A monetary policy accordion: Why do central banks from different countries expand and contract together?

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Abstract

During recent decades the monetary policies of central banks in emerging economies have shown significant co-movement mostly led by the policy changes of major countries such as the US. To understand this "monetary policy accordion" we develop a small open economy dynamic stochastic general equilibrium (DSGE) model that incorporates an agency problem in the banking sector. The home monetary policy is modelled as a standard inward looking Taylor rule. Our estimated model based on South Korean data suggests that the relationship between foreign and home monetary policies arises from the external terms of trade channel. A foreign interest rate shock influences the external terms of trade via the modified uncovered interest rate parity condition. The resulting fluctuations of the terms of trade impact home output and inflation via the expenditure switching effect, and as a result the home central bank adjusts interest rates according to the Taylor rule. The relationship between home and foreign rates becomes stronger when (a) the international assets transaction cost is lower, (b) openness of the home country is higher, (c) the home central bank is more aggressive in fighting inflation, (d) the home central bank's policy rate smoothing parameter is lower, and (e) the banking friction in the home country is larger.

Keywords: Monetary policy relationship, terms of trade, expenditure switching effect, financial friction.

JEL classification: E32, E52, E58, F42

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1 Introduction

The monetary policy of the US Federal Reserve (Fed) appears to have widespread international effects on the policy decisions of central banks in other countries. Since the beginning of the financial crisis in the late 2000s, many central banks cut their interest rates following the initial rate cut by the Fed. In particular, after the beginning of the expansionary policy in the US in 2007:Q3, the UK and Canada cut policy rates in the next quarter. In 2008:Q3, Australia and New Zealand started to cut policy rates, and in 2008:Q4, the EU, and many other advanced and developing economies began expansionary policies, including Indonesia, South Korea, Malaysia, Norway, Poland, South Africa, Sweden, Thailand, and others.

Figure 1 indicates that it was not the first time central banks followed the policy decisions of the major players such as the Fed. In the early 2000s, many central banks lowered interest rates right after the rapid monetary expansion of the US in response to the "dot com" bubble collapse and the 9/11 incident. In the mid-2000s, most central banks started to raise their policy rates in order to combat global inflationary pressure, which also aligned with the policy stance of the US. These examples indicate a pattern of co-movement between policies at the Fed and policies at other central banks. Table 1 presents correlation coefficients between the US federal funds rate (FFR) and short term rates in other countries. Except for India, the correlation coefficients are quite high.[1]

We address two questions in this paper. First, what is the transmission mechanism through which a change in a large country's monetary policy rate gives rise to a change in a small country's policy rate? Second, which structural factors in the small economy strengthen and enhance this transmission mechanism?

Our curiosity is sparked by the following observation. If the small economy's central bank follows a Taylor (1993) rule, then its policy rate decisions will be "inward looking" with a focus on domestic macro variables (inflation and the output gap). Then given this inward looking focus, why do the data reveal an apparent outward looking response to changes in the large economy's policy rate? Curious, indeed. A simple response would be that the small economy

[1] Chatterjee (2016) empirically characterizes the co-movement of the monetary policies of the US, UK, Canada, Japan, and Germany with a dynamic latent factor model.

Table 1: Correlation coefficients with US federal funds rate

Country	Coeff.	Country	Coeff.	Country	Coeff.	Country	Coeff.
Australia	0.64	Canada	0.95	Chile	0.57	Czech	0.73
Indonesia	0.52	India	0.24	Israel	0.72	South Korea	0.81
New Zealand	0.71	Norway	0.62	Poland	0.67	South Africa	0.54
Sweden	0.60	Taiwan	0.79	Thailand	0.68	UK	0.85

Note: Correlation coefficients of three month rates with US FFR during 1999:Q1-2015:Q2

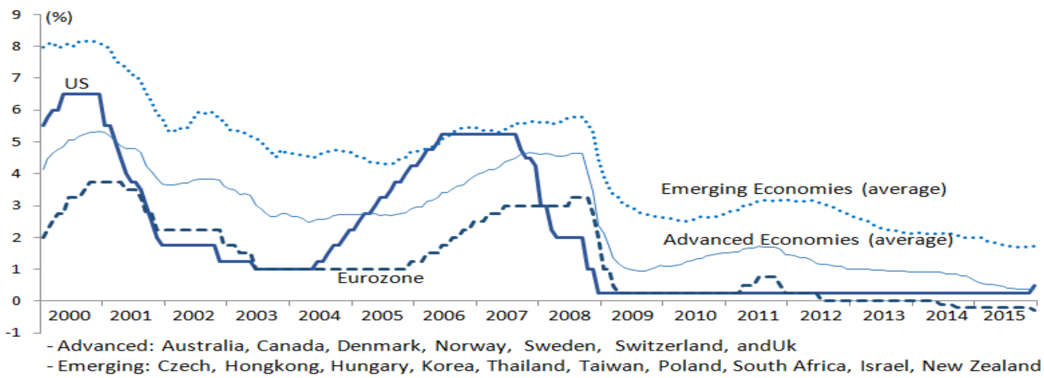

Figure 1: Monetary policy rates since 2001: US, EU, and other countries

does not follow a Taylor rule, but rather uses an augmented policy rule that reacts directly to changes in the large economy's policy rate. However, this would entail a loss of sovereignty by the small country, and perhaps for this reason the literature generally does not estimate augmented policy rules of this form.[2] But the central bank of the small country may use some other form of outward looking policy rule. In particular, the policy rule might respond directly to the exchange rate (whether that be the real/nominal or bilateral/effective exchange rate). If so, then we would not be surprised by co-movement between the policy rates in the large and small economies: with such a policy rule, a decrease in the large country's policy rate would appreciate the small country's currency and this would then feed directly into the small country's policy rule. Hence, we need to address this further. Do small economies use policy rules that respond directly to changes in the exchange rate?

Taylor's (2001) paper entitled "The role of the exchange rate in monetary-policy rules" has spawned a large literature, both normative and positive. We are primarily concerned with

[2]Caputo and Herrera (2017) is an exception. They estimate central bank policy rules in which the US federal funds rate is a regressor and they find that its coefficient is significant. Their panel regressions allow for country fixed effects but otherwise assume that the same policy rule applies to all countries in each regression.

the positive analysis.[3] This literature faces a difficult task in identifying the monetary policy rule. Among other considerations, all explanatory variables in the policy rule are endogenous; there may be regime changes; and leads, lags, and nonlinearities may be relevant. Perhaps as a consequence, across a number of country studies, there are differing views on whether the exchange rate directly enters the policy rule of the central bank.[4] However, our conclusion from this literature is that even where the policy rule does respond directly to the exchange rate, the magnitude of this response is generally too small to account for the co-movement of policy rates across countries. In order to account for the observations in Table 1 and Figure 1, some other mechanism must be at work.

What, then, causes the cross-country co-movement of policy rates? Since the answer apparently does not come from outward looking variables in the monetary policy rule we focus our attention on a small open economy with a purely inward looking Taylor rule. Now suppose a large country like the US lowers its policy rate. Then via capital flows this will cause an appreciation of the small country's exchange rate. In turn, there will be two consequences for the small economy. (i) The appreciation will push down the price of imports and thereby contribute to lower inflation in the small country. (ii) The appreciation will increase the small country's demand for imports and decrease the rest of the world's demand for the small country's exports (expenditure switching effect) and will thereby contribute to lower GDP in the small country. Both (i) and (ii) affect the Taylor rule in the same direction. The small country's central bank will thus lower its policy rate in response to the decline in the large country's rate. In this paper we formally model this international transmission mechanism, and then quantify it.

We estimate a two-country dynamic stochastic general equilibrium (DSGE) model. We

[3]The normative analysis generally finds that inward looking policy rules (that depend only on domestic inflation and the domestic output gap), while not necessarily optimal, are nonetheless very robust. They are close to optimal for a wide range of models and a wide range of parameter values. See Taylor and Williams (2011).

[4]The following examples are indicative of these differing views. Lubik and Schorfheide (2007) find that the exchange rate does not enter the policy rule for Australia and New Zealand while it does enter for Canada and the UK. Chen and MacDonald (2012) find that it does enter for the UK but with a very small coefficient (Table 8). Dong (2013) finds that it does not enter for Canada, New Zealand, and the UK while results for Australia are inconclusive. Bjørnland and Halvorsen (2014) use a structural VAR model and find that it does not enter for Australia and the UK while it does enter for Canada, New Zealand, Norway, and Sweden.

use South Korea as the test bed for the small country, denoted "home." The large country is "foreign" and can be identified with the US. The home country imports a range of intermediate goods that are used in the production of a non-traded final good. The only international asset is a foreign bond denominated in the foreign currency. The model has a number of frictions/imperfections: intermediate goods producers have market power and set sticky prices; trade in the foreign bond incurs transaction costs; household savings pass through financial intermediaries (banks) and the funds are borrowed by firms that need to cover their capital expenses. This intermediation is subject to banking frictions.

With regard to our second research question about the structural determinants of the strength of transmission, we use the DSGE model to conduct some quantitative experiments and determine which factors enhance the transmission of foreign interest rate shocks to the home interest rate. Our analysis suggests that the co-movement between home and foreign rates is stronger when (a) the international asset transaction cost facing the home country is lower, (b) openness of the home country is higher, (c) the home central bank is more aggressive in fighting inflation, (d) the home central bank's policy rate smoothing parameter is lower, and (e) the banking friction in the home country is larger. The lower transaction cost and higher openness make the expenditure switching effect stronger. Also, with a greater response to inflation and with less policy smoothing, the home central bank cuts its interest rate more sharply given an initial decrease in inflation.

A novel feature of our model is the inclusion of a banking friction in terms of an agency cost as in Gertler and Karadi (2011). In this respect, our model differs from other studies which focus on the agency problems of non-financial firms such as Kolasa and Lombardo (2014) and Bernanke, Gertler, and Gilchrist (1999). In our model, a banking friction strengthens the co-movement of home and foreign interest rates via the financial accelerator.

The paper is organized as follows. Section 2 reviews the related literature. In Section 3 we lay out our DSGE model. In Section 4, we present the estimation and calibration results. Section 5 presents impulse responses results. Section 6 concludes.

2 Literature Review

There are numerous empirical investigations of the policy relationship between central banks. Maćkowiak (2006) indicates that the US policy affects the short-term rates of other countries, and Bergin and Jordà (2004) show the European countries' significant responses to the US and German monetary policies before 1998. Clarida, Galí and Gertler (1998) show the influence of German policy on the policies of UK, France and Italy during 1979-1993. In a recent study, Kucharčuková, Claeys and Vašíček (2014) find immediate policy changes of non-EU European countries following the policy of the European Central Bank (ECB).

Regarding the international spill-over effects of monetary policy, there are influential studies that explore optimal monetary policy rules in open economy models. For instance, Ball (1998) and Corsetti and Pesenti (2005) conclude that the optimal policy needs to focus on reducing the volatility of the exchange rate as well as domestic variables such as output and the inflation rate. On the other hand, Galí and Monacelli (2005) and Batini, Harrison and Millard (2003) argue that domestic inflation targeting is optimal.

