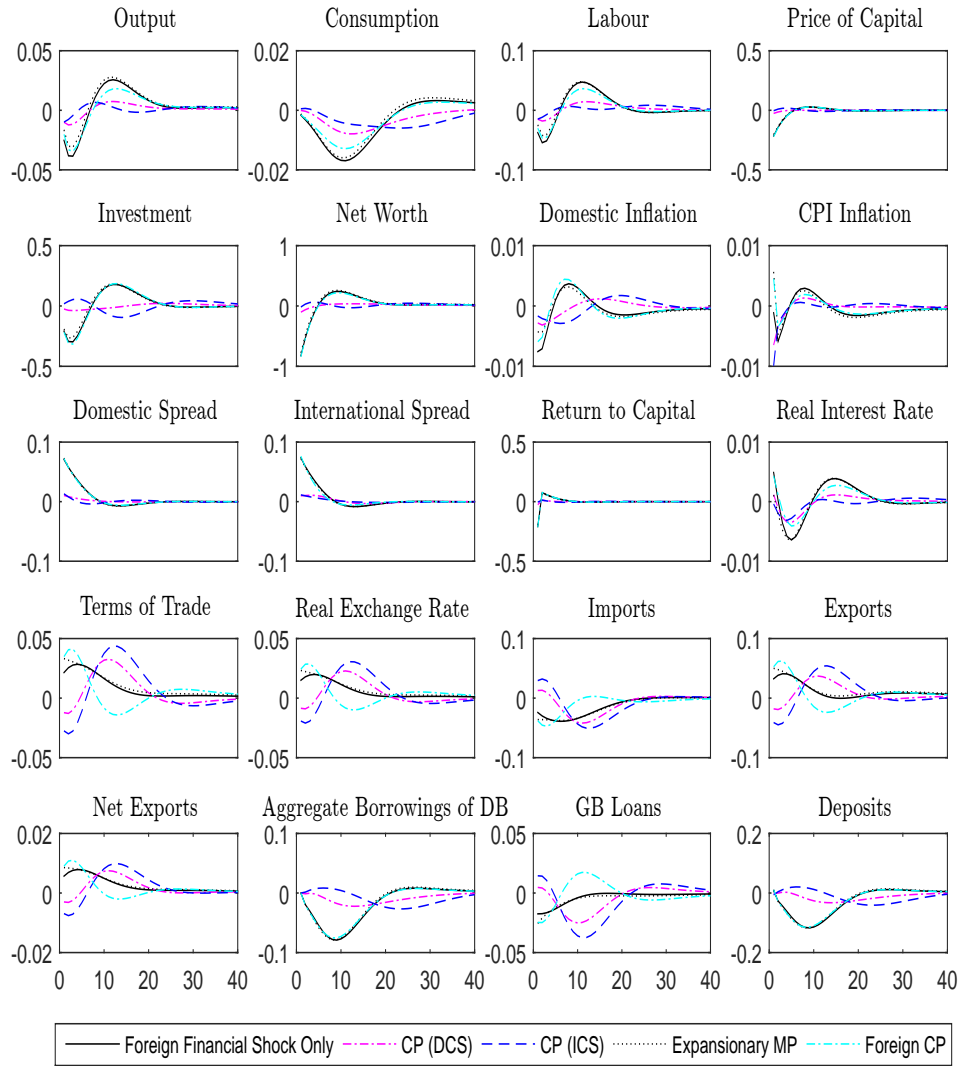


Figure 4: Credit Policy and Monetary Policy Under Foreign Financial Shocks, $\alpha = 0.3, \Gamma = 3.3$

NOTE: DB, GB, CP, DCS, ICS and MP refer to domestic bank, global bank, credit policy, domestic credit spread, international credit spread and monetary policy, respectively.

domestic deposits. Due to the depreciation of the real exchange rate which increases real cost of global bank loans, global bank loans denominated in foreign currency decline. Intermediate firms raise demand for capital and labour thereby increasing the production factor prices and domestic inflation. A depreciation of the nominal exchange rate leads to depreciation of the terms of trade and the real exchange rate and correspondingly, net exports increase and this further leads to expansion of domestic production. Thus, the expansionary monetary policy helps the economy to recover through lower real interest rates and a sharp

