Bank Globalization and Monetary Policy Transmission in Small Open Economies*

(Job Market Paper Draft)

Inhwan So†

November 17, 2015

Abstract

This paper investigates how the openness of the banking sector influences the transmission channels of domestic and international monetary policy shocks in small open economies. I study these relationships in a small open economy DSGE model enriched with a globalized banking sector. Two forms of bank globalization are considered: international finance of operating funds and import of foreign loan contracts. For a quantitative analysis of the channels linked to each type of bank globalization, I also construct alternative models that allow for different degrees of bank globalization. The comparison between the responses of benchmark and alternative models shows that bank globalization leads to a significant attenuation of domestic monetary policy transmission because, against domestic monetary shocks, banks' global activities help maintain bank rates and loan supplies to some extent in contrast to responses in a financial autarky. However, the opening of the banking sector intensifies the impact of foreign interest rate shocks on local bank activities. In addition to the indirect international monetary spillover through the interest-parity condition, global operation allows banks to adjust loan rates responding directly to foreign monetary shock.

JEL Classification: E32, E44, E52, E58, F36, F62
Keywords: Bank globalization, Monetary policy, Dynamic stochastic general equilibrium model, Small open economies

* I am grateful for valuable comments from Yu-chin Chen, Fabio Ghironi, Ji Hyung Lee, Jongrim Ha and seminar participants at the University of Washington. I gratefully acknowledge the Henry T. Buechel Fellowship for financial support. All remaining errors are my own.

† Correspondence: Department of Economics, University of Washington, Seattle, WA 98195-3330, U.S.A. Tel.: (206) 898-6081 E-mail: ihsoh@uw.edu Homepage: https://sites.google.com/site/inhwan2016

1 Introduction

This paper examines how the openness of the financial sector, particularly of banks, to international capital flows alters the transmission channels of local and international monetary shocks in SOEs. As banking industries become increasingly integrated, banks in small open economies (hereafter "SOEs") broaden their operations in international markets, diversifying funding sources and mediating foreign financial products to domestic consumers.[1] To the extent that financial intermediaries are the important bridges between monetary policy (hereafter "MP") and its macroeconomic policy targets, this changing environment in the banking industry gives rise to active debates about the consequent change of domestic MP transmission in open economies as well as their economic vulnerability to external macroeconomic and financial shocks (e.g., Bernanke 2007, Cetorelli and Goldberg 2012, Bruno and Shin 2015).

The relationship between financial integration and MP transmission is not a new research topic. However, the relevant literature has critical limitations in explaining the consequences of financial integration for MP transmission due to the lack of consideration of the role of the banks in SOEs. Figure 1 shows that financial markets have a higher dependency on banking (Panel A) and that banks play a more vital role in mediating global liquidity to the domestic sector in the financial globalization process in SOEs (Panel B) compared to a large economy, such as the U.S. Furthermore, the banking industry has some distinctive features that differ from direct finance markets. For instance, in most countries, financial supervisory authorities impose regulatory requirements on banks to guarantee financial stability (e.g., capital-asset ratio, macro-prudential measures). Banks also enjoy some degree of market power similar to profit maximizing firms (Freixas and Rochet 1997). However, existing studies on financial integration exclusively focus on the broad issues of capital market openness rather than on the stylized facts regarding the financial markets and the banking sector in SOEs.[2] Therefore, the channels through which bank globalization affects MP transmission are far from being understood despite the importance of the topic in the context of the SOE's MP transmission.

[Insert Figure 1 about here]

[1] Throughout the paper, I consider such entities as global banks and refer to their international activity as bank globalization.

[2] For instance, Woodford (2007) and Tille (2008) analyze the effects of financial globalization on the transmission of monetary shocks without attention to the role of financial intermediaries under the assumption of a frictionless MP transmission through domestic financial markets acting as conventional New Keynesian frameworks.

To bridge the gap and examine the systemic relationship between bank globalization and MP transmission, I set up and estimate a dynamic general equilibrium model incorporating a stylized banking sector into a SOE version of Iacoviello (2005). The most notable feature of the banking sector in my model is that banks operate global banking intermediations through the international interbank market in two forms: financing foreign operating funds and importing foreign loan contracts. Each type of global activity is closely related to banks' decisions on setting interest rates and credit supply. Thus, each activity affects the price (i.e., interest rate) and the quantity (i.e., credit amount) side of the credit market. I then study the effect of openness in the banking sector by comparing the results from alternative models that shut down each globalization channel.

The findings of the estimated DSGE model are as follows. First, bank globalization attenuates local MP transmission. Consider a monetary tightening shock. On one hand, compared to the responses in financial autarky, loan rates increase less in response to a negative monetary shock because banks set these rates by taking into account not only increased domestic policy rates but also unaffected international interest rates (referred to as *foreign interest rate channel*). A lower rise in loan rates first mitigates interest rate channels and alleviates the financial accelerator effect by not reducing the real value of borrowers outstanding debt obligations as much. However, global bank activity deters banks from reducing their loan-issue after a monetary contraction, thereby attenuating the transmission of MP shock (*foreign liquidity channel*). In financial autarky, the decline of deposits following policy rate rises pressures banks to reduce their supplies on bank loans according to the capital-asset ratio. This reduction leads to a decline in household and firms activities. However, the availability of foreign liquidity due to a globalized operation can buffer the shrinkage of bank assets to some extent against negative policy effects.

Second, bank globalization induces bank rates to respond more strongly to foreign MP shocks. In the alternative model without bank globalization factors, foreign monetary shocks affect domestic retail loan rates only *indirectly* through the adjustment of the local policy rate according to a no-arbitrage condition in the foreign exchange market. However, if banks can import foreign loan accounts and thus set loan rates that consider both the domestic policy rate and international interbank rates, a new channel is opened, in addition to the indirect channel, through which foreign monetary surprise can *directly* influence local loan rates. This new channel is supported by the recent empirical findings by Passari and Rey (2015) showing that the response of mortgage spread in SOEs to U.S monetary shocks is positive and of the same order of magnitude as the domestic U.S mortgage spread.

This paper contributes to the literature in the following ways. First, to the best of my knowledge, this paper is the first to demonstrate a direct link between bank globalization and MP transmission under the general equilibrium framework enriched with a stylized banking sector. In addition to globalized banking activities, the model adopts regulatory interventions when obtaining bank liabilities and market power in the banking sector. Over the last decade, a growing number of studies have investigated the role of these features in the banking sector in MP transmission.[3] However, relatively less attention has been paid to how bank globalization alters the channels of MP transmission under the structures, particularly in the theoretical literature. Scholars researching the role of the banking sector in open capital markets are increasingly investigating the role of financial integration in cross-border liquidity shock propagation.[4] Most closely related to my study are the studies of Cetorelli and Goldberg (2012) and Goldberg (2013), who empirically demonstrate that global banks insulate themselves from the impact of monetary surprises through their abilities to raise funds abroad as well as influence MP autonomy heterogeneously, depending on the frictions in the international capital market and the stickiness of claims. Although successful in providing some empirical evidence of the relationship between bank globalization and MP transmission, these researchers do not explain why such a link is formulated and how it affects other sectors, in part because of their partial equilibrium analyses. Conversely, this paper investigates the overall change in the supply side of the credit market to uncover the role of bank globalization in MP transmission in a general equilibrium framework.

Second, this paper provides subdivision and quantitative assessment of the effects of bank globalization on MP transmission. The link between bank globalization and MP transmission is ambiguous *a priori* in the sense that bank globalization involves an adjustment of banks' overall conditions for money mediation.[5] Two sets of global banking activity, loan contract import

[3] A burgeoning literature sheds light on the conditions from the supply side (i.e. financial intermediaries) of credit markets (Van den Heuvel 2008, Gerali et al. 2010). These studies demonstrate the channels in which typical MP transmission can be distorted by credit frictions embedded in the process of financial intermediaries money mediation, such as the regulatory capital-to-asset ratio (*bank capital channel*) and/or the degree of banking market competition (*bank attenuator channel*).

[4] See recent work on the international transmission of crises by Schnabl 2012, Kalemli-Ozcan, Papaioannou and Perri 2013, Devereux and Yu 2014, Kang and Dao 2012 and others.

[5] For instance, in the open banking market, banks do not necessarily rely on the domestic credit in their

and foreign liquidity borrowing, allow us to determine the effects of banking sector openness on the price and the quantity, respectively. By determining these effects, this study shows how bank globalization affects MP transmission and which channel is dominant. By contrast, existing studies that incorporate a banking sector into the model usually consider only one side, thereby providing a limited persective for understanding the overall features of change caused by bank globalization (e.g., *quantity side*: Kollmann 2013, Kang and Dao 2012, *price side*: Brzoza-Brzezina and Makarski 2011).