There is a voluminous literature analyzing the issue of monetary policy interdependence in a global economy within a cooperative framework such as Benigno and Benigno (2006) and Pappa (2004). Yet the monetary policy coordination is not easily triggered in reality. The gains from the coordination are non-trivial only when both economies are highly interdependent through trade. However, for instance, by some measures the US economy is not very open. Coenen, et al. (2010) indicates that for the US the gains from the monetary policy cooperation are small due to its low degree of openness. Banerjee and Basu (2016) develop a small open economy DSGE model to understand the effects of US quantitative easing on Indian economy. However, their model does not address the issue of co-movement between home and foreign policy rate.

A stream of literature expands the financial accelerator framework of Bernanke, Gertler and Gilchrist (BGG, 1999) to the open economy environment (Davis and Huang, 2011; Gertler, Gilchrist and Natalucci, 2007; Kolasa and Lombardo, 2014). These studies follow the BGG framework and focus on the agency problem in the non-financial sector rather than the banking sector. Even though Bruno and Shin (2013) and Hwang (2012) incorporate a banking friction in an open economy framework, Bruno and Shin (2013) is not based on a DSGE model and Hwang (2012) assumes an additional cost of lending in loan making which is not based on the agency problem.

3 Empirical Evidence of the Policy Rate Relationship

Table 1 and Figure 1 provided descriptive statistics for the co-movement of policy rates. The purpose of this section is to econometrically verify this co-movement further. We focus on the monetary policy relationships between the US and 14 other economies: Australia, Canada, Chile, Czech, Denmark, India, Indonesia, South Africa, South Korea, Malaysia, Norway, Sweden, Thailand, and UK. The US is treated as the foreign country. Using both the home and the foreign model equations, the effect of the foreign (home) policy rate changes on the home (foreign) policy rate is verified. Given that policy rates are not continuous and also not frequently adjusted, ordered probit models are used as in Bergin and Jordà (2004).

3.1 Ordered Probit Model

The probit model is useful when dependent variables are discrete; it adopts latent continuous variables which replace the original ones. In this model, the magnitudes of the policy rate changes of the home country are classified into five categories, keeping in mind that most Central banks adjust rates within thirty basis points in normal time: (i) strong tightening ($0.3\% \leq \Delta R$), (ii) normal tightening ($0 < \Delta R < 0.3\%$), (iii) no change ($\Delta R = 0$), (iv) normal expansion ($-0.3\% < \Delta R < 0$), and (v) strong expansion ($\Delta R \leq -0.3\%$). R denotes a gross nominal policy rate.

The observed discrete policy rate changes are then transformed into a series of ordered variables, $z_t \in \{-2, -1, 0, 1, 2\}$. In this series, '2' represents *strong tightening*, '-2' is for *strong expansion*, and '0' means *no policy change*.[5] It is then hypothesized that the discrete policy

[5] Regarding the federal funds rate target in the US, Hamilton and Jordà (2002) use a series of $\{\cdots$, -0.50, -0.25, 0, 0.25, 0.50,$\cdots\}$. In Bergin and Jordà (2004) the ordered variables are {-0.50, -0.25, 0, 0.25, 0.50}, and Scotti (2011) uses {-50, -25, 0, 25, 50}.

rate change (z_t) is related to the continuous latent variable z_t^* according to

$$z_t = f(z_t^*) = \begin{cases} -2\ (= s^1) & \text{if } z_t^* \in \{c_0(= -\infty), c_1\} \\ -1\ (=s^2) & \text{if } z_t^* \in \{c_1, c_2\} \\ \vdots & \\ 2\ (=s^5) & \text{if } z_t^* \in \{c_4, c_5(= \infty)\} \end{cases}$$

where $c_0 < c_1 < c_2 < c_3 < c_4 < c_5$. Given the decision making process of the central bank, the latent variable z_t^* is assumed to be determined by economic variables such as inflation and output.

The cross-border effect of monetary policy is represented by the role of the foreign country's short term rate (i) in influencing the home country's rate. Since current period data are not observable while making policy decisions, the policy rate is affected by the expected current period values of the output gap and domestic inflation.[6] The analysis then tests the significance of the coefficients of the other economy's interest rates. The ordered probit model is then illustrated as follow:

$$\begin{aligned} z_t^{H*} &= \beta_1 i_{t-1}^H + \beta_2 E\left(\pi_t^H \mid \Omega_t^H\right) + \beta_3 E\left(\widetilde{Y}_t^H \mid \Omega_t^H\right) + \beta_4 i_{t-1}^F + \varepsilon_t^H \\ z_t^{F*} &= \beta_1 i_{t-1}^F + \beta_2 E\left(\pi_t^F \mid \Omega_t^F\right) + \beta_3 E\left(\widetilde{Y}_t^H \mid \Omega_t^F\right) + \beta_4 i_{t-1}^H + \varepsilon_t^F \end{aligned}$$

where superscript F is for foreign and H is for home variables. Ω_t^H and Ω_t^F represent the available information sets at time t, which consist of the $t-1$ and $t-2$ data of CPI inflation, PPI inflation, the output gap and the nominal exchange rate. Under the rational expectations hypothesis, the coefficients are estimated using two-step procedures.

3.2 Results of the Analysis

The significance of the coefficient β_4 indicates the influence of the previous foreign (home) policy changes on the home (foreign) policy rate decision. If β_4 in the home policy equation

[6] This is similar to Clarida, Galí and Gertler (1998), where the central bank responds to the expected value of the current period output gap, based on an available information set.

Table 2: The policy relationships with the US (foreign economy)

Relationship	Home Country	Foreign → Home			Home → Foreign		
		β_4	z-statistic	MPE*	β_4	z-statistic	MPE*
One-way (7)	Australia	3.78	1.96	0.16	-1.24	-0.66	-
	Chile	5.32	2.88	0.28	0.22	0.41	-
	Czech	4.13	2.09	0.10	-1.23	-0.37	-
	India	6.72	3.08	0.34	0.89	0.85	-
	South Korea	4.50	2.27	0.14	4.13	1.68	-
	Malaysia	7.17	2.13	0.14	8.33	1.91	-
	UK	9.50	4.75	0.21	1.53	0.69	-
Two-way (1)	Canada	5.45	2.79	0.21	6.46	2.35	0.23
None (6)	Denmark	1.60	0.79	-	5.41	1.58	-
	Indonesia	1.75	0.85	-	0.25	1.76	-
	Norway	1.49	0.86	-	-0.11	-0.06	-
	South Africa	0.75	0.35	-	-1.65	-1.01	-
	Sweden	0.68	0.38	-	-0.60	-0.27	-
	Thailand	1.64	1.02	-	1.35	0.72	-

* Probability increase of raising policy rates when the other country raises its rate by 30 basis points (bp). MPE means marginal policy effect. MPE is not calculated when coefficients are not significant. The US is treated as the foreign country.

is significant and it is not in the foreign country's equation, it is categorized as an one-way relationship between central banks.

Table 2 illustrates the results of the probit model analyses which indicate each *home* economy's policy relationship with the US - the *foreign* economy. The foreign rate coefficients (β_4) of eight countries' models are significant. Seven of these economies have one-way relationships: Australia, Chile, Czech, India, South Korea, Malaysia, and the UK. Marginal probability effects (MPE) indicate that when the interest rate of the US is raised by 30bp, the probability of the *home* rate increase rises by 10-34% in these economies.[7] However, the US monetary policy is not affected by the short-term rate changes of these economies. Canada reveals a two-way relationships, because the economies of the US and Canada are highly integrated. Six other economies do not have any significant policy relationships with the US: Denmark, Indonesia, Norway, South Africa, Sweden, and Thailand.

[7]Marginal probability effects (MPE) are calculated as

$$MPE_{j,i} = \frac{\delta Pr\left[z_t = s^j \mid X\right]}{\delta x_i} = \left[f\left(c_{j-1} - X_t'\beta\right) - f\left(c_j - X_t'\beta\right)\right]\beta_i,$$

where $f(\cdot)$ is the standard normal distribution function.

4 An Open Economy DSGE Model

4.1 Model Description

The theoretical framework consists of an open economy general equilibrium model. There are two economies; home and foreign. The foreign economy can be interpreted as the US. Some international variables such as the foreign inflation rate, foreign aggregate demand and interest rate are exogenously given. Also, home households can purchase both home and foreign assets by holding deposits. As in Benigno (2009), home assets cannot be traded in international markets since the home currency is not a global currency. We set up the model primarily from the home country's (South Korea) perspective.

There are seven types of agents: households, financial intermediaries, the central bank, the government, capital producers, final and intermediate goods producers. Home final goods are produced with domestic and imported intermediate goods. These tradeable differentiated intermediate goods are produced with the help of capital and labour by both home and foreign countries. Final goods are purchased for consumption by households, investment by capital producers and government spending. The government receives income tax from the households, and the central bank sets the nominal risk free interest rate.

Home financial intermediaries obtain funds only from home household deposits. Financial intermediaries purchase claims on intermediate goods producers, transferring funds between households and producers. As in Gertler and Karadi (2011), the financial intermediaries face borrowing constraints due to the agency problem, which can be interpreted as the financial friction.

In the open economy setup, incomplete markets are assumed and financial integration across borders is not perfect as in Benigno (2009).[8] There is an international assets transaction cost which is determined by the aggregate foreign assets (deposits) position of the economy. Due to this cost, the standard uncovered interest rate parity (UIP) condition does not hold.

[8] Similar features can be found in Basu and Thoenissen (2011) and Banerjee and Basu (2017).

4.2 Intermediate Goods Producers

Each home intermediate good firm i produces a tradeable differentiated good $Y_t(i)$ with a Cobb-Douglas technology. $K_t(i)$ and $L_t(i)$ are the amounts of capital and labour that are used for production. The variable A_t denotes the level of technology common to all firms.

$$Y_t(i) = A_t K_t(i)^{\psi} L_t(i)^{1-\psi} \tag{1}$$

At the end of each period, intermediate goods firms borrow funds from financial intermediaries by issuing claims (S_t) to them. They purchase the capital stock (K_{t+1}) from the capital producer for production next period. As in Gertler and Karadi (2011), the number of claims issued by the firm i is the same as the amount of capital it purchases ($S_t(i) = K_{t+1}(i)$). Thus, given a relative price of capital Q_t, in units of the output good per unit of capital,

$$Q_t S_t(i) = Q_t K_{t+1}(i). \tag{2}$$

After production in period t, the intermediate good firm i pays back $r_{S,t} Q_{t-1} S_{t-1}(i)$ to the financial intermediaries for $S_{t-1}(i)$, where $r_{S,t}$ is the gross real return of each claim. In order to repay the fund $r_{S,t} Q_{t-1} S_{t-1}(i)$ at time t, the firm i resells the used and depreciated capital, $(1-\delta)K_t$, to the capital producer with the price of Q_t, where δ is the depreciation ratio. Since $S_{t-1}(i) = K_t(i)$, the real cost of using $K_t(i)$ in production by funding from the financial intermediaries is $[r_{S,t} Q_{t-1} - (1-\delta) Q_t] K_t(i)$. Given the real wage ($W_t$) paid to households, the total real cost is $r_{K,t} K_t(i) + W_t L_t(i)$ where the user cost of capital is given by $r_{K,t} = r_{S,t} Q_{t-1} - (1-\delta) Q_t$. Then the optimality condition implies

$$\frac{L_t(i)}{K_t(i)} = \frac{1-\psi}{\psi} \frac{r_{K,t}}{W_t} \tag{3}$$

$$MC_t = \frac{1}{A_t \psi^{\psi} (1-\psi)^{1-\psi}} r_{K,t}^{\psi} W_t^{1-\psi}. \tag{4}$$