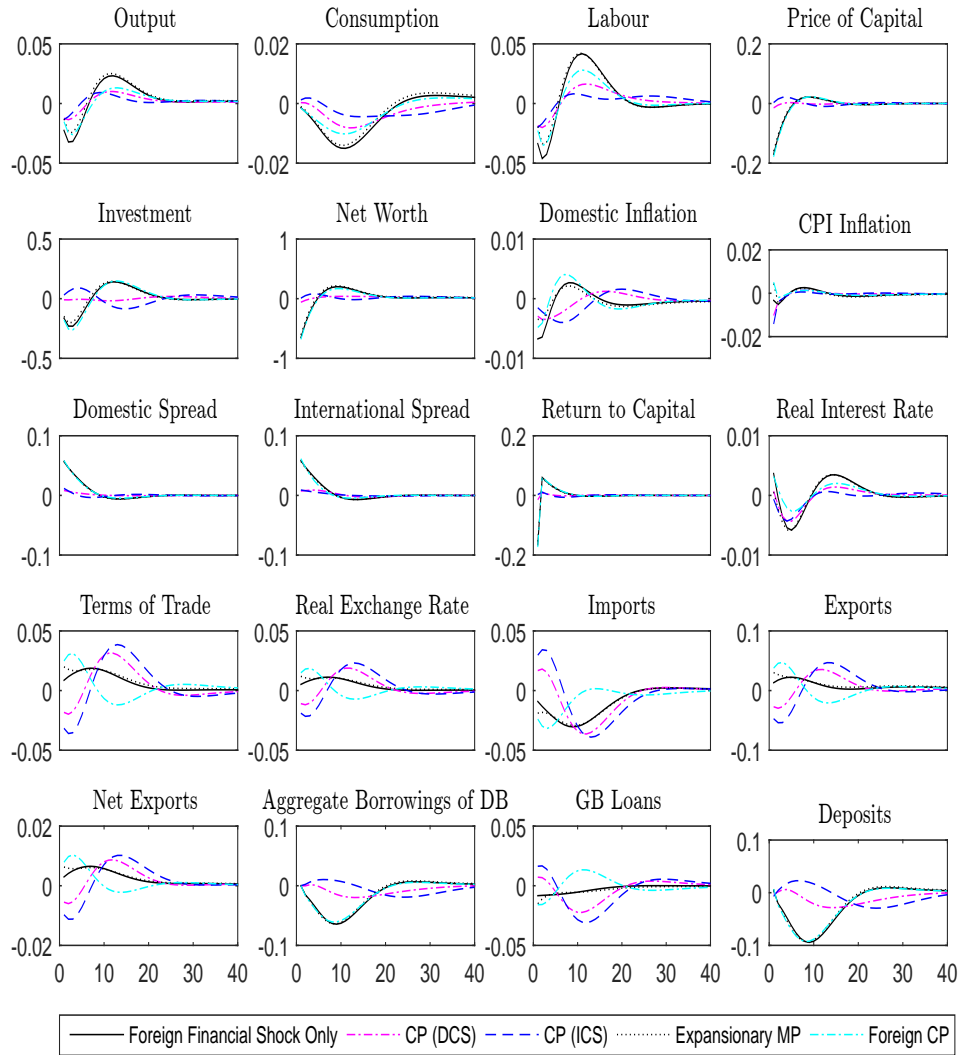


Figure 5: Credit Policy and Monetary Policy Under Foreign Financial Shocks, $\alpha = 0.4, \Gamma = 2.7$

NOTE: DB, GB, CP, DCS, ICS and MP refer to domestic bank, global bank, credit policy, domestic credit spread, international credit spread and monetary policy, respectively.

depreciation of the terms of trade and the real exchange rate. However, it does not provide sufficient remedy for the global financial crisis and amplifies capital flight. Thus, it appears that credit policy offers a better way of responding to foreign financial shocks. Notice that regardless of different parameter values given, credit policy based on international credit spread outperforms the monetary policy and credit policy based on domestic credit spread without foreign credit policy.