The rest of this paper is organized as follows. Section 2 presents empirical evidence on bank globalization using a VAR model. Section 3 describes the baseline SOE DSGE model. Section 4 discusses the calibration/estimation procedure. Section 5 provides an overview of the transmission mechanism of MP shocks through the banking sector and the results of domestic and foreign MP restriction. Section 6 concludes the paper.

2 Vector Autoregressive (VAR) Analysis

Before describing the theoretical channels of the interaction between bank globalization and MP transmission, this section first documents the key relationships in data by presenting VAR evidences.

The VAR model is composed of foreign (the U.S.) policy rates, logs of seasonally adjusted industrial production, logs of domestic consumer price indexes, domestic policy rates, short-term (3-month) interest rates, bank lending rates, and logs of nominal exchange rates.[6] The three focal countries - the U.K., Korea, and Canada - represent open economies that depend heavily on foreign economies from both real economic and financial market perspectives.[7] These SOEs are more largely dependent upon the banking sector in intermediating credit domestically and internationally than the U.S., as depicted in Figure 1. Furthermore, these countries have adopted inflation targeting regimes and used short-term interest rates as MP operating instruments. For the purpose of comparing the empirical results, I also estimate a SVAR model with U.S. data

operation. This may change their strategies on interest rate setting and capital position.

[6]The variables are specified in levels to implicitly determine any potential co-integrating relationship between them. See Hamilton (1994).

[7]To identify a stable MP regime, the following quarterly data are used for each country: the U.K. (1997Q1∼2013Q4), Korea (1999Q1∼2013Q4), and Canada (1996Q1∼2013Q4). The lag order is determined by two quarters for all focal countries according to various information criteria.

as a benchmark. Additionally, following procedures employed in the literature, four external variables are included to isolate exogenous latent factors that may influence endogenous variables in the VAR system simultaneously: the international commodity price index, a crisis dummy, the CBOE volatility index, and the dollar index (e.g., Kim 2001 and Bjørnland 2009).

I use a standard Cholesky decomposition to identify VAR (ordered listed as above).[8] For ease of comparison, I graph all of the impulse responses of the interest rates to one percentage point of domestic MP shock in each panel in Figure 2. Overall, the scales of the effect are shown to be smaller in bank loan rates (red line) than those in policy rates (black line) and short-term rates (blue line) at the time of a contractionary MP shock in SOEs. Notably, this feature is distinct from the responses in the U.S. (Panel A) where loan rates react similarly to the movement of the federal fund rate. To shed light on this situation, Figure 3 compares the responses of loan rates in SOEs with those in the U.S. on a contractionary monetary shock. The shaded area plotted in the graph is the 90% bootstrap probability band. The transmission of MP shock to loan rates in SOEs is significantly smaller than in a large closed economy, such as that of the U.S. for the first two quarters. The fact that the bank rates react less to policy shock could be because the banking sector in focal countries has some degree of market power (Gerali et al. 2010, Ha and So 2013). However, as we shall see in Section 5, the attenuation of MP transmission in banking could also appear due to the bank's global activity.

[Insert Figure 2 about here]

[Insert Figure 3 about here]

Figure 4 plots the impulse responses of the domestic policy rate (black line) and loan rates (red line) to one percentage point of foreign (U.S.) MP shock. Many open economy studies typically assume that foreign monetary shocks transmit internationally through the adjustment of short-term rates in a SOE according to interest rate parity (Obstfeld and Rogoff 1995, Kim 2001). Considering the international transmission channel as well as the frictions in the banking sector found above, the response of loan rates to foreign monetary shock is predicted to be less than that of the home policy rate (foreign MP shock $\rightarrow$ SOE policy rate $\rightarrow$ (frictions) $\rightarrow$ SOE loan rates). However, the result of VAR seems to be inconsistent with the prediction of this

[8] I test the robustness of the identifying short-run restriction by specifying an alternative Cholesky decomposition, where the SOE's interest rates change order considering the simultaneity issues raised among financial variables (Gertler and Karadi 2015, Bjørnland 2009).The results remain robust to these variations.

framework. Loan rates in SOEs respond to foreign MP shock as much as policy rates in the U.K. where its response is lower than the policy rate. This result may indicate the presence of additional channels of international monetary transmission (foreign MP shock $\rightarrow$ SOE loan rates) besides indirect transmission through the SOE policy rate. A theoretical model will be described in next section.

[Insert Figure 4 about here]

3 Model

The world economy is composed of a continuum of SOEs that are represented by the unit interval. Each SOE is populated by patient households, impatient households, entrepreneurs, and banks, with each group having a unit mass. Households consume, work, accumulate housing stock, and make one-period deposits (patient households) or loans (impatient households).[9] Entrepreneurs produce homogenous intermediate goods using capital, real estate, and labor supplied by households. Furthermore, entrepreneurs can also borrow from banks to finance capital purchases. In between the households and the entrepreneurs, banks intermediate funds by supplying financial assets while enjoying some degree of market power. They give out collateralized loans to both impatient households and firms, and obtain funding via deposits and foreign liquidity borrowing.

[Insert Figure 5 about here]

Three types of frictions coexist and interact in the financial sector. First, when having a bank loan, agents face a collateral constraint that is tied to the present value of housing stock holdings. Second, banks are credit constrained in how much they can raise from home savers and foreign economies. Third, due to a bank's market power, bank rates on loans and savings are set differently from the interbank interest rate, which is controlled by the central bank.

Furthermore, I consider two forms of bank globalization. First, banks import foreign loan contracts in the international market. Thus, banks set retail loan rates based on both the domestic and foreign interbank rates. Second, banks can raise foreign liquidity to accommodate the expansion of credit demand.

[9] I consider heterogeneity in households to apply financial frictions to both firms and households (e.g. Iacoviello 2005, Gerali et al. 2010). Under the assumption of different agents' discount factors, this set-up allows positive flows of fund among agents (patient households $\rightarrow$ banks $\rightarrow$ impatient households and entrepreneurs).

3.1 Patient Households

A continuum of patient households consume composite good $c_{P,t}$ and housing $h_{P,t}$, deposit d_t, and supply labor $n_{P,t}$. The expected lifetime utility of a representative patient household is given as:

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\ln c_{P,t} + j_t \ln h_{P,t} - (n_{P,t})^\eta / \eta\right] \tag{1}$$

where E_0 is a conditional expectation at t=0, β_P is the utility discount factor and η is the elasticity of marginal utility of labor. j_t is a random variable that is introduced to reflect the change in housing preference, which follows an AR(1) process with i.i.d. normal innovations such as Eq (2):

$$lnj_t = (1 - \theta_j) \ln j + \theta_j \ln j_{t-1} + \varepsilon_{j,t} \tag{2}$$

The patient households use labor income $w_{P,t}n_{P,t}$ and dividend income $\Pi_{P,t}^E$ and $\Pi_{P,t}^B$ generated from owning firms and banks, respectively, as well as its real interest income $R_{d,t-1}d_{t-1}/\pi_t$ to finance its consumption, housing expenditure and new deposits. The patient households face the following budget constraint:

$$c_{P,t} + q_t h_{P,t} + d_t \leq w_{P,t} n_{P,t} + q_t h_{P,t-1} + \frac{R_{d,t-1}}{\pi_t} d_{t-1} + \Pi_{P,t}^E + \Pi_{P,t}^B \tag{3}$$

where q_t and $\pi_t (\equiv P_t/P_{t-1})$ denote, respectively, the price of housing and the inflation rate. Solving this problem yields first-order conditions for the consumption Euler equation, housing demand and labor supply:

$$\frac{1}{c_{P,t}} = E_t \left[\frac{\beta_P}{c_{P,t+1}} \frac{R_{d,t}}{\pi_{t+1}}\right] \tag{4}$$

$$\frac{q_t}{c_{P,t}} = \frac{j_t}{h_{P,t}} + E_t \left[\beta_P \frac{q_{t+1}}{c_{P,t+1}}\right] \tag{5}$$

$$w_{P,t} = (n_{P,t})^{\eta-1} c_{P,t} \tag{6}$$

Notice that the consumers' consumption aggregate is determined as a constant elasticity of substitution (CES) index composed of both home c_t^H and import goods c_t^F [10]:

$$c_t = \left[a^{\frac{1}{\omega}} \left(c_t^H\right)^{\frac{\omega-1}{\omega}} + (1-a)^{\frac{1}{\omega}} \left(c_t^F\right)^{\frac{\omega-1}{\omega}}\right]^{\frac{\omega}{\omega-1}}$$

where a and $\omega > 0$ are the home bias parameter and elasticity of substitution (EOS) between home and import consumption goods. Given the CES aggregator, the demands for domestic goods and imports are:

$$c_t^H = a\left(\frac{P_t^H}{P_t}\right)^{-\omega} c_t \text{ and } c_t^F = (1-a)\left(\frac{P_t^F}{P_t}\right)^{-\omega} c_t$$

where the corresponding price index is:

$$P_t = \left[a\left(P_t^H\right)^{1-\omega} + (1-a)\left(P_t^F\right)^{1-\omega}\right]^{\frac{1}{1-\omega}}.$$