The home intermediate goods of firm i are purchased in the home economy and exported abroad: $Y_t(i) = Y_{H,t}(i) + Y^*_{H,t}(i)$, where $Y_{H,t}(i)$ is the amount sold in the domestic market and

$Y^*_{H,t}(i)$ is the amount sold in the foreign market (home exports).[9] The demand function for an individual intermediate good is determined by the cost minimization problem of the final good producer in each economy. Defining $P_{H,t}(i)$ and $P^*_{H,t}(i)$ as the prices of home produced goods in home and foreign currencies respectively, the demand function for good i in each economy is given by

$$Y_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} Y_{H,t} \qquad Y^*_{H,t}(i) = \left(\frac{P^*_{H,t}(i)}{P^*_{H,t}}\right)^{-\varepsilon} Y^*_{H,t} \tag{5}$$

where ε is the elasticity of substitution among individual intermediate goods in both home and foreign markets. $Y_{H,t}$ and $Y^*_{H,t}$ are aggregate demands for home goods in both markets. $P_{H,t}$ and $P^*_{H,t}$ are the aggregate prices. The aggregate demands and prices follow the aggregator form of Dixit and Stiglitz (1977):

$$Y_{H,t} = \left[\int_0^1 Y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \qquad Y^*_{H,t} = \left[\int_0^1 Y^*_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{6}$$

$$P_{H,t} = \left[\int_0^1 P_{H,t}(i)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} \qquad P^*_{H,t} = \left[\int_0^1 P^*_{H,t}(i)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} \tag{7}$$

In a symmetric way, the demand functions for foreign intermediate good j in the home and foreign (indexed as F) economies are

$$Y_{F,t}(j) = \left(\frac{P_{F,t}(j)}{P_{F,t}}\right)^{-\varepsilon} Y_{F,t} \qquad Y^*_{F,t}(j) = \left(\frac{P^*_{F,t}(j)}{P^*_{F,t}}\right)^{-\varepsilon} Y^*_{F,t} \tag{8}$$

where $P^*_{F,t}(j)$ is the foreign currency price of the foreign-produced intermediate good. The aggregators are

$$Y_{F,t} = \left[\int_0^1 Y_{F,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{1-\varepsilon}} \qquad Y^*_{F,t} = \left[\int_0^1 Y^*_{F,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{1-\varepsilon}} \tag{9}$$

[9] For quantity variables (inputs and outputs), the subscript H or F denotes the country of production. An asterisk indicates foreign consumption/use, while no asterisk indicates home consumption/use. Prices denominated in foreign currency are indicated with an asterisk.

$$P_{F,t} = \left[\int_0^1 P_{F,t}(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}} \qquad P_{F,t}^* = \left[\int_0^1 P_{F,t}^*(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}} \tag{10}$$

Following a classical view of the New Open Economy Macroeconomics literature (i.e. Obstfeld and Rogoff, 1995), home firms set export prices in domestic currency, which means producer currency pricing (PCP). Firms choose identical prices for both domestically purchased goods and exported goods. Also, there are no trade costs or trade barriers. With identical preference and technology across border, the law of one price (LOOP) holds, which means $P_{H,t}(i) = \mathcal{E}_t P_{H,t}^*(i)$, where $\mathcal{E}_t$ denotes the nominal exchange rate in units of home currency per unit of foreign currency. With the LOOP, using the two equations in (10) it follows that the aggregate price indices for domestically purchased goods ($P_{H,t}$) and exported goods ($P_{H,t}^*$) have a relationship

$$P_{H,t} = \mathcal{E}_t P_{H,t}^*, \tag{11}$$

and

$$P_{F,t} = \mathcal{E}_t P_{F,t}^*. \tag{12}$$

Since the home intermediate goods firm i sells its goods in both home and foreign markets, its revenue in period t is the sum of the revenue from each market. Its real cash flow is

$$\frac{P_{H,t}(i)}{P_t} Y_{H,t}(i) + \frac{\mathcal{E}_t P_{H,t}^*(i)}{P_t} Y_{H,t}^*(i) - r_{K,t} K_t(i) - W_t L_t(i). \tag{13}$$

Alternatively defining $\Phi\left(Y_{H,t}(i) + Y_{H,t}^*(i)\right)$ as the nominal costs of producing $Y_{H,t}(i) + Y_{H,t}^*(i)$, the nominal cash flow at time t can be expressed as

$$P_{H,t}(i) Y_{H,t}(i) + \mathcal{E}_t P_{H,t}^*(i) Y_{H,t}^*(i) - \Phi(Y_{H,t}(i) + Y_{H,t}^*(i)). \tag{14}$$

Following Calvo (1983), in the home market an individual intermediate good producer can adjust its price with a probability $1 - \xi$ each period. As in Yun (1996), when it cannot optimally change the price, its home price is increasing at the steady state home inflation rate ($\bar{\Pi}$). The steady state inflation of the home and foreign economies are assumed to be the same ($\bar{\Pi} = \bar{\Pi}^*$). Define $\tilde{P}_{H,t}$ and $\tilde{P}_{H,t}^*$ as the home and foreign prices of home produced goods optimized at time t. Also define $P_{H,t+\tau|t}$ and $P^*_{H,t+\tau|t}$ as the prices τ periods later if no further optimization has taken place. Since the LOOP holds, the price of home produced goods in the foreign economy is indexed to not only the steady state inflation rate ($\bar{\Pi}^*$), but also the inverse of the nominal exchange rate change.[10] Then

$$\begin{aligned} P_{H,t+\tau|t} &= \bar{\Pi} P_{H,t+\tau-1|t} = \bar{\Pi}^\tau \tilde{P}_{H,t} \\ P^*_{H,t+\tau|t} &= \left(\frac{\mathcal{E}_{t+\tau-1}}{\mathcal{E}_{t+\tau}}\right) \bar{\Pi}^* P^*_{H,t+\tau-1|t} = \left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+\tau}}\right) \bar{\Pi}^{*\tau} \tilde{P}^*_{H,t}. \end{aligned}$$

In the foreign economy, the price stickiness parameter (ξ^*) and the elasticity of substitution among intermediate goods (ε^*) are assumed to be the same as the home economy. Considering the nominal exchange rate ($\mathcal{E}_{t+\tau}$), for the firm whose last price reset was at time t, the home currency value of exports at time $t+\tau$ ($Y^*_{H,t+\tau|t}$) would be $\bar{\Pi}^{*\tau} \mathcal{E}_t \tilde{P}^*_{H,t} Y^*_{H,t+\tau|t}$. The monopolistic home producer sets the price $\tilde{P}_{H,t}$ to maximize profits.

Given the LOOP and the steady state inflation rate, $\bar{\Pi} = \bar{\Pi}^*$, the price setting problem facing the home intermediate goods producer is given by:[11]

$$\max_{\tilde{P}_{H,t}} \sum_{\tau=0}^{\infty} \beta^\tau \xi^\tau E_t \left\{ D_{t,t+\tau} \left[\bar{\Pi}^\tau \tilde{P}_{H,t} \left(\frac{P_{H,t+\tau|t}}{P_{H,t+\tau}}\right)^{-\varepsilon} \left(Y_{H,t+\tau} + Y^*_{H,t+\tau}\right) - \Phi(Y_{t+\tau|t}) \right] \right\}. \tag{15}$$

where $\beta^\tau D_{t,t+\tau} (= \beta^\tau \Lambda_{t,t+\tau} \frac{P_t}{P_{t+\tau}})$ is the stochastic discount factor for nominal payoffs. The real discount factor $\Lambda_{t,t+\tau}$ will be defined later. $Y_{t+\tau|t}$ denotes output at $t+\tau$ for a firm that last reset its price at date t, which is the sum of the domestically sold goods ($Y_{H,t+\tau|t}$) and the exported home goods ($Y^*_{H,t+\tau|t}$). Profit maximization yields the following domestic relative price equation:[12]

$$\frac{\tilde{P}_{H,t}}{P_t} = \frac{\frac{\varepsilon}{\varepsilon-1} \sum\limits_{\tau=0}^{\infty} \tilde{\beta}^\tau E_t \left(D_{t,t+\tau} \bar{\Pi}^{-\varepsilon\tau} \Pi^{\varepsilon}_{H,t,t+\tau} \Pi_{t,t+\tau} Y_{t+\tau} V_{t+\tau} MC_{t+\tau} \right)}{\sum\limits_{\tau=0}^{\infty} \tilde{\beta}^\tau E_t \left(D_{t,t+\tau} \bar{\Pi}^{(1-\varepsilon)\tau} \Pi^{\varepsilon}_{H,t,t+\tau} Y_{t+\tau} V_{t+\tau} \right)} \tag{16}$$

[10] Assuming the LOOP and $\bar{\Pi} = \bar{\Pi}^*$, we have $P_{H,t+\tau|t} = \bar{\Pi}^\tau \tilde{P}_{H,t} = \bar{\Pi}^{*\tau} \mathcal{E}_t \tilde{P}^*_{H,t}$. From $P_{H,t+\tau|t} = \mathcal{E}_{t+\tau} P^*_{H,t+\tau|t}$, $\bar{\Pi}^{*\tau} (\mathcal{E}_t / \mathcal{E}_{t+\tau}) \tilde{P}^*_{H,t} = P^*_{H,t+\tau|t}$.

[11] The rate of depreciation of home currency is zero in the steady state which means $\bar{\Pi} = \bar{\Pi}^*$.

[12] A recursive representation of equation (16) is available in a technical appendix available from the authors upon request.

where $MC_{t+\tau}$ is the real marginal cost at $t+\tau$. $\Pi_{H,t,t+\tau}$ indicates cumulative inflation of home produced goods in the home market between t and $t+\tau$. Also, $\tilde{\beta} = \beta\xi$ and $V_{t+\tau} = \left[\int_0^1 \left(\frac{P_{H,t+\tau}(i)}{P_{H,t+\tau}}\right)^{-\varepsilon} di\right]^{-1}$.

As in Yun (1996), the aggregate price index $P_{H,t}$ evolves over time according to the recursive form below:

$$P_{H,t} = \left[\xi \left(P_{H,t-1}\bar{\Pi}\right)^{1-\varepsilon} + (1-\xi)\tilde{P}_{H,t}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{17}$$

which can be rewritten by

$$\frac{P_{H,t}}{P_t} = \left[\xi \left(\frac{\bar{\Pi}}{\Pi_t}\right)^{1-\varepsilon} \left(\frac{P_{H,t-1}}{P_{t-1}}\right)^{1-\varepsilon} + (1-\xi)\left(\frac{\tilde{P}_{H,t}}{P_t}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{18}$$

4.3 Final Goods Producers

Final goods producing firms in the home and the foreign markets produce final goods Z_t and Z_t^* by combining home and foreign intermediate goods. The final goods production functions are given by:

$$Z_t = \left[\alpha^{\frac{1}{\theta}} Y_{H,t}^{\frac{\theta-1}{\theta}} + (1-\alpha)^{\frac{1}{\theta}} Y_{F,t}^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{19}$$

$$Z_t^* = \left[\alpha^{*\frac{1}{\theta}} Y_{F,t}^{*\frac{\theta-1}{\theta}} + (1-\alpha^*)^{\frac{1}{\theta}} Y_{H,t}^{*\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \tag{20}$$

where the parameter θ denotes the intratemporal elasticity of substitution between home and foreign intermediate goods, which is identical in the home and the foreign economies. $\alpha \in (0,1)$ and $\alpha^* \in (0,1)$ represent the long-run weights of domestic goods in the home and the foreign economies, respectively. The amount of foreign final goods production (Z_t^*) is exogenously given.