Now, we consider welfare gains and losses associated with domestic and foreign credit policy, and

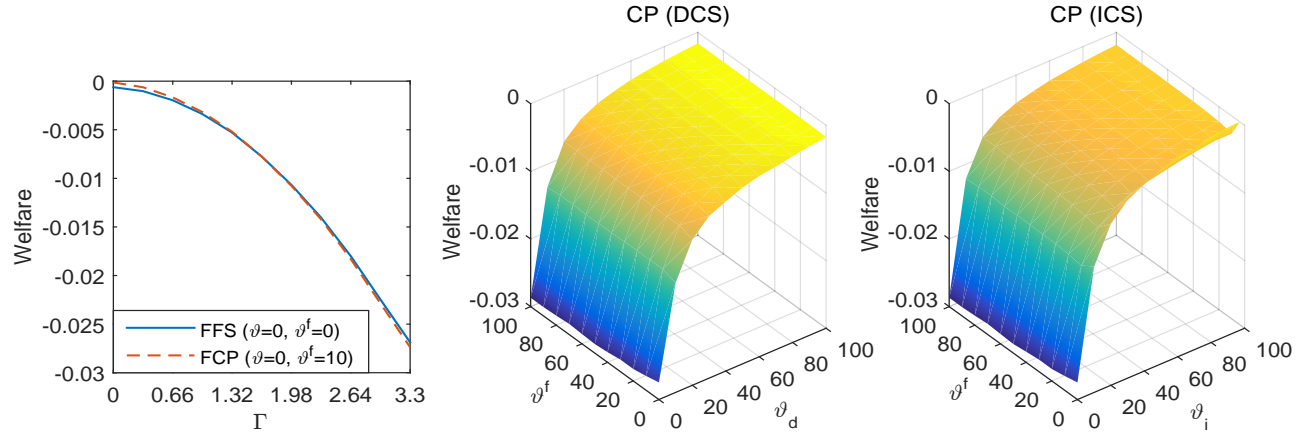


Figure 6: Welfare Analysis of Credit Policy according to Foreign Credit Policy

NOTE: FFS, FCP, CP, DCS and ICS refer to foreign financial shocks, foreign credit policy, credit policy, domestic credit spread and international credit spread, respectively.

financial imperfections in response to foreign financial shocks. We take a second order approximation of the whole non-linear model around the steady state and thus, all values are expressed as percentage units of steady state consumption.

Figure 6 illustrates welfare gains and losses of foreign credit policy according to Γ , and domestic credit policy according to domestic and foreign credit policy coefficients (i.e., ϑ and ϑ^f). Surprising result is that without domestic credit policy, an increase in ϑ^f can reduce the domestic welfare. As explained, while foreign credit policy raises net exports, output and consumption, it also leads to capital flights, an increase in the real cost of global bank loans, and more volatile CPI inflation. Specifically, foreign credit policy reduces the welfare for high values of $\Gamma \geq 1.98$ but for every values of Γ , it has a negligible influence on the domestic welfare. Since higher values of ϑ (ϑ_d and ϑ_i) monotonically increase the welfare regardless of the value of ϑ^f , the small open economy can effectively reduce welfare losses from the shocks only if the economy conducts its own credit policy.