3.2 Impatient Households

Similar to patient households, impatient households consume goods and housing and supply labor. $c_{I,t}$, $h_{I,t}$, and $n_{I,t}$ are impatient households' consumption, housing and labor supply, and they maximize the following expected utility:

$$E_0 \sum_{t=0}^{\infty} \beta_I^t \left[\ln c_{I,t} + j_t \ln h_{I,t} - (n_{I,t})^{\eta}/\eta\right] \tag{7}$$

However, impatient households borrow money from banks $b_{I,t}$ to finance consumption and pay the real interest cost of loans in the previous period $R_{bI,t-1} b_{I,t-1}/\pi_t$ and can borrow only up to the expected real value of their housing stock. The budget constraint and the borrowing constraint are:

$$c_{I,t} + q_t h_{I,t} + \frac{R_{bI,t-1}}{\pi_t} b_{I,t-1} \leq w_{I,t} n_{I,t} + q_t h_{I,t-1} + b_{I,t} \tag{8}$$

$$R_{bI,t} b_{I,t} \leq m_I E_t \left[q_{t+1} h_{I,t} \pi_{t+1}\right] \tag{9}$$

[10]Composites for domestic and foreign goods are defined as $c_t^H = \left[\int_0^1 \left(c_t^H(z)\right)^{\frac{\varepsilon^H-1}{\varepsilon^H}} dz\right]^{\frac{\varepsilon^H}{\varepsilon^H-1}}$ and $c_t^F = \left[\int_0^1 \left(c_t^F(z)\right)^{\frac{\varepsilon^F-1}{\varepsilon^F}} dz\right]^{\frac{\varepsilon^F}{\varepsilon^F-1}}$ which denote varieties, and $\varepsilon^H, \varepsilon^F > 1$ is the EOS across goods. For simplicity, the model does not distinguish between EOS between individual goods and EOS between home and import goods (Obstfeld and Rogoff 1995).

where m_I is household's loan-to-value (LTV) ratio. The first-order conditions of impatient households are consumption, housing choice and labor supply:

$$\frac{1}{c_{I,t}} = E_t\left[\frac{\beta_I}{c_{I,t+1}}\frac{R_{bI,t}}{\pi_{t+1}}\right] + \lambda'_{I,t}R_{bI,t} \tag{10}$$

$$\frac{q_t}{c_{I,t}} = \frac{j_t}{h_{I,t}} + E_t\left[\beta_I\frac{q_{t+1}}{c_{I,t+1}} + \lambda'_{I,t}m_I q_{t+1}\pi_{t+1}\right] \tag{11}$$

$$\frac{w_{I,t}}{c_{I,t}} = \left(n_{I,t}\right)^{\eta-1} \tag{12}$$

$\lambda'_{I,t}$ is the Lagrangian multiplier of impatient households' borrowing constraint.

3.3 Entrepreneurs

Entrepreneurs draw utility only from their consumption $c_{E,t}$, and their utility function has the following form:

$$E_0\sum_{t=0}^{\infty}\beta_E^t \ln c_{E,t} \tag{13}$$

Entrepreneurs produce homogeneous intermediate goods $y_{W,t}$ with labor hired from households plus capital k_t accumulated through investment activities and real estate $h_{E,t}$ using a Cobb-Douglas type production function as expressed by Eq (14). Here A_t is total factor productivity, which follows an exogenous AR(1) process.[11]

$$y_{W,t} = A_t\left(k_{t-1}\right)^{\mu}\left(h_{E,t-1}\right)^{\upsilon}\left[\left(n_{P,t}\right)^{\alpha}\left(n_{I,t}\right)^{1-\alpha}\right]^{1-\mu-\upsilon} \tag{14}$$

To finance their expenditure on consumption, real estate, labor services, capital accumulation and repayment of debt, entrepreneurs use the revenue from their output sales and new loans $b_{E,t}$:

$$c_{E,t} + i_t + w_{P,t}n_{P,t} + w_{I,t}n_{I,t} + q_t h_{E,t} + \frac{R_{bE,t-1}}{\pi_t}b_{E,t-1} + \xi_{K,t} \leq \frac{y_{W,t}}{x_t} + q_t h_{E,t-1} + b_{E,t} \tag{15}$$

where $i_t\,(= k_t - (1-\delta)\,k_{t-1})$ is investment, $x_t\,(= P_t/P_{W,t})$ is the markup of final over intermedi-

[11] The autoregressive coefficient is θ_A, and the standard deviation is σ_A.

ate goods, and $\xi_{K,t} = \frac{\kappa_i}{2\delta}\left(\frac{i_t}{k_{t-1}} - \delta\right)^2 k_{t-1}$ is the convex capital adjustment cost that entrepreneurs face when they change their capital stock. Additionally, the amount of loans that entrepreneurs borrow from banks cannot exceed the expected value of their real estate [12]

$$R_{bE,t} b_{E,t} \leq m_E E_t \left[q_{t+1} h_{E,t} \pi_{t+1}\right] \tag{16}$$

Entrepreneurs' first-order conditions are the consumption Euler equation, capital demand, real estate demand and labor demands:

$$\frac{1}{c_{E,t}} = E_t \left[\frac{\beta_E}{c_{E,t+1}} \frac{R_{bE,t}}{\pi_{t+1}}\right] + \lambda'_{E,t} R_{bE,t} \tag{17}$$

$$\begin{aligned} &\frac{1}{c_{E,t}}\left(1 + \frac{\kappa_i}{\delta}\left(\frac{i_t}{k_{t-1}} - \delta\right)\right) \\ &= E_t \left[\frac{\beta_E}{c_{E,t+1}}\left(1 - \delta + \mu \frac{y_{W,t+1}}{x_{t+1}} \frac{1}{k_t} + \frac{\kappa_i}{\delta}\left(\frac{i_{t+1}}{k_t} - \delta\right)\left(\frac{1}{2}\left(\frac{i_{t+1}}{k_t} + \delta\right) + 1 - \delta\right)\right)\right] \end{aligned} \tag{18}$$

$$\frac{q_t}{c_{E,t}} = E_t \left[\frac{\beta_E}{c_{E,t+1}}\left(q_{t+1} + \frac{y_{W,t+1}}{x_{t+1}} \upsilon \frac{1}{h_{E,t}}\right)\right] + \lambda'_{E,t} m_E E_t \left[q_{t+1} \pi_{t+1}\right] \tag{19}$$

$$w_{P,t} = \alpha(1-\mu)\frac{y_{W,t}}{x_t}\frac{1}{n_{P.t}} \tag{20}$$

$$w_{I,t} = (1-\alpha)(1-\mu)\frac{y_{W,t}}{x_t}\frac{1}{n_{I,t}} \tag{21}$$

3.4 Firms

There are two sets of firms. As in Gali and Monacelli (2005), for example, firms in the import goods sector purchase foreign intermediate goods at given world prices and turn them into differentiated import goods that can be used for domestic consumption. Firms in the home goods sector produce differentiated goods using domestic intermediate goods purchased from entrepreneurs. Both groups face a quadratic cost of price adjustment, following Rotemberg

[12] I assume that firms use real estate as collateral as in Iacoviello (2005), noting that there are many more cases in SOEs where firms provide real estate as collateral rather than as a moveable estate, including capital. For example, according to the data of the type of collateral against loans supplied by the banks in Korea as of late 2008, real estate, including housing and land, accounted for 88% of the total collateral value provided by firms and 94% of that provided by households.