For the home and the foreign (imported) intermediate goods in the home economy, cost minimization by the home final goods producers yields the following demand equations:

$$Y_{H,t} = \alpha \left(\frac{P_{H,t}}{P_t} \right)^{-\theta} Z_t \tag{21}$$

$$Y_{F,t} = (1-\alpha) \left(\frac{P_{F,t}}{P_t} \right)^{-\theta} Z_t, \tag{22}$$

with a price index

$$P_t = \left[\alpha P_{H,t}^{1-\theta} + (1-\alpha) P_{F,t}^{1-\theta} \right]^{\frac{1}{1-\theta}} . \tag{23}$$

Dividing both sides of the equation (23) by P_{t-1} yields

$$\Pi_t = \left[\alpha \left(\Pi_{H,t} \frac{P_{H,t-1}}{P_{t-1}} \right)^{1-\theta} + (1-\alpha) \left(\Pi_{F,t} \frac{P_{F,t-1}}{P_{t-1}} \right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{24}$$

where $\Pi_{H,t} = P_{H,t}/P_{H,t-1}$ and $\Pi_{F,t} = P_{F,t}/P_{F,t-1}$.

Similarly in the foreign economy (with superscript *),

$$Y_{F,t}^* = \alpha^* \left(\frac{P_{F,t}^*}{P_t^*} \right)^{-\theta} Z_t^* \tag{25}$$

$$Y_{H,t}^* = (1-\alpha^*) \left(\frac{P_{H,t}^*}{P_t^*} \right)^{-\theta} Z_t^* \tag{26}$$

with a price index

$$P_t^* = \left[\alpha^* P_{F,t}^{*1-\theta} + (1-\alpha^*) P_{H,t}^{*1-\theta} \right]^{\frac{1}{1-\theta}} . \tag{27}$$

Dividing both sides of the equation (27) by P_{t-1}^* leads to

$$\Pi_t^* = \left[\alpha^* \left(\Pi_{F,t}^* \frac{P_{F,t-1}^*}{P_{t-1}^*} \right)^{1-\theta} + (1-\alpha^*) \left(\Pi_{F,t}^* \frac{P_{F,t-1}^*}{P_{t-1}^*} \right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{28}$$

where $\Pi_t^* = P_t^*/P_{t-1}^*$, $\Pi_{F,t}^* = P_{F,t}^*/P_{F,t-1}^*$ and $\Pi_{H,t}^* = P_{H,t}^*/P_{H,t-1}^*$. The foreign inflation rate is assumed to be at its long-run level ($\Pi_t^* = \bar{\Pi}^*$).

Given the LOOP ($\mathcal{E}_t P_{H,t}^* = P_{H,t}$ and $\mathcal{E}_t P_{F,t}^* = P_{F,t}$) and the definition of the real exchange rate ($\mathcal{E}_{R,t} = \mathcal{E}_t P_t^*/P_t$), the intermediate goods' relative prices in the home and the foreign economies have the relationships as follow:

$$\frac{P_{H,t}^*}{P_t^*} = \frac{P_{H,t}}{P_t}\mathcal{E}_{R,t}^{-1} \tag{29}$$

$$\frac{P_{F,t}^*}{P_t^*} = \frac{P_{F,t}}{P_t}\mathcal{E}_{R,t}^{-1}. \tag{30}$$

4.4 Households

There is a continuum of identical households in this economy, indicated by $h \in (0, 1)$. As in Gertler and Karadi (2011), there are two types of members in each household: workers and bankers. At any moment the fraction $1 - f$ of the members are workers, and f are bankers who are running financial intermediaries. Workers can consume and deposit money at home and foreign financial intermediaries. Households (Workers) supply labour to the intermediate goods firms and receive wages. The household h has a preference over consumption and labour supply as follows:

$$E_\tau \sum_{t=\tau}^{\infty} \beta^{t-\tau} \left[\frac{1}{1-\sigma} C_t(h)^{1-\sigma} - \frac{\nu}{1+\chi} L_t(h)^{1+\chi} \right] \tag{31}$$

where $C_t(h)$ and $L_t(h)$ denote individual levels of consumption and labour supply at time t, respectively. σ represents the coefficient of relative risk aversion of households or the reciprocal of the intertemporal elasticity of substitutions, and χ is the inverse of the elasticity of labour supply. ν indicates the relative weight given to the disutility of labour. The household h faces a nominal flow budget constraint,

$$P_t C_t(h) + R_t^{-1} B_{H,t}(h) + [1 - \Gamma(b_{F,t})]^{-1} R_t^{*-1} \mathcal{E}_t B_{F,t}(h) =$$
$$P_t(1-m) W_t L_t(h) + D_t(h) + B_{H,t-1}(h) + \mathcal{E}_t B_{F,t-1}(h) + P_t \Omega_t(h)$$

where P_t is the overall price level, W_t is the real wage and R_t and R_t^* are home and foreign nominal risk-free interest rates determined by central banks. $R_t^{-1} B_{H,t}(h)$ and $R_t^{*-1} \mathcal{E}_t B_{F,t}(h)$ are nominal amount of deposits in home and foreign financial intermediaries at time t. $B_{F,t}(h)$ is denominated in foreign currency, and all deposits are for one period. $m \in (0, 1)$ is an income tax ratio, and $D_t(h)$ is the sum of dividends from intermediate goods and capital producing firms, owned by households. $\Omega_t(h)$ is the real net transfer from the financial intermediary sector, which will be explained later. The real budget constraint for each household h can be obtained by dividing the nominal one by the overall price level, P_t.

$$C_t(h) + \left(\frac{R_t}{\Pi_{t+1}}\right)^{-1} b_{H,t}(h) + [1 - \Gamma(b_{F,t})]^{-1} \left(\frac{R_t^*}{\Pi_{t+1}}\right)^{-1} \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} b_{F,t}(h) =$$
$$(1 - m)W_t L_t(h) + D_t(h) + b_{H,t-1}(h) + b_{F,t-1}(h) + \Omega_t(h)$$

where $b_{H,t}(h)$ and $b_{F,t}(h)$ denote real amounts of home and foreign deposits, respectively ($b_{H,t}(h) = B_{H,t}(h)/P_{t+1}$ and $b_{F,t}(h) = \mathcal{E}_{t+1} B_{F,t}(h)/P_{t+1}$). Also, defining $r_s = R_s/\Pi_{s+1}$ and $r_{F,s} = R_s^*/\Pi_{s+1}$, $\underset{t\to\infty}{lim} \prod_{s=1}^{t} r_s^{-1} b_{H,t}(h) = 0$ and $\underset{t\to\infty}{lim} \prod_{s=1}^{t} r_{F,s}^{-1} b_{F,t}(h) = 0$ (no-Ponzi scheme).

Households bear the international assets transaction cost ($\Gamma(b_{F,t})$) when changing the foreign deposits holding.[13] As in Schmitt-Grohé and Uribe (2003) and Benigno (2009) the assets transaction cost is determined by the total amount of the foreign deposits holding in the entire economy. Each household regards this cost as given when choosing an optimal consumption and the foreign asset holding combination. Each household receives a lower return compared to the steady state when they increase or reduce foreign deposit holding from the steady state. The asset transaction cost function is given by

$$\Gamma(b_{F,t}) = \mu_T \left(\frac{b_{F,t}}{\bar{b}_F} - 1\right) \tag{32}$$

where μ_T represents the level of the cost and $\mu_T > 0$. In the steady state, the asset transaction cost is assumed to be zero as in Benigno (2009).

Defining as $\lambda_{M,t}$ the Lagrange multipliers associated with the flow budget constraint, the

[13] The asset markets are incomplete in the sense that there is only one international bond $B_{F,t}$ which is subject to an asset transaction cost. $B_{H,t}$ is a nontradable asset. In other words, banks do not hold any foreign deposits, which is in line with the banking practice of many emerging economies.

first order conditions facing the household h are:

$$\begin{aligned}
\lambda_{M,t} &= C_t(h)^{-\sigma} && (33)\\
\lambda_{M,t}(1-m)W_t &= L_t(h)^{\chi} && (34)\\
\beta R_t E_t\left[\left(\frac{C_{t+1}(h)}{C_t(h)}\right)^{-\sigma}\frac{1}{\Pi_{t+1}}\right] &= 1 && (35)\\
\beta R_t^*\left[1-\Gamma(b_{F,t})\right]E_t\left[\left(\frac{C_{t+1}(h)}{C_t(h)}\right)^{-\sigma}\frac{1}{\Pi_{t+1}}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\right] &= 1 && (36)
\end{aligned}$$

Combining the log-linearized equations of (35) and (36) yields the following modified uncovered interest rate parity (UIP) condition:

$$\hat{R}_t = \hat{R}_t^* + E_t\left(\widehat{\Delta\mathcal{E}}_{t+1}\right) - \mu_T\hat{b}_{F,t}, \tag{37}$$

where $\hat{x} = (x_t - \bar{x})/\bar{x}$ and $\bar{x}$ represents the steady state level of x_t.

In the producer's optimization problem (11), $\Lambda_{t,t+\tau}$ is now determined by

$$\Lambda_{t,t+\tau} = \left(\frac{C_{t+\tau}(h)}{C_t(h)}\right)^{-\sigma}. \tag{38}$$

4.5 Financial Intermediaries

Financial intermediaries are modelled as in Gertler and Karadi (2011). There is a continuum of financial intermediaries indexed by $j \in (0,1)$. Each intermediary obtains funds from household deposits. Using the funds and its own net worth, it holds claims ($S_t(j)$) on intermediate goods producers. The nominal balance sheet of an individual financial intermediary j can be written as:

$$Q_t S_t(j) = N_t(j) + r_t^{-1} b_{H,t}(j) \tag{39}$$

where $N_t(j)$ is the amount of the intermediary j's net worth in real terms. Q_t is the relative price of each claim which is identical across the financial intermediaries. $b_{H,t}(j)$ denotes the real amount of funds borrowed from home households (deposits), and $b_{H,t}(j) = B_{H,t}(j)/P_{t+1}$. Also, r_t is the real interest rate ($r_t = R_t/\Pi_{t+1}$).

Given the real gross return from the intermediate goods firms for each claim ($r_{S,t}$), the real profit at each period is accumulated as net worth:

$$N_t(j) = r_{S,t} Q_{t-1} S_{t-1}(j) - b_{H,t-1}(j). \tag{40}$$

Combining (39) and (40) yields the following law of motion of net worth:

$$N_t(j) = (r_{S,t} - r_{t-1})\, Q_{t-1} S_{t-1}(j) + r_{t-1} N_{t-1}(j) \tag{41}$$

where $r_{S,t} - r_{t-1}$ represents the *excess return* on the claims.