Figure 7 shows the welfare gains from credit policy according to the feedback parameter, the degree of trade openness and the degree of banking system instability. Firstly, notice that the shocks reduce the welfare by 2.7% of steady state welfare per period without credit policy. While an increase in the feedback coefficient monotonically increase the welfare, a welfare gap between the coefficients with international credit spread and those with domestic credit spread broadens by 0.33% as the coefficients increase. However, when the foreign central bank injects credit, benefits from the credit policy based on international credit

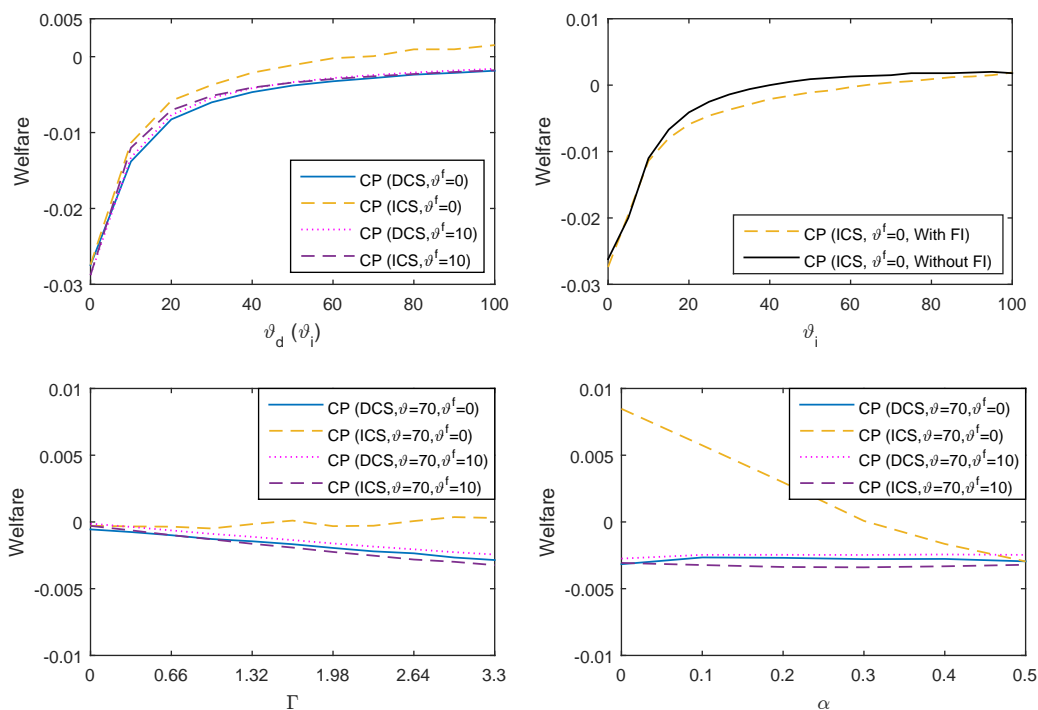


Figure 7: Welfare Analysis of Credit Policy

NOTE: CP, DCS, ICS and FI refer to credit policy, domestic credit spread, international credit spread and financial imperfection, respectively.

spread become small. Importantly, given the domestic credit policy based on international credit spread, foreign credit policy functions as financial market distortions, reducing domestic welfare and showing a substantial welfare gap between international credit spread rules with and without foreign credit policy. In other words, while foreign credit policy reduces domestic welfare losses through the indirect channels, it distorts domestic financial markets through the direct channels and this dominates positive spillovers of foreign credit policy. As for financial imperfections (i.e., $\Upsilon \neq 0, \chi \neq 0$), the imperfections reduce the welfare approximately by 0.1% without credit policy and 0.2% with credit policy based on international credit spread for the values of $20 \leq \vartheta_i \leq 80$. Thus, financial imperfections amplifies welfare losses in the crisis and deteriorates effectiveness of credit policy. Turning to Γ and α , international credit spread rules outperform domestic credit spread rules for various parameter values given and thus, our results are invariant with respect to the parameter values given when $\vartheta^f = 0$. Under the international credit spread rules and $\vartheta^f = 0$, an increase (decrease) in Γ (α) monotonically raises the welfare gap so that the economy with higher (lower) degree of banking system instability (trade openness) benefits more from the rules.