(1982).[13]

The price of home goods is sticky and is indexed to a combination of past and steady-state inflation, with relative weights parameterized by ζ. If firms in the domestic sector want to change their prices beyond what indexation allows, they face a quadratic adjustment cost that is parameterized by κ_p^H. The domestic firm z would set price $P_t^H(z)$ for the domestic goods to maximize the net present value of future profits:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[P_t^H(z) y_t^H(z) - P_{W,t} y_t^H(z) - \frac{\kappa_p^H}{2} \left(\pi_t^H(z) - \left(\pi_{t-1}^H\right)^{\zeta} \left(\pi^H\right)^{1-\zeta} \right)^2 p_t^H y_t^H \right] \tag{22}$$

subject to the demand function, $y_t^H(z) = \left(\frac{P_t^H(z)}{P_t^H} \right)^{-\omega} y_t^H$.[14] Here, $\Lambda_{0,t}$ is an inter-temporal discount rate. The first-order condition yields the following hybrid Phillips curve in the home goods market:

$$\begin{aligned} 1 - \omega + \frac{\omega}{x_t^H} - \kappa_p^H \left(\pi_t^H - \left(\pi_{t-1}^H\right)^{\zeta} \left(\pi^H\right)^{1-\zeta} \right) \pi_t^H \\ + \beta_P \frac{c_{P,t}}{c_{P,t+1}} \kappa_p^H E_t \left[\left(\pi_{t+1}^H - \left(\pi_t^H\right)^{\zeta} \left(\pi^H\right)^{1-\zeta} \right) \left(\pi_{t+1}^H\right)^2 \frac{y_{t+1}^H}{y_t^H} \right] = 0 \end{aligned} \tag{23}$$

Log-linearizing Eq (23) (with hat denoting the log deviation from the steady state) yields:

$$\widehat{\pi_t^H} = -\frac{\omega - 1}{\kappa_p^H (1 + \beta_P \xi)} \widehat{x_t^H} + \frac{\beta_P}{1 + \beta_P \zeta} \widehat{\pi_{t+1}^H} + \frac{\zeta}{1 + \beta_P \zeta} \widehat{\pi_{t-1}^H} \tag{24}$$

where $\widehat{\pi_t^H}$ is the inflation of home goods defined as the rate of change in the index of domestic goods, i.e. $\widehat{\pi_t^H} \equiv \widehat{P_t^H} - \widehat{P_{t-1}^H}$. Domestic inflation is thus driven by expected inflation, lagged inflation, and mark-up rate.

As with the price of home goods, the price of imported goods is sticky. Importing firms face a quadratic adjustment cost when they determine the prices for import $P_t^F(z)$ to maximize the profit:

[13] Calvo-pricing and Rotemberg-pricing are two widely used pricing assumptions in the New-Keynesian literature. To a first order of approximation, both pricing assumptions yield similar dynamics of the economy. However, at a higher order of approximation, these assumptions may entail different welfare costs. See Blanchard and Fischer (1989 Ch. 8.2), and Lombardo and Vestin(2008) further details.

[14] I assume that an index for the aggregate output for each country is analogous to the index introduced for consumption.

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^E \left[P_t^F(z) y_t^F(z) - e_t P_t^*(z) y_t^F(z) - \frac{\kappa_p^F}{2} \left(\pi_t^F(z) - \left(\pi_{t-1}^F\right)^{\zeta} \left(\pi^F\right)^{1-\zeta} \right)^2 p_t^F y_t^F \right] \tag{25}$$

subject to $y_t^F(z) = \left(\frac{P_t^F(z)}{P_t}\right)^{-\omega} y_t^F$, where κ_p^F denotes the adjustment cost parameter measuring the degree of stickiness for imported good price. The hybrid Phillips curve for the importing firms is obtained as Eq (26), or log-linearized expression (27):

$$\begin{aligned} 1 - \omega + \omega \psi_t - \kappa_p^F \left(\pi_t^F - \left(\pi_{t-1}^F\right)^{\zeta} \left(\pi^F\right)^{1-\zeta} \right) \pi_t^F \\ + \beta_P \frac{c_{P,t}}{c_{P,t+1}} \kappa_p^F E_t \left[\left(\pi_{t+1}^F - \left(\pi_t^F\right)^{\zeta} \left(\pi^F\right)^{1-\zeta} \right) \left(\pi_{t+1}^F\right)^2 \frac{y_{t+1}^F}{y_t^F} \right] = 0 \end{aligned} \tag{26}$$

$$\widehat{\pi_t^F} = \frac{\omega - 1}{\kappa_P^F (1 + \beta_P \zeta)} \widehat{\psi}_t + \frac{\beta_P}{1 + \beta_P \zeta} \widehat{\pi_{t+1}^F} + \frac{\zeta}{1 + \beta_P \zeta} \widehat{\pi_{t-1}^F} \tag{27}$$

where $\psi_t = e_t P_t^* / P_{F,t}$ denotes the law of one price (LOP) gap defined as the difference between the world price and domestic price of imports and $\widehat{\pi_t^F}$ is the inflation of imported goods expressed in home currency. Import goods inflation is thus driven by expected inflation, lagged inflation, and deviations from LOP.

3.5 Inflation, Real Exchange Rate and Terms of Trade

In an open economy, CPI inflation is distinct from home goods inflation because the prices of imported goods influence the domestic economy. From the definition of CPI, the log-linearized expression for CPI inflation is:

$$\widehat{\pi}_t = a \widehat{\pi_t^H} + (1 - a) \widehat{\pi_t^F} \tag{28}$$

The terms of trade, which are defined as the relative prices of exports, i.e., $S_t \equiv P_t^H / P_t^F$, are linked to home goods inflation and CPI inflation according to

$$\widehat{\pi}_t = \widehat{\pi_t^H} - (1 - a) \Delta \widehat{S}_t \tag{29}$$

I assume that LOP does not hold. A key source of deviations from purchasing power parity (PPP) in this model arises from deviation from LOP. The real exchange rate $Q_t \equiv e_t P_t^* / P_t$ can be written in logs as

$$\widehat{Q_t} = a\widehat{S}_t + \widehat{\psi}_t \tag{30}$$

3.6 Banks

Banks, as an intermediary, are in charge of all financial transactions among households and entrepreneurs in the model economy. To capture the market power in the banking sector, banks are assumed to be monopolistically competitive. Each bank $j \in [0,1]$ is composed of a retail and a wholesale unit, and each unit can access the international interbank market. The retail branch obtains funding by purchasing differentiated deposits from patient households and provides differentiated loans that are made from each unit of credit taken in the domestic and international interbank markets to impatient households and entrepreneurs. The wholesale branch manages the capital position of the bank using the liability raised in the domestic and international interbank markets while providing financial instruments to its retail unit. They also face regulatory intervention in their operations, such as capital adequacy constraints and foreign debt requirements.

3.6.1 Loan and Deposit Demand

I model market power in the banking industry with a Dixit-Stiglitz framework after Gerali et al (2010). First, I assume that a unit of deposit contracts purchased by patient households is a composite constant elasticity of substitution (CES) basket of differentiated deposits supplied by a bank j:[15]

$$d_t = \left[\int_0^1 d_t(j)^{\frac{\varepsilon_d - 1}{\varepsilon_d}} dj\right]^{\frac{\varepsilon_d}{\varepsilon_d - 1}} \tag{31}$$

Demand for deposits of patient households can be obtained by minimizing over $d_t(j)$ total interest payment given by the formula subject to (31):[16]

[15] For simplicity, I treat the EOSs between deposits and between loans as exogenously determined.

[16] To understand the problem of the bank it is convenient to think about the deposit as a product with price $1/R_d$. Note that this formulation is equivalent to a formulation where banks maximize profit from taking deposits defined as $\frac{1}{R_{d,t}} d_t - \int_0^1 \frac{1}{R_{d,t}(j)} d_t(j) dj$.

$$\int_0^1 \frac{1}{R_{d,t}(j)} d_t(j)dj \tag{32}$$

Similarly to deposits, I assume that loan contracts purchased by impatient households and entrepreneurs are a composite CES basket of differentiated loans intermediated by a bank j.

$$b_{s,t} = \left[\int_0^1 b_{s,t}(j)^{\frac{\varepsilon_{bs}-1}{\varepsilon_{bs}}} dj \right]^{\frac{\varepsilon_{bs}}{\varepsilon_{bs}-1}} \tag{33}$$

for $s = I, E$. Demand for loans to impatient households and firms can be derived from maximizing over $b_{s,t}(j)$ over the revenue of total loans given by

$$\int_0^1 R_{bs,t}(j) b_{s,t}(j)dj \tag{34}$$

subject to (33).