The probability that a banker continues its business next period is ζ. The number of bankers exiting from the financial intermediary sector is assumed to be the same as the number of new bankers each period. The exiting bankers bring final net worth back to the households; the financial intermediary j then maximizes the expected final net worth ($V_t^E(j)$) which can be expressed by

$$V_t^E(j) = E_t \sum_{\tau=t}^{\infty} (1-\zeta) \zeta^{\tau-t} \beta^{\tau+1-t} \Lambda_{t,\tau+1} N_{\tau+1}(j) \tag{42}$$

where $N_{\tau+1}(j) = (r_{S,\tau+1} - r_\tau)\, Q_\tau S_\tau(j) + r_\tau N_\tau(j)$. When $E_t(r_{S,\tau+1} - r_\tau)$ is positive[14] and there is no other constraint, the financial intermediary would increase its assets indefinitely. However, a moral hazard problem sets a limit on borrowing; at each period, the banker j can divert a fraction (λ) of its available funds. The banker j then exits from the banking sector with $\lambda Q_t S_t(j)$. However, in this case the banker sacrifices the expected value of the business ($V_t^E(j)$). Therefore, an incentive constraint must be satisfied in order for the depositors to be willing to supply funds to the banking sector as below:

$$V_t^E(j) \geq \lambda Q_t S_t(j). \tag{43}$$

The expected value of the banking business ($V_t^E(j)$) can be expressed by a recursive form

[14] With imperfect capital markets, the excess return can be positive due to the limits to arbitrage imposed by banking frictions (Gertler and Karadi, 2011).

as follows:

$$V_t^E(j) = \upsilon_t Q_t S_t(j) + \eta_t N_t(j) \tag{44}$$

where υ_t is the expected discounted marginal gain of expanding assets $Q_t S_t(j)$ by one unit, holding $N_t(j)$ constant; η_t indicates the expected discounted value of having one additional unit of $N_t(j)$ while holding $S_t(j)$ constant. x_t is the gross growth rate of assets, and h_t denotes the gross growth rate of net worth.

$$x_t = Q_t S_t(j)/Q_{t-1} S_{t-1}(j) \qquad\qquad h_t = N_t(j)/N_{t-1}(j). \tag{45}$$

From the equation (44), the incentive constraint (43) can be rewritten by:

$$\upsilon_t Q_t S_t(j) + \eta_t N_t(j) \geq \lambda Q_t S_t(j).$$

As in Gertler and Karadi (2011), we assume that the incentive constraint (43) binds. Thus the amount of the financial intermediary j's available funds depends positively on its net worth:

$$Q_t S_t(j) = \phi_t N_t(j) \qquad \text{where} \qquad \phi_t = \frac{\eta_t}{\lambda - \upsilon_t}. \tag{46}$$

The variable ϕ_t implies the leverage ratio of the intermediary j, which is determined such that the benefit of diverting funds is balanced by the opportunity cost. Since the leverage ratio (ϕ_t) does not depend on individual factors, from the equation (46), the aggregate demand for claims is determined by:

$$Q_t S_t = \phi_t N_t \tag{47}$$

where N_t denotes aggregate net worth after new bankers enter into the banking sector and S_t is the aggregate claims of all banks. Therefore, N_t can be illustrated as the sum of existing net worth ($N_{e,t}$) and net worth of the new bankers ($N_{n,t}$) as below:

$$N_t = N_{e,t} + N_{n,t}. \tag{48}$$

Given the survival ratio (ζ) of banks, the existing net worth of all banks can be written as:

$$N_{e,t} = \zeta \left(r_{S,t} Q_{t-1} S_{t-1} - b_{H,t-1} \right). \tag{49}$$

When exiting bankers transfer terminal net worth to households, they pay an income tax at the rate m to the government. As in Gertler and Karadi (2011), new banks receive a transfer of start up capital from households and the amount is a proportion $\omega/(1-\zeta)$ of the assets that were managed by exiting bankers:

$$N_{n,t} = \omega Q_t S_{t-1} \tag{50}$$

which together with (49) and the aggregated balance sheet eq (40) yields the law of motion of the net worth:

$$N_t = \zeta[(r_{S,t} - r_{t-1})\phi_{t-1} + r_{t-1}]N_{t-1} + \omega Q_t S_{t-1}. \tag{51}$$

4.6 Capital Producing Firm

As in Gertler and Karadi (2011), at the end of each period t after the intermediate goods production, a representative capital producing firm purchases $(1-\delta)K_t$ units of used capital from intermediate goods firms given a relative capital price Q_t. By investing (I_t), it produces new capital (K_{t+1}). Using the linear investment technology:

$$K_{t+1} = (1-\delta)K_t + I_t. \tag{52}$$

For investment I_t, the capital producer purchases $[1 + g(A_{I,t}I_t/I_{t-1})]\, I_t$ amount of final goods, where $g(\cdot)$ can be interpreted as an investment adjustment cost and $A_{I,t}$ is an investment adjustment cost shock with an expected value of one. The capital producing firm solves

$$\max_{\{I_t\}_\tau^\infty} \sum_{t=\tau}^{\infty} \beta^{t-\tau} E_\tau \left\{ \Lambda_{\tau,t} \left[Q_t I_t - I_t - g\left(\frac{A_{I,t} I_t}{I_{t-1}} \right) I_t \right] \right\}.$$

The first order condition can be written as

$$Q_t = 1 + g\left(\frac{A_{I,t}I_t}{I_{t-1}}\right) + \frac{A_{I,t}I_t}{I_{t-1}}g'\left(\frac{A_{I,t}I_t}{I_{t-1}}\right) - \beta E_t\left\{A_{I,t+1}\Lambda_{t,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 g'\left(\frac{A_{I,t+1}I_{t+1}}{I_t}\right)\right\} \tag{53}$$

where the investment adjustment cost is given as

$$g\left(\frac{I_t}{I_{t-1}}\right) = \frac{\mu_I}{2}\left(\frac{A_{I,t}I_t}{I_{t-1}} - 1\right)^2. \tag{54}$$

with the investment adjustment cost parameter $\mu_I > 0$.

4.7 Government

The home government purchases G_t of final goods, and the government spending is financed by taxing labour and exiting net worth from the banking sector ($N_{x,t}$). With the income tax ratio m, the government budget constraint is

$$m(W_t L_t + N_{x,t}) = G_t \tag{55}$$

where $N_{x,t}$ denotes the amount of exiting bankers' net worth, and $N_{x,t} = (1-\zeta)\left(r_{S,t}Q_{t-1}S_{t-1} - b^s_{H,t-1}\right)$.

4.8 Central Bank

The home central bank adjusts the short-term interest rate in response to the inflation and the output changes, following a standard inward looking Taylor (1993) rule with a monetary policy smoothing parameter $\rho_R \in (0,1)$. The interest rate rule can be written as

$$R_t = \kappa R_{t-1}^{\rho_R}\left(\Pi_t^{\gamma_P} Y_t^{\gamma_Y}\right)^{1-\rho_R}\mu_t \tag{56}$$

where Y_t denotes aggregate output ($\int_0^1 Y_t(i)di$). κ is a scale parameter, and γ_P and γ_Y represent the policy weights on the inflation rate and the output changes, respectively. μ_t is a policy shock with an expected value of one. On the other hand the foreign policy rate (R_t^*) is treated as exogenous.

4.9 Market Clearing

The following market clearing conditions hold for the home country:

(i) Home final goods market clears.

$$C_t + I_t + G_t + g\left(\frac{I_t}{I_{t-1}}\right) I_t = Z_t \tag{57}$$

(ii) Home produced intermediate goods market clears which means

$$Y_t = Y_{H,t} \int_0^1 \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} di + Y_{H,t}^* \int_0^1 \left(\frac{P_{H,t}^*(i)}{P_{H,t}^*}\right)^{-\varepsilon} di \tag{58}$$

where $Y_t = \int_0^1 Y_t(i)di$ and $Y_t(i) = Y_{H,t}(i) + Y_{H,t}^*(i)$ and the terms in the integrals in (58) are the price dispersion costs.

(iii) The international asset market clears which means the following current account balance condition holds.

$$[1 - \Gamma(b_{F,t})]^{-1} R_t^{*-1} \mathcal{E}_t B_{F,t} - \mathcal{E}_t B_{F,t-1} = P_t NX_t \tag{59}$$

where NX_t is net exports.

(iv) Capital, labour and home lending markets clear.

4.10 Exogenous Variables

Home technology (A_t), the investment adjustment cost ($A_{I,t}$), the home policy rate shock (μ_t), the foreign policy rate (R_t^*) and foreign final goods production (Z_t^*) follow

$$A_t = \bar{A}^{1-\rho_A} A_{t-1}^{\rho_A} \varepsilon_{A,t} \tag{60}$$

$$A_{I,t} = \bar{A}_I^{1-\rho_{AI}} A_{t-1}^{\rho_{AI}} \varepsilon_{AI,t} \tag{61}$$

$$\mu_t = \bar{\mu}^{1-\rho_m} \mu_{t-1}^{\rho_m} \varepsilon_{m,t} \tag{62}$$

$$R_t^* = \bar{R}^{*1-\rho_{mf}} R_{t-1}^{*\rho_{mf}} \varepsilon_{mf,t} \tag{63}$$

$$Z_t^* = \bar{Z}^{*1-\rho_Z} Z_{t-1}^{*\rho_Z} \varepsilon_{zf,t} \tag{64}$$

where variables with bars represent the steady state values. The expected values of $\varepsilon_{A,t}$, $\varepsilon_{AI,t}$, $\varepsilon_{m,t}$, $\varepsilon_{mf,t}$ and $\varepsilon_{zf,t}$ are all unity, and for the coefficients, $\rho_A, \rho_{AI}, \rho_m, \rho_{mf}, \rho_Z \in (0,1)$.

5 Estimation and Calibration

5.1 Data

We use a combination of two methods for model validation namely, calibration and Bayesian estimation. For model validation, South Korea is used as the test bed mainly for the following reasons. First, its foreign bias (0.515) is close to the world average (0.463).[15] The size of GDP (around 1.7% of the global GDP) is justifiable for a small open economy. Third, the central bank is conducting an independent inflation targeting monetary policy. Finally, South Korea is a major emerging economy for which relevant quarterly real and financial data are available.

Given that there are five shocks, five series of quarterly data are used in Bayesian estimation: (1) output, (2) the inflation rate (CPI), (3) consumption, (4) investment and (5) the real exchange rate (effective). The sample period ranges from 1982:Q1 to 2014:Q4. All the variables are percentage deviations from the long-run levels.[16]

For calibrating the key structural parameters, many of the steady state values of related variables are derived from the quarterly data 1999:Q1-2014:Q4. For long-run inflation, quarterly changes of CPI are used and the steady state excess return is derived from the lending-deposit rate spreads. Deriving the steady state level of openness of the home economy, 'imports/GDP' and 'exports/GDP' data in 2013 are used. For the financial intermediary sector, the aggregate balance sheet data during 2008-2013 for all domestic banks are used. Data sources are reported in the appendix.

[15] Data for refer to year 2013.

[16] The model's steady state and log-linearized equation system are contained in a technical appendix available from the authors upon request.