Table 2: Evaluation of Monetary Policy Rules

ρ_J	Alternative Taylor-Type Rules					
	Y	Q	H	DCS	ICS	MU
0	-0.0293	-0.0293	-0.0293	-0.0293	-0.0293	-0.0293
0.025	-0.0287	-0.0290	-0.0278	-0.0284	-0.0284	-0.0288
0.075	-0.0278	-0.0285	-0.0260	-0.0270	-0.0270	-0.0281
0.125	-0.0274	-0.0283	-0.0257	-0.0263	-0.0263	-0.0276
0.175	-0.0272	-0.0285	-0.0260	-0.0261	-0.0260	-0.0273
0.225	-0.0273	-0.0293	-0.0272	-0.0266	-0.0263	-0.0271

NOTE: DCS, ICS and MU refer to domestic credit spread, international credit spread and mark-up, respectively.

The central bank may not be able to resort to credit policy in the global financial crisis and thus, we evaluate various types of monetary policy rules associated with the welfare. Specifically, the different types of CPI inflation-based Taylor rules follow

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1 - \rho_i)(\rho_\pi \hat{\pi}_t + \rho_J \hat{J}_t) \quad (73)$$

where $J \in \{Y, Q, H, DCS, ICS, MU\}$.

Table 2 reports welfare losses in response to the shocks for the different types of the Taylor rules when $\vartheta = 0$ and $\vartheta^f = 0$. Under the conventional Taylor coefficients, $\rho_J = 0.125$, the Taylor rules with price of capital, domestic credit spread (DCS) and international credit spread (ICS) outperform the Taylor rules with output, real exchange rate and mark-up (MU). In particular, the price of capital based Taylor rule reduces the welfare losses by 0.17% per period, compared with the output based Taylor rule. Also, welfare losses of the output based rule show a reverted U-shape, reaching a pick at around $\rho_Y = 0.175$. This implies that the expansionary monetary policy provides an insufficient remedy¹³. Thus, in the global financial crisis, “*leaning against the wind*” monetary policy,¹⁴ reducing interest rates when asset prices fall, can be the best alternative policy by stabilizing fluctuations of asset prices if the central bank is unable to resort to credit policy while it still has a limited capacity to alleviate the crisis.

¹³In fact, the expansionary monetary policy decreasing a 50 basis point in $\varepsilon_{m,t}$ reduces welfare losses approximately by 0.14% when $\vartheta = 0$ and $\vartheta^f = 0$.

¹⁴The role of monetary policy associated with asset prices has been analysed by Bernanke & Gertler (1999), Gilchrist & Leahy (2002), Galí (2014) and many others.

5 Concluding Remarks

In this paper, we have developed a small open economy DSGE model with financial intermediaries and a global banking system where domestic banks can obtain additional funds from global banks thereby exposing to the currency risk. Then, we have assessed quantitatively how domestic and foreign shocks (financial and capital quality shocks) affect the small open economy, and evaluated the effects of credit policy based on domestic and international credit spread, and an expansionary monetary policy in order to combat a financial crisis. Three main findings stand out.

Firstly, foreign financial shocks capture cross-border spillovers in the small open economy rather than foreign capital quality shocks. In particular, the shocks mimic a global financial crisis in the small open economy : (a) contractions of output and investment, (b) decline in the net worth and asset prices, (c) a fall in CPI inflation, (d) reversals of international capital flows in terms of an increase in net exports and drops of global bank loans, (e) a depreciation of the terms of trade and the real exchange rate. Also, we show that country differences in the severity of the shocks depend on the degree of trade openness and banking system stability.

Secondly, credit policy could be more powerful than the monetary policy to alleviate foreign financial shocks since the monetary policy does not provide a sufficient remedy. In particular, credit policy according to international credit spread outperforms credit policy according to domestic credit spread since the latter leads to “excess smoothness” in the real exchange rate and interrupts a role of the exchange rate as a foreign financial shock absorber.

Lastly, foreign credit policy has a negligible influence on domestic welfare so that the small open economy can effectively reduce welfare losses only if the central bank in the economy expands credit regardless of foreign credit policy. We interpret this consideration as credit policy in the small open economy could be the first best rather than the second best policy by the zero lower bound constraint of the nominal interest rate in the financial crisis.

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