Solving the problems above yields the demand for deposits and loans as

$$d_t(j) = \left(\frac{R_{d,t}(j)}{R_{d,t}} \right)^{\varepsilon_d} d_t \tag{35}$$

$$b_{s,t}(j) = \left(\frac{R_{bs,t}(j)}{R_{bs,t}} \right)^{-\varepsilon_{bs}} b_{s,t} \tag{36}$$

3.6.2 Wholesale Branch

Each wholesale branch operates under perfect competition. On the liability side, the branch combines wholesale deposits d_t raised from patient households and foreign funds l_t^F borrowed on the international interbank market. On the asset side, the branch issues wholesale loans $b_{I,t}^H$ and $b_{E,t}^H$.

A wholesale unit maximizes:

$$E_0 \sum_{t=0}^{\infty} \beta_B^t \ln c_{B,t} \tag{37}$$

subject to budget constraint:

$$
\begin{aligned}
c_{B,t} + \frac{R_{t-1}^{IB}}{\pi_t} d_{t-1} + b_{I,t}^H + b_{E,t}^H + Q_t \frac{R_{t-1}^{IB*}}{\pi_t} l_{t-1}^F & \\
\leq d_t + \frac{R_{t-1}^{IB}}{\pi_t} \left(b_{I,t-1}^H + b_{E,t-1}^H \right) + Q_t l_t^F - \xi_{d,t} - \xi_{bI,t} - \xi_{bE,t} - \xi_{l,t} &
\end{aligned} \tag{38}
$$

where $c_{B,t}$ is the wholesale bank's consumption, R_t^{IB} and R_t^{IB*} are domestic and international interbank rates,[17] and $\xi_{d,t} \equiv \frac{\phi_d}{2} (\Delta d_t)^2$, $\xi_{bI} \equiv \frac{\phi_{bI}}{2} \left(\Delta b_{I,t}^H \right)^2$, $\xi_{bE} \equiv \frac{\phi_{bE}}{2} \left(\Delta b_{E,t}^H \right)^2$, and $\xi_l \equiv \frac{\phi_l}{2} \left(\Delta l_t^F \right)^2$ are quadratic portfolio adjustment costs.[18] To reflect the standard capital requirements that are imposed on banks, I assume that a bank's capacity to issue liabilities is constrained by the amount of equity (total asset $b_{I,t} + b_{E,t}$ minus liabilities $d_t + Q_t l_t^F$) in its portfolio, as in (39). Additionally, the bank's borrowing in the international interbank market cannot exceed the net value of domestic capital (total asset $b_{I,t} + b_{E,t}$ minus domestic liability d_t), as in (40).[19]

$$
d_t + Q_t l_t^F \leq \gamma \left(b_{I,t} + b_{E,t} \right) \tag{39}
$$

$$
Q_t l_t^F \leq m_F \left(b_{I,t} + b_{E,t} - d_t \right) \tag{40}
$$

The first-order conditions are banks' credit supply to households and entrepreneurs and demand for foreign bank liquidity:

$$
\frac{1}{c_{B,t}} \left(1 - \phi_d \left(d_t - d_{t-1} \right) \right) = \frac{\beta_B}{c_{B,t+1}} \left(\frac{R_t^{IB}}{\pi_{t+1}} - \phi_d (d_{t+1} - d_t) \right) - \lambda_{B,t}^{'} - \lambda_{B,t}^{''} m_F \tag{41}
$$

$$
\frac{1}{c_{B,t}} \left(1 + \phi_{bI} \left(b_{I,t} - b_{I,t-1} \right) \right) = \frac{\beta_B}{c_{B,t+1}} \left(\frac{R_t^{IB}}{\pi_{t+1}} + \phi_{bI} \left(b_{I,t+1} - b_{I,t} \right) \right) - \lambda_{B,t}^{'} \gamma - \lambda_{B,t}^{''} m_F \tag{42}
$$

$$
\frac{1}{c_{B,t}} \left(1 + \phi_{bE} \left(b_{E,t} - b_{E,t-1} \right) \right) = \frac{\beta_B}{c_{B,t+1}} \left(\frac{R_t^{IB}}{\pi_{t+1}} + \phi_{bE} \left(b_{E,t+1} - b_{E,t} \right) \right) - \lambda_{B,t}^{'} \gamma - \lambda_{B,t}^{''} m_F \tag{43}
$$

$$
\frac{1}{c_{B,t}} \left(1 - \phi_l \left(l_t^F - l_{t-1}^F \right) \right) = \frac{\beta_B}{c_{B,t+1}} \left(Q_{t+1} \frac{R_t^{IB*}}{\pi_{t+1}^*} - \phi_l (l_{t+1} - l_t) \right) - \lambda_{B,t}^{'} Q_t - \lambda_{B,t}^{''} Q_t \tag{44}
$$

[17] I assume that banks can access unlimited finance at interbank rate R_t^{IB} supplied by the central bank. Thus, by arbitrage, the wholesale bank rates are equal to the interbank rate.

[18] Although the introduction of portfolio adjustment costs in the model helps to characterize real world financial frictions and derives the supply and demand of financial contracts, it simultaneously resolves the nonstationarity problem of the SOE model with incomplete financial markets. See Schmitt-Grohe and Uribe (2003) for details.

[19] Similar assumptions on bank constraints are adopted by Iacoviello (2015) and Kang and Dao (2012).

where $\lambda^{'}_{B,t}$ and $\lambda^{''}_{B,t}$ are Lagrangian multipliers on the capital requirement and the foreign debt constraints.

3.6.3 Retail Branch

Retail branches operate in a monopolistically competitive manner with the demand function given by (35) and (35). Each retail branch faces quadratic adjustment costs for adjusting its retail rates on loans and deposits.

As for deposits, the retail branch of bank j collects deposit $d_t(j)$ from patient households at the interest rate $R_{d,t}(j)$ and passes them on to the wholesale unit, which remunerates them at rate R_t^{IB}. The retail branch sets deposit rates to maximize the profit from deposit taking:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{B} \left[R_t^{IB} d_t(j) - R_{d,t}(j) d_t(j) - \frac{\kappa_d}{2} \left(\frac{R_{d,t}(j)}{R_{d,t-1}(j)} - 1 \right)^2 R_{d,t} d_t \right] \tag{45}$$

subject to demand (35). Here, κ_d is an adjustment cost parameter measuring the degree of stickiness for deposit rate and $\Lambda_{0,t}^{B}$ is the discount factor between time 0 and t.[20] After imposing symmetry, the first-order condition for deposit interest rate setting reads:

$$\begin{aligned} 1 - \varepsilon_d + \varepsilon_d \frac{R_t^{IB}}{R_{d,t}} - \kappa_d \left(\frac{R_{d,t}}{R_{d,t-1}} - 1 \right) \frac{R_{d,t}}{R_{d,t-1}} \\ + \beta_P E_t \left[\frac{c_{P,t}}{c_{P,t+1}} \kappa_d \frac{d_{t+1}}{d_t} \left(\frac{R_{d,t+1}}{R_{d,t}} - 1 \right) \left(\frac{R_{d,t+1}}{R_{d,t}} \right)^2 \right] = 0 \end{aligned} \tag{46}$$

The log-linearized version of deposit rate dynamics is drawn as:

$$\begin{aligned} \widehat{R_{d,t}} = & \frac{1+\varepsilon_d}{1+\varepsilon_d+(1+\beta_P)\kappa_d} \widehat{R_t^{IB}} \\ & + \frac{\kappa_d}{1+\varepsilon_d+(1+\beta_P)\kappa_d} \widehat{R_{d,t-1}} + \frac{\beta_P \kappa_d}{1+\varepsilon_d+(1+\beta_P)\kappa_d} E_t \widehat{R_{d,t+1}} \end{aligned} \tag{47}$$

This equation highlights how the deposit rate is set based on its past and future rate as well as the domestic interbank rate given the intensity of adjustment costs and the degree of competition in the deposit market measured by $1/\varepsilon_d$.