Table 3: Calibrated values of parameters

parameter	value	parameter	value	parameter	value
α	0.485	ζ	0.899	m	0.20
α^*	0.990	ω	0.018	ρ_A	0.85
δ	0.025	λ	0.270	ρ_{AI}	0.85
β	0.996	γ_P	1.500	ρ_m	0.85
ξ	0.750	γ_Y	0.500	ρ_{mf}	0.85
ϕ	4.510	ρ_R	0.800	ρ_Z	0.85

5.2 Calibration

In extant studies such as Galí and Monacelli (2005), and Christoffel, Coenen and Warne (2008), openness $(1-\alpha)$ is calculated by the 'import/GDP' ratios. However, in this model the degree of openness is defined as the steady state level of 'import/final goods production' (Y_F/Z). Using the data, the home bias parameters for home and foreign country (α and α^*) are calibrated as 0.485 and 0.990 respectively.[17]

In the financial intermediary sector, the quarterly excess return from borrowing and lending is derived as 41 basis point (bp) based on the long-run lending-deposit spread, which is higher than 25bp in Gertler and Karadi (2011). Also, the long-run leverage is calculated from the ratio of 'loans to business/net equity' in the aggregate balance sheet of South Korean banks, which yields $\bar{\phi} = 4.51$. The calibrated leverage is higher than that (4.00) in Gertler and Karadi (2011). The fraction of the possible funds diversion (λ) is related to the deposit holder's expected loss when a financial intermediary is at a state of bankruptcy. From the ratio of recovery during the financial crisis bailout since 1998, calibration suggests $\lambda = 0.270$, which is lower than 0.381 of Gertler and Karadi (2013).[18] The corresponding survival ratio of an individual banker (ζ) is 0.899. This means that bankers return final net worth $(N_{x,t})$ from the financial intermediary sector to the households every 9.9 quarters (equal to 1/(1-0.899)) on average.

[17] The home bias of South Korea (α) is derived from output, consumption, investment, government spending, and net exports data. The parameter α^* is derived from South Korea Exports/World GDP.

[18] Among the total amount of South Korean banks bailout regarding the financial crisis in 1997-1998, 44.6% has not been recovered during 1998-2014. Given that 60.6% of total loans are not insured by Korea Deposit Insurance Corporation (KDIC) (2014), the expected loss when an asset (deposit) is in default is calibrated as 27.0%.

Using the CPI, the long-run quarterly inflation rate ($\bar{\Pi}$) is calibrated as 1.0067 which means the annual inflation rate is 2.70% at the steady state. Using the data of the deposit rate, the long-run nominal interest rate ($\bar{R}$) is determined at 1.0107, which yields the corresponding discount rate ($\beta = 0.996$) and the real interest rate ($\bar{r} = 1.004$). In the monetary policy rule, the smoothing parameter ρ_R is 0.8 following Gertler and Karadi (2013). For the weights on the output gap and the inflation rate, the parameter values of Taylor (1993) are used ($\gamma_P = 1.5$ and $\gamma_Y = 0.5$). The annual depreciation ratio of capital is 10% ($\delta = 0.025$) and the price stickiness parameter (ξ) is 0.75. In household preference, the relative weight given to the disutility of labour (ν) is unity. The tax rate (m) is 0.20 such that 'government spending/GDP ratio' in the model fits the average ratio of it during the sample period (14.7%). Using the long-run levels of net worth of the financial intermediary sector, the leverage, and net foreign assets (NFA), the steady state ratio of b_H/b_F is determined at 1.98. For exogenous variables, the coefficient parameters, $\rho_A, \rho_{AI}, \rho_m, \rho_{mf}$ and ρ_Z, are 0.85 following Kolasa and Lombardo (2014). Table 3 summarizes the calibrated values of the baseline parameters.

5.3 Bayesian Estimation

A Bayesian estimation is performed for the second moments of the five exogenous shocks and for seven parameters which are not calibrated.[19] These parameters are: (i) the share of the capital income in production (ψ), (ii) consumer's preference parameters (σ and χ), (iii) elasticities of substitution between intermediate goods (ε), and between home and foreign intermediate goods (θ), (iv) the investment adjustment cost (μ_I), and (v) the international assets holding cost (μ_T).

For the Bayesian approach, the Metropolis-Hastings algorithm (MH) is used with 50,000 draws. The first three columns of Table 4 provide the assumptions regarding the prior distributions of the parameters and the exogenous shocks. The share of the capital income (ψ) is assumed to have a beta distribution with a mean 0.33. Following Christoffel, Coenen and

[19]We estimate these seven parameters because of the lack of availability of reliable estimates for South Korea. Identification of the parameters and the second moments of the shocks are verified by the visual inspection of the plots of information matrix. The details of these graphs are available in a technical appendix available from the authors upon request.

Table 4: Bayesian parameter estimates

	Prior Distribution			Posterior Distribution				
	Type	Mean	St.error	Mode	Median	Mean	5%	95%
ψ	beta	0.33	0.02	0.383	0.381	0.381	0.356	0.405
σ	normal	1.50	0.30	2.161	2.191	2.194	1.934	2.462
χ	normal	1.00	0.30	1.346	1.300	1.303	0.841	1.754
ε	gamma	6.00	1.00	6.827	6.921	6.998	5.354	8.539
θ	gamma	1.50	0.30	0.849	0.867	0.870	0.763	0.964
μ_I	gamma	4.00	0.50	2.968	3.035	3.043	2.566	3.587
μ_T	gamma	0.30	0.03	0.221	0.224	0.226	0.184	0.272
SE of ε_A	inv.gamma	0.10	-	0.110	0.113	0.113	0.097	0.130
SE of ε_{AI}	inv.gamma	0.10	-	0.283	0.284	0.285	0.244	0.322
SE of ε_m	inv.gamma	0.10	-	0.013	0.013	0.013	0.012	0.014
SE of ε_{mf}	inv.gamma	0.10	-	0.037	0.038	0.038	0.031	0.044
SE of ε_{zf}	inv.gamma	0.10	-	0.081	0.083	0.084	0.071	0.097

* Note: SE denotes standard errors.

Warne (2008), the prior mean of the elasticity of substitution between home and foreign goods (θ) is 1.5 and that of the investment adjustment cost (μ_I) is 4 with gamma distributions. As in Kollmann (2002), the prior mean of ε is 6 with a gamma distribution. Household preference parameters σ and χ have means 1.5 and 1.0 with normal distributions. The prior mean of the international assets holding cost (μ_T) is 0.3. All the standard errors (SE) of the shocks are assumed to have inverse gamma distributions.

The modes of the posterior distributions are significantly different from the prior distributions that suggest that enough information is extracted from the data to compute the posterior means. Figures 2 plots the prior versus posterior distributions. The posterior mean of ψ is 0.38 during the sample period which means that capital has a share more than the conventional level, 0.33. The elasticity of substitution between home intermediate goods is lower ($\varepsilon = 7.00$) than the prior mean, and the elasticity of substitution between home and foreign goods (θ) is 0.87. The posterior mean of the investment adjustment cost parameter (μ_I) is 3.04, and for the international holding cost parameter (μ_T), it is 0.23. Regarding consumer's preference, both σ and χ have means higher than unity, 2.19 and 1.30, respectively.

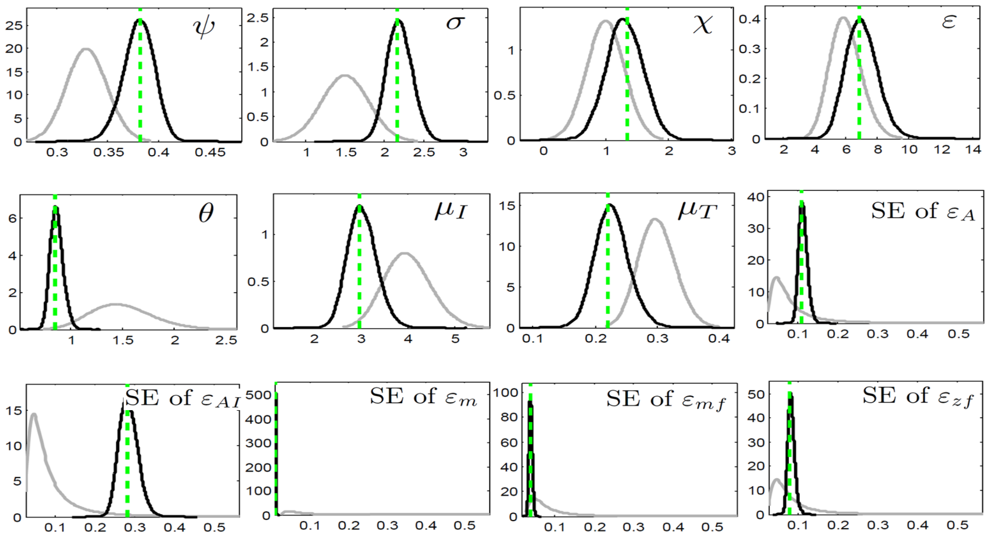

Figure 2: Prior and posterior distributions

6 Impulse Response Analysis

6.1 Effect of a Foreign Interest Rate Shock

Given that the relationship between home and foreign monetary policies is the focal point of attention in this paper, we report the results of impulse responses of home macroeconomic variables with respect to the foreign policy rate shock only. Figure 3 reports the Bayesian impulse responses with respect to a negative foreign policy rate shock. The figure illustrates the mean responses (solid line) with the 5 and 95 per cent confidence bands (dotted line).

We explain here only the impact effects of a negative foreign rate shock. The lower foreign rate induces home households to decrease their foreign assets holdings. Moreover, the nominal exchange rate initially declines following the modified UIP condition[20] which lowers the real exchange rate (home currency appreciation).[21] Consequently, the relative price of home produced goods rises, and this lowers exports, while boosting imports (expenditure switching effect). The fall in net exports then reduces home output. On the other hand, home inflation declines, as the drop in import price inflation (Π_F) drags it down. The decline

[20]In the modified UIP condition (37), a negative shock on R_t^* puts downward pressure on $b_{F,t}^d$ and $\mathcal{E}_t$.

[21]Our results differ from Banerjee and Basu (2016). In Banerjee abd Basu, lower foreign interest rate makes the home currency depreciate via the UIP condition. In our setting, home currency initially appreciates because home households lower their foreign asset holding which depresses the asset transaction cost. This endogenous change in foreign asset holding via the modified UIP condition is absent in Banerjee and Basu (2016).