As with the deposit taking, the retail branch of bank j obtains wholesale loans $b_{s,t}(j)$ from

[20] Note that the bank is owned by patient households so that discount factor is taken from the problem of patient households.

the wholesale unit ($b^H_{s,t}(j)$) at rate R^{IB}_t or in the international interbank market ($b^F_{s,t}(j)$) at rate R^{IB*}_t for $s = I, E$. As in Brzoza-Brzezina and Makarski (2011), I assume that the bank is equipped with a technology of transforming each unit of credit taken in the interbank (in home currency) into a unit of retail loan contract:

$$b_{s,t}(j) = b^H_{s,t}(j) + Q_t b^F_{s,t}(j) \tag{48}$$

The retail branch maximizes, over loan rates $R_{bs,t}(j)$, the profit from loan issuance:

$$E_0 \sum_{t=0}^{\infty} \Lambda^B_{0,t}[R_{bs,t}(j) b_{s,t}(j) - R^{IB}_t{}_t b^H_{s,t}(j) - R^{IB*}_t Q_t b^F_{s,t}(j) - \frac{\kappa_{bs}}{2}(\frac{R_{bs,t}(j)}{R_{bs,t-1}(j)} - 1)^2 R_{bs,t} b_{s,t}] \tag{49}$$

subject to demand (35), and with a technology (48) for $s = I, E$. The first-order conditions for loan rates and their log-linearized versions yield:

$$\begin{aligned} 1 - \varepsilon_{bs} + \varepsilon_{bs} \frac{m R^{IB}_t + (1-m) Q_t R^{IB*}_t}{R_{bs,t}} - \kappa_{bs} \left(\frac{R_{bs,t}}{R_{bs,t-1}} - 1 \right) \frac{R_{bs,t}}{R_{bs,t-1}} \\ + \beta_P E_t \left[\frac{c_{P,t}}{c_{P,t+1}} \kappa_{bs} \frac{b_{s,t+1}}{b_{s,t}} \left(\frac{R_{bs,t+1}}{R_{bs,t}} - 1 \right) \left(\frac{R_{bs,t+1}}{R_{bs,t}} \right)^2 \right] = 0 \end{aligned} \tag{50}$$

$$\begin{aligned} \widehat{R_{bs,t}} = & \underbrace{\frac{\varepsilon_{bs} m R^{IB}}{R_{bs}\left(\varepsilon_{bs} - 1 + \kappa_{bs}(1+\beta_P)\right)} \widehat{R^{IB}_t}}_{\textit{domestic interbank rate}} \\ & + \underbrace{\frac{\varepsilon_{bs}(1-m) R^{IB*}}{R_{bs}\left(\varepsilon_{bs} - 1 + \kappa_{bs}(1+\beta_P)\right)} \widehat{R^{IB*}_t}}_{\textit{foreign interbank rate}} + \underbrace{\frac{\varepsilon_{bs}(1-m) R^{IB*}}{R_{bs}\left(\varepsilon_{bs} - 1 + \kappa_{bs}(1+\beta_P)\right)} \widehat{Q_t}}_{\textit{real exchage rate}} \\ & + \underbrace{\frac{\kappa_{bs}}{\varepsilon_{bs} - 1 + \kappa_{bs}(1+\beta_P)} \widehat{R_{bs,t-1}}}_{\textit{past loan rate}} + \underbrace{\frac{\beta_P \kappa_{bs}}{\varepsilon_{bs} - 1 + \kappa_{bs}(1+\beta_P)} E_t \widehat{R_{bs,t+1}}}_{\textit{future loan rate}} \end{aligned} \tag{51}$$

These equations indicate that banks set the loan rates based on the domestic and foreign interbank rates, their past and future rates and the real exchange rate, taking into account adjustment costs and the degree of market competition.[21]

Additionally, the bank's problem originates the standard uncovered interest parity condition

[21] Note that in financial autarky, the dynamics of the loan rate are formulated based only on domestic interbank rates and past and future rates.

(UIP) because banks can obtain resources on the international interbank market. UIP shock ($\varepsilon_{UIP,t}$ and its standard deviation σ_{UIP}) is assumed, as in Kollmann (2002), given the empirical evidence of a strong and persistent deviation from the UIP condition during the post-Bretton Woods era (e.g., Lewis 1995).

$$R_t^{IB} = R_t^{IB*} E_t \left(\frac{e_{t+1} \varepsilon_{UIP,t}}{e_t} \right) \tag{52}$$

3.7 The Foreign Sector and Monetary Policy

Because I assume a SOE, the foreign economy is exogenous to the domestic economy and there is some flexibility in specifying the behavior of foreign variables, $\widehat{\pi_t^*}$, $\widehat{y_t^*}$ and $\widehat{R_{t+1}^{IB*}}$. To explore the dynamic relationships among the variables of the rest-of-the-world, approximated by the U.S. economy, I consider a structural VAR of three U.S. variables (ordered as listed above) as in Ghironi (2000).[22] The data used for estimation is between 1980Q1 and 2008Q2 from Federal Reserve Economic Data (FRED), and the lag order is chosen as two quarters according to the various information criteria. The details of the set-up and estimation results are summarized in Appendix A-1.

As it is common in the New Keynesian literature, a central bank determines the nominal policy rate according to a Taylor rule given by

$$R_t^{IB} = \left(R_{t-1}^{IB}\right)^{\rho} \left[\left(R^{IB}\right) \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y} \right]^{1-\rho} \varepsilon_{R^{IB},t} \tag{53}$$

where ρ, ϕ_π, and ϕ_y are weight parameters of the policy rate at the previous period, inflation, and output growth, respectively. R^{IB} and π stand for steady state value of policy rate and inflation and $\varepsilon_{R^{IB},t}$ (the standard deviation is $\sigma_{R^{IB}}$) represents monetary policy shocks which is white noise.

3.8 Market Clearing

The model is closed by specifying the market clearing conditions for the goods markets and the housing market as well as the balance of payments. The market clearing condition in the final goods market is:

[22] Another popular way to model the exogenous rest-of-the-world is to assume that foreign variables are AR processes. See Matheson (2010) for example.

$$y_t = c_{P,t} + c_{I,t} + c_{E,t} + c_{B,t} + i_t \tag{54}$$

Next, the market clearing condition in the housing market is given by:

$$\overline{h} = h_{P,t} + h_{I,t} + h_{E,t} \tag{55}$$

where $\overline{h}$ is fixed housing stock. The market clearing condition for balance of payment (in home currency) is:

$$\frac{P_t^H}{P_t} y_{W,t} - y_t = Q_t \frac{R_{t-1}^{IB*}}{\pi_t^*} \left(b_{I,t-1}^F + b_{E,t-1}^F + l_{t-1}^F \right) - Q_t \left(b_{I,t}^F + b_{E,t}^F + l_t^F \right) \tag{56}$$

4 Calibration and Estimation

I use data from Korea for the estimation of the model because Korea is a typical small open economy where the financial system largely depends on the banking sector.[23] I first calibrate some parameters that can be relatively easily obtained in the data and that have been well established in the previous literature. The rests are estimated with the Bayesian methods described in An and Schorfheide (2007).

4.1 Calibrated Parameters

The discount factors for each agent are within the range of the band interval (0.91, 0.99) estimated by Carroll and Samwick (1997). The discount factor of patient households (β_P) is set to 0.99 to match the long-term average of a quarterly household deposit of 3.8% in the sample. I set the discount factors of impatient households, entrepreneurs and banks (β_I, β_E and β_B) as 0.95, 0.95, and 0.96, respectively, close to Kang and Dao (2012) to ensure positive financial flow in the steady state.[24] The technology parameters (μ, υ and α) are chosen as 0.36, 0.04 and 0.70

[23]The Korean financial market shows low dependency on bonds and stocks for financing or business methods, but a high portion of indirect financing such as through bank loans. Financing through indirect financing channels occupied approximately 90% and 54% for households and corporations, respectively. Moreover, the portion of corporations financing funds through the direct financing market such as by corporate bonds and stocks was approximately 20% (as of 2008). For more details on country-specific financial institutions, see Levine (2004).

	U.S	U.K	Korea	Japan	Germany
Aggregate Market Value of Listed Stocks/Nominal GDP (%)	144.8	141.9	106.4	105.7	63.4

[24]Home banks borrow the funds from abroad only if the borrowing cost is cheaper than the domestic financing cost ($R^{IB*} < R_d$). For impatient households and entrepreneurs to borrow from banks, the interest rates that the

on the basis of the data sample mean. The EOSs between deposits and loans (ε_d, ε_{bI} and ε_{bE}) are determined to match the steady-state markups of each rate on the policy rate. The LTV ratios on loans to households and entrepreneurs (m_I and m_E) and capital adequacy ratios (γ and m_F) are calibrated to the long-term average of data obtained from bank business analysis data and the financial information statistics system (FISIS). The parameters in Taylor rule ρ, ϕ_y and ϕ_π are set to 0.75, 1.9 and 0.4 according to the Bank of Korea's empirical estimates. The rest of the calibrated parameters are taken from Iacoviello (2005) and Gerali et al. (2010).

[Insert Table 1 about here]

4.2 Data and Estimation

To estimate the remaining parameters, adjustment cost parameters and the standard error and autoregressive coefficients of all shocks, I use seven quarterly macroeconomic and financial time-series data imported from the Economic Statistics System of the Bank of Korea (ECOS). These data include (seasonally adjusted) the real GDP, CPI inflation, overnight call rate, bank loans to households and firms, and bank loan rates to households and firms.[25] The sample period is chosen as 1999Q3 $\sim$ 2014Q4 to correspond to a period of a homogeneous monetary policy regime.[26] The data are detrended using an HP-filter with a smoothing parameter of 1,600. The detrended data are plotted in Figure 6.

[Insert Figure 6 about here]

I use the Metropolis-Hastings (MH) algorithm to obtain the posterior distribution of the parameters by running 10 chains, with 100,000 draws each. The convergence properties of the MH algorithm are assessed using the diagnostics proposed by Brooks and Gelman (1998) shown in Figure 7.[27]

[Insert Figure 7 about here]

banks charge must be low enough for borrowers, i.e. $\frac{1}{\beta_I} > R_{bI}$ and $\frac{1}{\beta_E} > R_{bE}$.

[25]The model allows for seven shocks. Following usual practice, I use as many shocks as observable variables.

[26]The Bank of Korea has been adopting inflation targeting since 1999 and manipulates short-term interest rates (overnight call rate before February 2008, base rate after February 2008) as a policy instrument.

[27]Markov Chain Monte Carlo (MCMC) should sequence as if drawn from a posterior distribution. The minimum requirement is that the distribution is identical (i) for different parts of the same chain, and (ii) across chains. For the results to be sensible, between- and within-chain measures for each moment should converge to zero and a constant, respectively.

Tables 2 and 3 report the summary statistics of prior and posterior distributions. Similar to Gerali et al. (2010) prior means of parameters controlling price stickiness (κ_p^H and κ_p^F) are set at 50, and those for interest rate adjustment costs (κ_d, κ_{bI} and κ_{bE}) are set at 10. The prior mean for the capital adjustment cost (κ_K) is set at 2.5. Following Iacoviello (2015) and Kang and Dao (2012), I also set the prior means of banks' adjustment cost parameters (ϕ_d, ϕ_{bI} and ϕ_{bE}) at 0.25.[28] Priors for the standard deviations of the above parameters are imposed reasonably loosely or set as common values that are found in the literature. As for the shock processes, the prior means of standard deviations for shocks are set at 0.01.

[Insert Table 2 about here]

[Insert Table 3 about here]

For the parameters governing the degree of stickiness in bank rates, deposit rates change more rapidly than loan rates to the adjustment of the policy rate. Regarding portfolio adjustment costs, deposits change faster than loans. These results are in line with Gerali et al. (2010) and may be attributable to the fact that the measure of deposits includes time deposits, which are more reactive to the changes of money market instruments. Concerning the nominal rigidities, I find that the stickiness of the foreign price is slightly stronger than that of the domestic price. The median of the capital adjustment costs is 1.6, somewhat lower than Smets and Wouters (2007) estimate. The shocks following AR(1) processes are persistent.

4.3 Empirical Fit of the Model

The empirical fit of the model is first assessed by the comparison between the steady state values and the long-term average of variables (1998Q1∼2014Q4). Table 4 shows the steady state values of the main macroeconomic variables, including consumption, investment and the interest rate, obtained from the model compared with observed values. Overall, the steady state ratios of key variables (e.g., the ratio of macroeconomic variables to GDP) are largely similar to the actual data, which implies that the parameters in the model represent the reality of the Korean economy.[29]

[28] These parameters measure the semielasticity of loan and deposit supplies. The derivatives of loan adjustment cost functions, for instance, can be written as $\frac{d\xi_{bs}}{db_s} = \phi_{bs}\left(b_{s,t} - b_{s,t-1}\right)$. This situation indicates that when quarterly loan rates rise by 25bp (100bp in annual), the loan supply increases by $0.25/\phi_{bs}$ in percentage terms. Thus, the value of the parameters as 0.25 implies an increase of loan supply by 1% responding to a 1% rise in loan rates.

[Insert Table 4 about here]

As an additional test of the reliability of model, I assess the model in fitting actual data that are not used in the model estimation. This exercise is performed to address the critique that the DSGE model performs well in fitting the data in the sample but is poor at fitting the rest of the data (e.g., Iacoviello 2015). Figure 8 contrasts the actual data for consumption, deposit, deposit rate (from the Bank of Korea), and housing price (from the Kookmin bank housing price index) with the model simulated series. Overall, the model's smoothed estimates trace well their data counterparts.

[Insert Figure 8 about here]

5 The Transmission Mechanism of MP Shocks

As in existing studies, the model suggests several channels that explain the transmission of local MP shocks: real rate, nominal debt, financial accelerator, bank attenuator and bank capital channel (mainly closed economy model; see Iacoviello 2005, Gerali et al. 2010 and Van den Heuvel 2008 for instance).[30] Additionally, foreign interest rate shocks can be migrated to the SOE's financial market by adjusting the domestic interbank rate according to the interest-parity condition or by adjusting the bank's interest rate setting with consideration for the domestic and international interbank rate (Obstfeld 2014, Passari and Rey 2015).

In this section, I study how banking sector openness alters the transmission mechanism of home and foreign MP shocks, particularly focusing on the channels related to the banking sector.

[29]Steady state ratios of banks' deposits and loans to GDP are smaller than the ratios of their data counterparts. This discrepancy may be attributed to an assumption on the banks' balance sheets. For instance, banks' reserves and cash holdings are not considered in the model.

[30]In response to a policy rate rise, real rates increase due to the presence of price stickiness, thus leading to a fall in the aggregate spending of households and firms (*real rate channel*). A fall in the price caused by a policy rate increase raises the real cost of borrowers' current debt obligation and the real remuneration on saver's deposits (*nominal debt channel*). On a contractionary MP shock, banks cut their loans to constrained borrowers due to the decline of the net present value of tomorrow's collateral, thereby creating an additional downward pressure on aggregate demand (*financial accelerator channel*). Bank presence influences the impact of MP shocks on the economy. However, the overall effect is not clear. In response to a negative shock to the bank capital/asset ratio caused by bank loan cuts, banks tighten their lending standards, which worsens credit conditions (*bank capital channel*). Due to the presence of a bank's market power, banks raise the remuneration of deposits and the cost of loans by a lower amount following the policy rate increase, and thus financial intermediation moderates the overall effects listed above (*bank attenuator channel*).

5.1 Transmission of Home MP Shock

The introduction of banking sector openness attenuates the impulse responses to an unanticipated contractionary MP shock via the following two channels:[31]

First, on the price side of the credit market, the effects of domestic policy rate adjustment are transmitted less to loan rates (i.e., *foreign interest rate channel*). In financial autarky, the banks can take loans only domestically at the cost of R_t^{IB}, and thus the retail rates for loans are set based on the markup over the policy rate (Gerali et al. 2010, Ha and So 2013). By contrast, if banks can access the international interbank market to import loan accounts at rate R_t^{IB*}, they can set loan rates, taking into account not only domestic but foreign interbank rates. Loan rates under banking sector openness are therefore affected by domestic MP shocks only up to the portion for which banks rely on the domestic saver. This situation reduces the strength of the real rate effect (depression of consumption and investment triggered by real rates increases) and the financial accelerator effect (downward pressure on aggregate demand created by the contraction in bank loans to constrained agents' net present value of collaterals).

Second, the global liquidity management of SOE banks can insulate credit supply from domestic monetary shock (i.e., *foreign liquidity channel*). Contractions in deposits caused by policy rate increases tightens banks' balance sheet conditions. Under financial autarky, the shock is transmitted to the banks' asset side. Banks that cannot substitute liabilities with other external funding sources must reduce their assets (or loans) against the change of the balance sheet. Banks' adjustment of lending activity puts additional strain on aggregate demand because households and firms depend on bank credit to run their activities. Meanwhile, in a model with bank globalization, globalized banks can accommodate the shock. Foreign liquidity that banks raise in the international interbank market plays a role as a buffer for absorbing the negative MP impact on the balance sheet.

To understand which of the two effects prevails when bank globalization is introduced and to quantitatively assess the relevance of the different channels in shaping the dynamic properties of the economy, I compare the responses of the baseline model examined in the previous section with those of the alternative models where I shut down the transmission channels of MP one

[31] As proposed by Gerali et al. (2010), domestic MP transmission may also be attenuated due to the presence of monopolistic power in the deposit and loan markets. I provide the analysis of the effect of market power in the banking industries in Appendix A-2. Overall, the attenuating effect of bank globalization is comparable to the bank attenuator effect.

by one against the same contractionary monetary shocks (25 basis points increase): (i) only the foreign interest rate channel is blocked in AM1 and (ii) both the foreign interest rate channel and foreign liquidity channel are blocked in AM2. However, all channels work with significance in BM as previously assumed.[32] Table 5 briefly describes the strategy of verifying the direction and strength of each channel by comparing the results between each model in response to the same MP shocks.