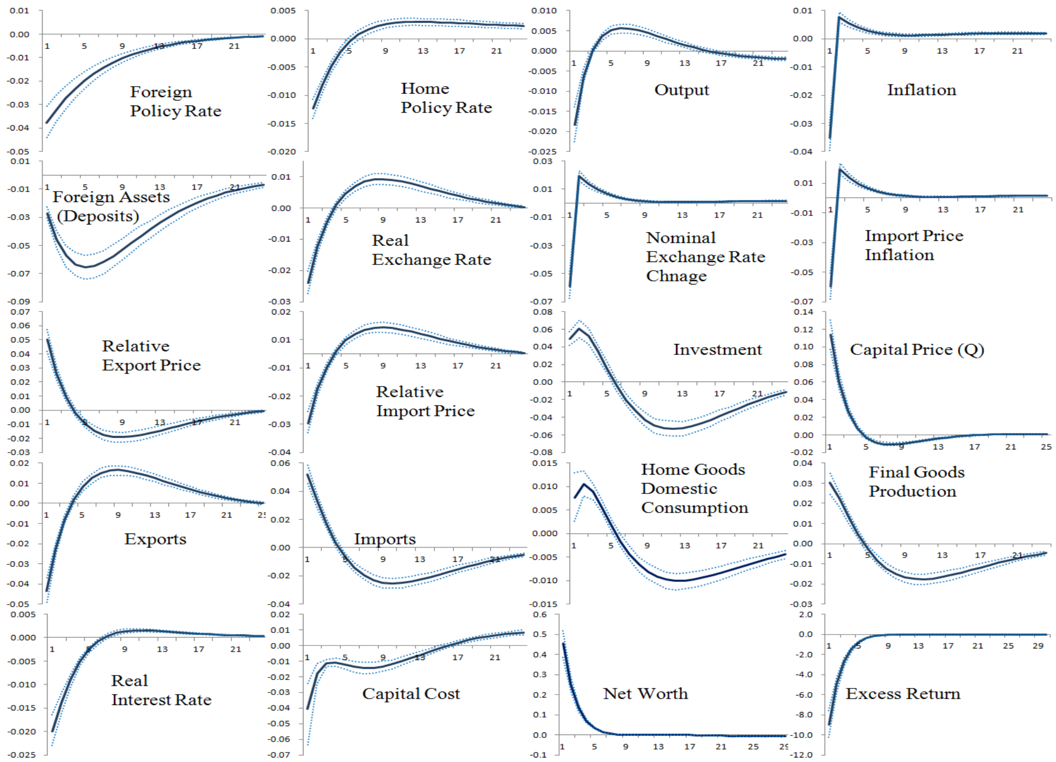

Figure 3: Responses to foreign policy shock: Baseline model

in the import price is caused by the home currency appreciation. Following the policy rule which responds to home output and inflation, the home central bank lowers its policy rate.

As the amount of imports of intermediate inputs increases, final goods production (Z) rises, thus boosting investment. The unanticipated increase in investment raises the capital price (Q), and as a result the balance sheet of the entrepreneur sector expands; the amount of net worth increases and the excess return on claims ($E(r_S) - r$) falls. This raises investment and the capital price further (financial accelerator). The higher level of Q lowers the intermediate goods producers' capital hiring costs.[22]

6.2 Comparative Statics of Impulse Responses

In this section, we study the effects of a parameter value change or model modification on the monetary policy relationship. All other parameters are fixed at the calibrated or estimated levels. There is a negative 1% foreign policy rate shock.

[22]The producer's capital hiring cost is $r_{K,t} = r_{S,t}Q_{t-1} - (1-\delta)\,Q_t$.

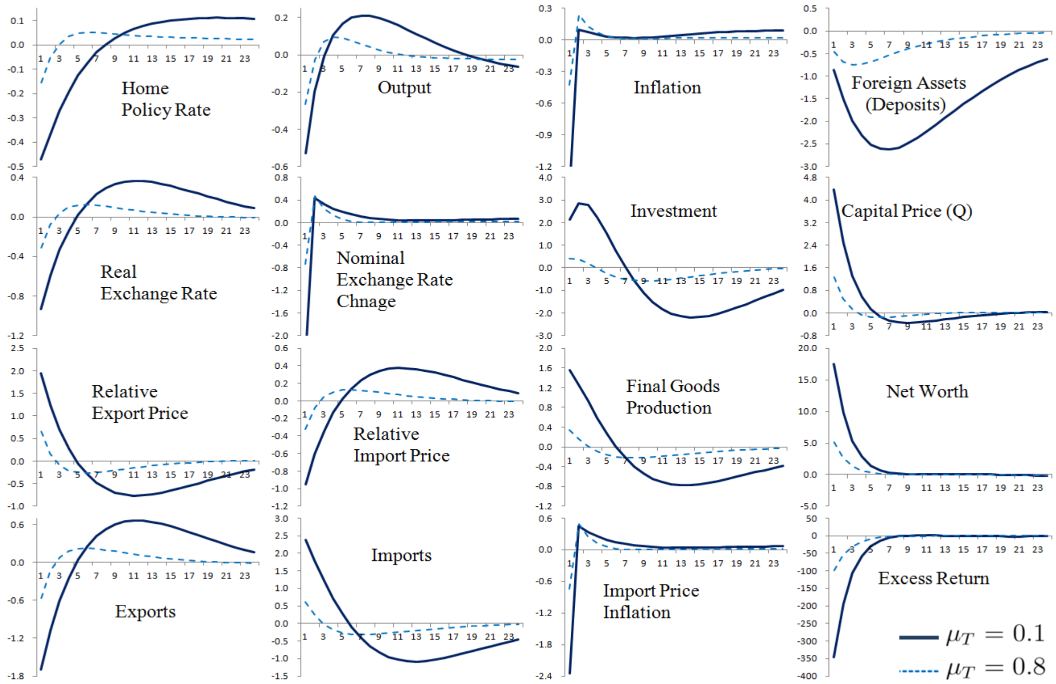

Figure 4: Responses to foreign policy shock: Different foreign assets holding costs

6.2.1 Effect of a Change in the International Assets holding Cost

The level of the international assets holding cost is represented by the parameter μ_T in the equation (32). The effect of a change in this cost on the impulse responses to a foreign rate shock is illustrated by Figure 4. The result indicates that the lower international assets holding cost ($\mu_T = 0.1$) makes the home policy rate follow the foreign rate more aggressively than the higher cost case ($\mu_T = 0.8$).

When the international assets holding cost is lower, home and foreign bonds are closer substitutes so the home agents' foreign assets holding decreases more in response to a negative foreign interest rate shock. Moreover, the nominal and the real exchange rates decline more significantly; the relative import and export prices also change more. This leads to a stronger expenditure switching effect and a greater decrease in net exports. Import price inflation also falls rapidly following the nominal exchange rate change. As a result, home output and inflation decline more sharply. Following the monetary policy rule, the home central bank responds by cutting the policy rate more. This implies that the co-movements of policy

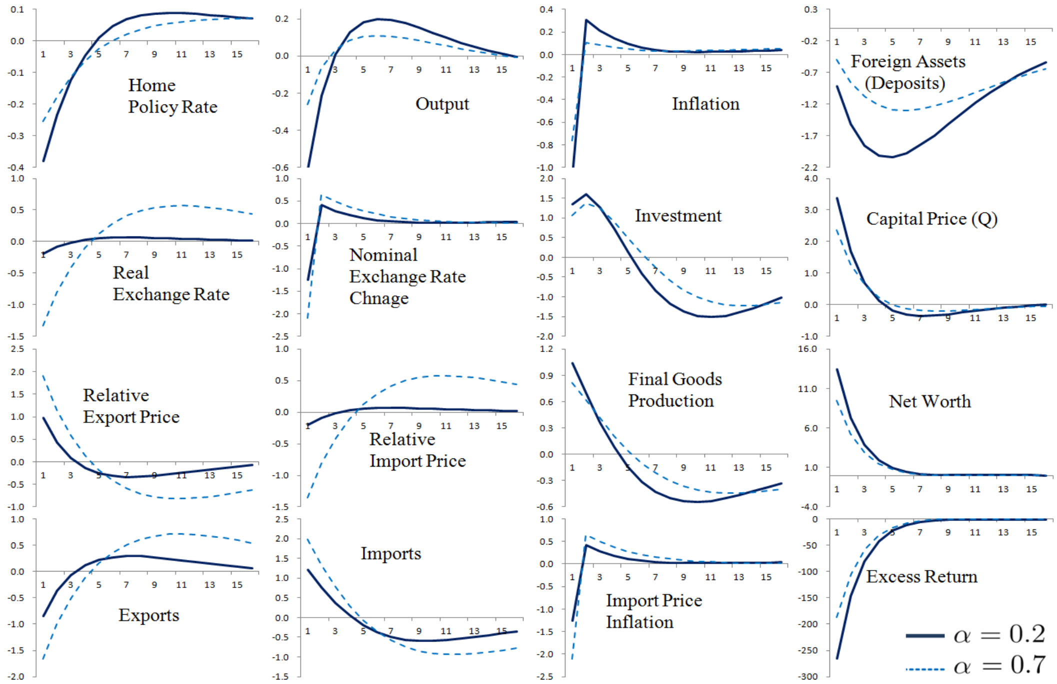

Figure 5: Responses to foreign policy shock: Different openness

rates become more significant as the financial markets are more globalized and international investment becomes easier.

6.2.2 Effect of a Change in Openness

The impulse responses in two different openness environments are compared in Figure 5. When the degree of home openness is higher ($\alpha = 0.2$) or the home bias is lower, a fall in net exports yields a sharp decline in home output, inducing a stronger expenditure switching effect. Even though the exports and imports changes are smaller in terms of the deviation from the steady state, the larger portion of trade in the home economy leads to a greater decline in output than the other case with lower openness ($\alpha = 0.7$).

When the amount of of imports is larger, downward pressure of the fall in the import price on the home inflation rate becomes stronger. Therefore, home inflation declines more with higher openness. Combined with the fall in output, this leads to a more aggressive home policy rate cut. Higher openness strengthens the correlation between the home and the foreign policy rates when there is a foreign policy shock.

With higher openness, the rise in imports yields a further increase in final goods production; this raises investment, and the capital price rises more. Thus, net worth rises and the excess return drops more significantly. As trade volume is larger, home agents' foreign assets holding decreases more in response to the fall in net exports. This dampens the decline in the nominal and the real exchange rates.[23]

6.2.3 Effect of Aggressive Monetary Policy

Inflation Targeting

Since inflation targeting was initially adopted by New Zealand in 1989, many central banks have established the inflation-targeting frameworks.[24] Given that still many central banks are in the process of adopting inflation-targeting regimes, it is meaningful to investigate the effect of such a policy framework on the policy relationship.

The sensitivity analysis is performed with different degrees of inflation targeting, as illustrated by Figure 6(a). The aggressiveness of targeting is measured by the parameter γ_P in the policy rate rule equation with two different values: (i) strong targeting with $\gamma_P = 2.5$ and (ii) weak targeting with $\gamma_P = 1.2$. In response to a negative foreign rate shock, the home central bank with strong inflation targeting cuts its policy rate more aggressively than the case of weaker inflation targeting, and hence the co-movement between foreign and home policy rates is stronger when inflation targeting is stronger.

Policy Rate Smoothing

Central banks prefer smaller and frequent changes of the target interest rates. However, when there is a financial turmoil, as explained in Gertler and Karadi (2011), the central bank might abandon the gradualism in order to cope with rapid changes in macroeconomic circumstances. Mishkin (2011) also argues that when a financial market disruption occurs,

[23]In the modified UIP (37), a further decrease in $b^d_{F,t}$ puts upward pressure on $\mathcal{E}_t$.

[24]In the first half of 1990s, Canada, Israel, UK, Australia and Sweden joined the inflation-targeting regime. During 1997-2002, 15 more countries adopted inflation-targeting: Czech, Poland, South Korea, Brazil, Chile, Colombia, South Africa, Thailand, Hungary, Iceland, Mexico, Norway, Ghana, Peru and Philippine (Hammond, 2012).

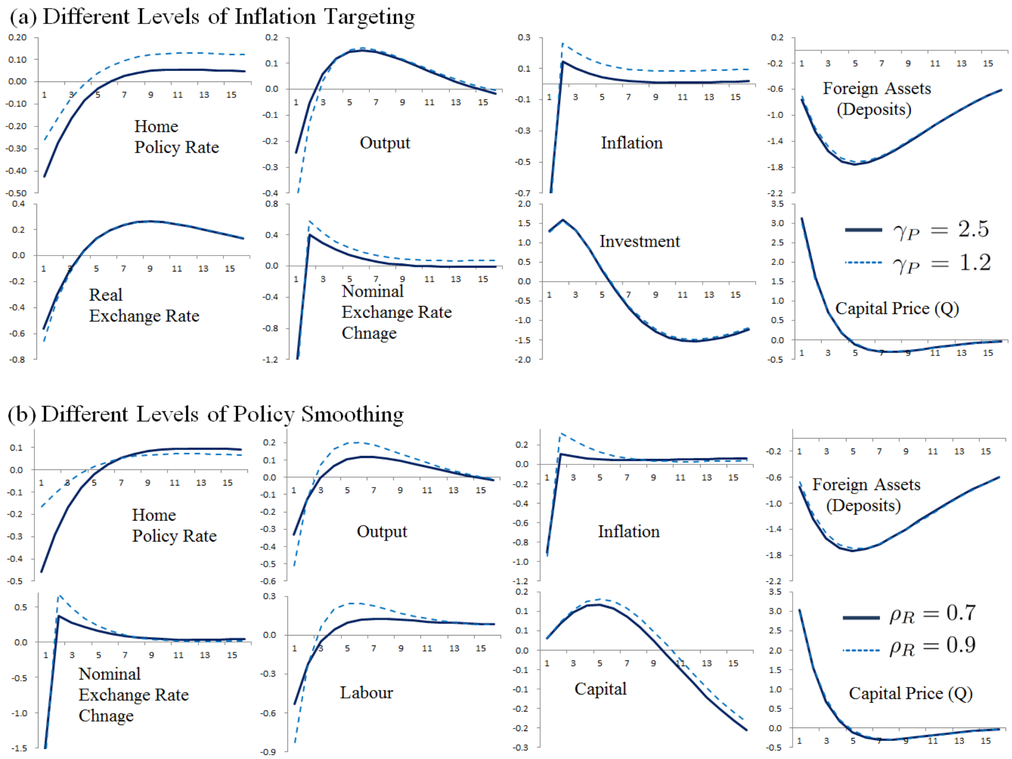

Figure 6: Effects of aggressive inflation targeting and policy smoothing

the optimal monetary policy shows much less smoothing than that in other circumstances.

Given this, the effects of different levels of monetary policy smoothing are investigated. Figure 6(b) indicates that the home policy rate is influenced by the foreign policy rate more when the central bank adjusts its rate quickly ($\rho_R = 0.7$), rather than taking gradual steps ($\rho_R = 0.9$). In the less smoothing case, the home central bank responds to the foreign rate cut by lowering its policy rate more, which leads to a strong co-movement between the home and the foreign rates. Being influenced by the aggressive policy change of the home central bank, many of the home economic variables show less fluctuations, such as the output, inflation and the nominal exchange rate.

6.2.4 Effect of the Financial Friction

The financial friction strengthens the co-movements of the home and the foreign policy rates. This is related to the financial accelerator, which amplifies the movements of investment and the asset price through the changes in entrepreneurs' net worth and the excess return on the

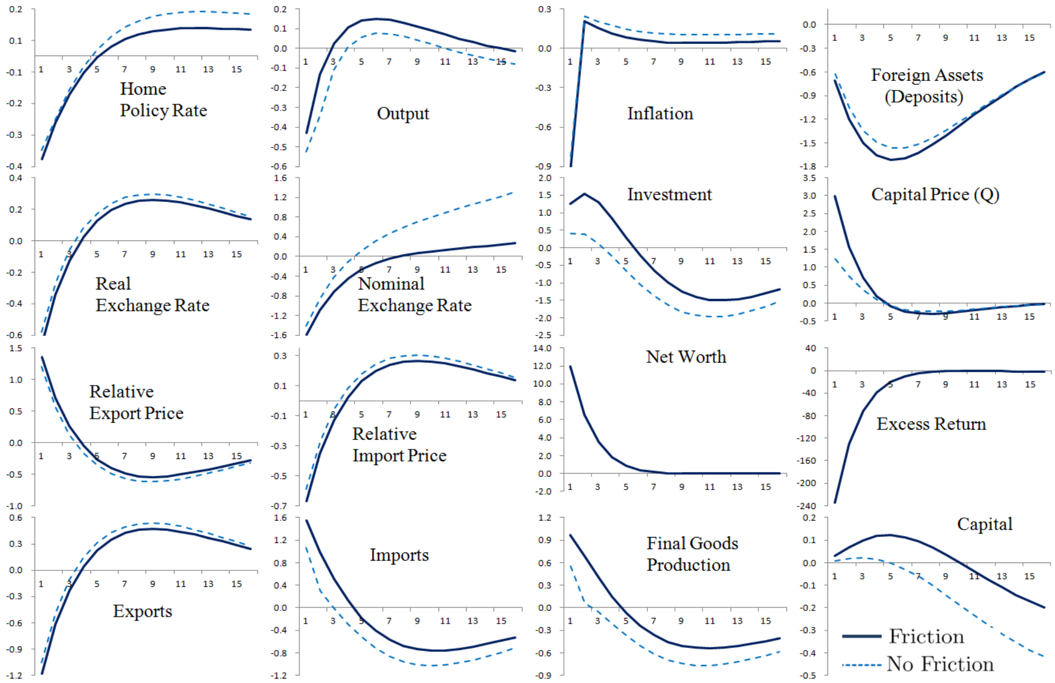

Figure 7: Responses to foreign policy shock: Effects of financial friction

claims $(E_t(r_{S,t+1}) - r_t)$. Two cases are compared in Figure 7: *with* and *without* the financial friction. Although Figure 7 gives only a slight indication of the effect of the friction, Table 5 below will give further evidence.

Without the friction, financial intermediaries simply intermediate funds without the agency problem, and the excess return remains zero $(E_t(r_{S,t+1}) = r_t)$.[25] With the friction, the foreign policy rate cut lowers the home excess return, as the unanticipated increase in investment and the following rise in the asset price boost entrepreneurs' balance sheets; the expansion of net worth forces down the excess return. The fall in the excess return then lowers the cost of capital and raises capital demand more. This leads to further increases in investment and the asset price (financial accelerator).

The additional increase in investment requires more final goods (Z) in the home economy, which yields a further decline in exports and a rise in imports - a larger drop in net exports. The international asset market clearing condition leads to a more significant fall in the foreign

[25]Without the financial friction, the financial intermediaries are assumed to have no net worth, which means $Q_t S_t = r_t^{-1} b_{H,t}$.

Table 5: Correlation coefficient between R_t and R_t^* with a foreign rate (R_t^*) shock

Case		Corr(R_t, R_t^*)	Case		Corr(R_t, R_t^*)
International	High	0.06	Inflation Targeting	Weak	0.09
Transaction Cost	Low	0.63		Strong	0.66
Openness	Low	0.42	Policy Smoothing	Strong	0.17
	High	0.43		Weak	0.49
Financial Fricion	None	0.16			
	Baseline	0.39			

assets holding (b_F^d). The modified UIP suggests that, given the decline in R^*, the greater fall in b_F^d puts downward pressure on the exchange rate changes ($\Delta\mathcal{E}$), and as a result the nominal and the real exchange rates remain lower with the financial friction.[26] As higher home currency value lowers the relative import price, home inflation remains below the level without the financial friction; the home central bank keeps its policy rate lower. This makes the home policy rate closer to the foreign policy rate.

6.3 Correlation between Home and Foreign Rates

The co-movement of home and foreign rates when there is a foreign rate shock is the center of attention in this paper, since it demonstrates the relationship between them. A summary measure of the co-movement is the correlation coefficient between home and foreign rates with a foreign rate shock. Table 5 reports the results of the sensitivity analysis with different parameters.

In the baseline model, with a foreign rate shock the correlation coefficient between home and foreign rates is 0.39. This correlation is substantial but smaller than the values in Table 1: our model explains part of the correlation that we see in the data, but not all. With the lower international assets transaction cost the correlation coefficient is higher (0.63) than the higher cost case (0.06). Also, as openness of the home economy is higher the correlation is marginally stronger (0.43) than the lower openness case (0.42). When the home central bank adopts more aggressive inflation targeting the correlation is higher (0.66) than weaker

[26]The modified UIP condition is given by $\hat{R}_t = \hat{R}_t^* + E_t\left(\widehat{\Delta\mathcal{E}}_{t+1}\right) - \mu_T \hat{b}_{F,t}$ (38). As $b_{F,t}^d$ becomes lower, the nominal exchange rate increase ($\Delta\mathcal{E}$) is smaller. The nominal exchange rate in the figure 7 is derived from $\hat{\mathcal{E}}_t = \sum_{\tau=1}^{t} \widehat{\Delta\mathcal{E}}_\tau$ since $\mathcal{E}_t$ is not stationary.

targeting case (0.09). Weaker policy smoothing leads to a higher correlation (0.49). Finally, without the financial friction the coefficient is lower (0.16) than the baseline model (0.39).

7 Conclusion

During recent decades many emerging countries' central banks apparently followed the interest rate policies of major central banks such as the US Fed and the ECB. In this paper, we investigate the factors that strengthen the relationship between the policy rates of different central banks. We develop a DSGE model to address this question. Using an open economy model with a standard inward-looking Taylor rule of the home country, we argue that such a relationship between foreign and home policy rates could emerge through the terms of trade channel that affects output and the inflation rate of the home economy via the expenditure switching effect.

We identify five conditions under which our DSGE model exhibits a stronger relationship between home and foreign policy rates, namely (a) a lower international assets transaction cost, (b) greater openness of the home country, (c) more aggressive home inflation targeting, (d) less policy rate smoothing by the home central bank, and (e) a larger banking friction in the home economy. Our paper is one of the very few in the extant literature which blends domestic financial frictions in an open economy DSGE model to understand monetary policy relationship between countries.

A future extension of this paper would be to add a borrower's moral hazard problem in the model along the lines of Bernanke, Gertler and Gilchrist (1999). Such an extension could provide a useful framework to analyze the international transmission channel of the unconventional monetary policy of leading countries.

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A Appendix

A.1 Data Description

Table 6: List of data sources

Data	Source (code)
Output (GDP)	Datastream: KOGDP...D
Inflation (CPI), Investment	Bank of Korea
Real Exchange Rate	Datastream: KOQCC011H
Government Spending	Datastream: KOCNGOV.D
Consumption	Datastream: KOCNPER.D
[Imports, Exports]/Output	The World Bank Data
Net Foreign Assets	The World Bank Data
Certificate Deposit Rate	Datastream: KODPNNCD
Loan-Deposit Spread	The World Bank Data
Bank Balance Sheet	Financial Supervisory Service (FSS Korea)
Bailout and Recovery	Financial Services Commission (FSC Korea)