[Insert Table 5 about here]

Figure 9 exhibits the impacts of policy tightening on key macroeconomic and financial variables through each transmission channel, and Table 6 summarizes the average impulse response of key variables in the first year. Parameter values are set at the estimated posterior median. The responses of BM (black line) are standard. Deposit and loan rates increase following policy rate increases. This change in bank rates leads to housing price declines (-0.11% in the first year), which reduces the value of tomorrow's collateral holding. Consequently, the amount of loans decreases and output (-0.20%) and inflation (-0.04%) fall because the productive sector of the economy relies on bank credit.[33]

[Insert Figure 9 about here]

[Insert Table 6 about here]

The role of bank globalization begins to appear when we consider the responses of the AM1 (red line) and the AM2 (green line), which block the foreign interest rate channel and the foreign liquidity channel, respectively. The main result that emerges from comparing AM1 and AM2 with the baseline is that the introduction of bank globalization attenuates the effects of contractionary MP shocks.

First, when comparing BM and AM1 with regard to the responses of each macroeconomic and financial variable to the shocks stemming from the MP tightening by 25bp, the responses of loan rates are smaller in the former model than the latter with a gap of 0.11%p in the loan rate to impatient households and a gap of 0.07%p in the loan rate to entrepreneurs, on average,

[32] To be specific, the foreign liquidity channel is blocked if bank borrowing from abroad is set to zero ($l_t^F = 0$). Similarly, to shut down the foreign interest rate channel, we may assume that bank can collect and sell loan accounts only in their home countries ($b_{s,t} = b_{s,t}^H$ for $s = I, E$).

[33] For your reference, on the same policy shock, output and inflation decrease by 0.18% and 0.05%, respectively, according to the Bank of Korea's BOKDSGE model.

during the first year after shock. This smaller response of loan rates induces a smaller change in loan and deposit demands, thus reducing output by a lower amount (0.07%p less).[34] This result indicates that MP shocks are weakened in global banking intermediation, particularly by the existence of foreign interest rate channels consistent with theoretical direction.

Second, according to the comparison between AM1 and AM2 regarding responses to MP shocks, although deposits shrink more in AM1 than in AM2 against policy rate increases, smaller loan responses are seen in the former than in the latter, with a gap of 0.03%p in loans to impatient households and a gap of 0.01%p in loans to entrepreneurs. Consequently, output drops by less than 0.03%p in AM1 compared to AM2. The responses of the variables confirms the existence of a foreign liquidity channel in line with much of the available literature (e.g., Cetorelli and Goldberg 2012).

The findings verify that the attenuation effect of bank globalization after an MP shock is mainly due to the foreign interest rate channel, which dampens the response of loan rates, thereby hindering the decline of loans and aggregate demand. The impact of the foreign liquidity effect is limited, reflecting the opposite and mutually offsetting effects on the demand and supply of foreign liquidity. Due to foreign debt constraint, the amount of net domestic bank capital determines the availability of foreign capital, thus limiting the foreign liquidity channel if the bank deposit shrinks more than the loan on a negative MP shock.

5.2 Transmission of Foreign MP Shock

Bank globalization intensifies the transmission of foreign MP shocks to domestic interest rates. Conventional open economy models assume that foreign monetary shocks affect short-term rates in SOEs following the interest-parity relationship, and inevitably influence other market rates that are set based on the movement of the short-term rate (referred to as *indirect international monetary transmission*). In addition to the foreign monetary transmission channel, globalization in the banking sector induces bank rates to react directly to the change in foreign MP shocks because global banks that import foreign loan contracts determine their loan rates by considering the costs of raising funds on both domestic and international interbank markets (*direct international monetary transmission*).

The mechanism of international monetary transmission is studied by looking at the impulse

[34]Consumption and investment also react less in BM than in AM1 by 0.07%p and 0.04%p respectively.

responses coming from BM and AM1, as illustrated in the previous section.[35] Figure 10 shows the impulse responses from an unanticipated 25bp increase in the foreign policy rate. Table 7 summarizes the average impulse response of key variables in the first year.

[Insert Figure 10 about here]

[Insert Table 7 about here]

Overall, in the two models, the response of domestic interest rates, including policy rates, is positive against negative foreign MP shock and leads to a fall in output. However, compared to a model lacking a foreign interest rate channel (AM1, red line), the interest rates, particularly loan rates, in the baseline model (black line) show more sensitive responsiveness to foreign monetary surprises. To gain intuition from the results, it is useful to discuss how bank globalization modifies the international transmission channels of foreign MP shocks.

In AM1, loan rates are determined based on the domestic policy rate (R^{IB}) and past and future rates, as in Gerali et al. (2010). The only channel through which foreign interest rates can affect the movement of loan rates is that of a SOE's policy rate adjustment (0.04%p on average in the first year) after a foreign shock. However, due to the presence of frictions between policy rates and loan rates in models, this transmission channel may exert limited impacts on loan rate movement. The responses of loan rates to impatient households and entrepreneurs are smaller than the response of domestic policy rates by 0.003%p and 0.014%p, respectively.

However, when we introduce a banking sector that imports foreign loan accounts (BM), loan rates are set based on both domestic (R^{IB}) and foreign (R^{IB*}) policy rates, as shown in equations (50) and (51). This situation adds a stronger propagation mechanism: in addtion to indirect transmission channel through policy rate adjustment (0.01%p on average in the first year), foreign monetary shocks can influence the loan rates directly in this process. Thus, loan rates respond even more (0.05%p in loan rates to entrepreneurs and impatient households) than domestic policy rates.

For ease of comparison, each panel in Figure 11 plots the responses of loan rates and domestic policy rates to foreign monetary shock together. In Panel A, which describes the responses of variables in AM1, loan rates react to foreign monetary surprises by a lower amount than to

[35]In the model, the relationship between foreign monetary policy and foreign loan conditions is not clearly defined for simplicity (see Section 3.7 for details). Therefore, I compare only the responses from BM with those from AM1 to focus on the price-side impact of foreign MP shocks.

the domestic policy rate for the initial four quarters. However, for BM in Panel B, loan rates respond more to a contractionary foreign MP shock than do domestic policy rates for the period.

[Insert Figure 11 about here]

6 Conclusions

This paper revisits the conventional topic of MP transmission in SOEs but focuses on how well domestic and international MP shocks propagate through banking sectors and whether such transmission channels are altered by bank globalization. To that end, the model in this paper is a first attempt to investigate the channels through which bank globalization influences MP transmission under the general equilibrium framework. Furthermore, to disentangle the complex workings of bank globalization into price and quantity sides, I introduce two sets of bank globalization factors in the model: imported loan contracts and foreign operating funds.

The study's findings are twofold. First, bank globalization attenuates MP transmission. Compared to the financial autarky model, loan rates increase less in response to a negative monetary shock, thereby exerting a foreign interest rate effect. This channel alleviates the strength of the real rate effect and financial accelerator effect. However, through a foreign liquidity channel, banks that face capital requirement constraints can also avoid negative policy effects to some extent by expanding credit through foreign bank capital. The impulse response of output to a contractionary MP shock (25 basis point increase in policy rate) declines by 0.07%p due to the foreign interest rate effect and by 0.03%p due to the foreign liquidity effect in the first year, respectively. Second, bank globalization amplifies international monetary spillovers. In addition to the international monetary spillover through the interest-parity condition, globalized banking activities directly link foreign interbank rates and domestic loan rates. Thus, compared to the model without bank globalization, the impulse response of loan rates to foreign MP shock shows that the direct international monetary transmission channel accounts for approximately 0.03∼0.04%p of loan rate responses.

The results indicate that bank rates do not always react in the way that central banks intend due to the degree of openness in the banking sector. In my analysis, transmission of home MP shocks is attenuated whereas international monetary transmission is substantially intensified by bank globalization. Central bankers are confronted with an expanded need for taking into consideration the role of global banking intermediation in MP transmission when determining the scale and timing of policies.

References

[1] An, S., Schorfheide, F. (2007). Bayesian analysis of DSGE models. *Econometric Reviews, 26(2-4), 113-172.*

[2] Bernanke, B. (2007). Globalization and Monetary Policy. *Speech at the Fourth Economic Summit, Stanford Institute for Economic Policy Research.*

[3] Bernanke, B. S., Gertler, M. (1995). Inside the black box: The credit channel of monetary policy transmission. *The Journal of Economic Perspectives, 9(4), 27-48.*

[4] Bjørnland, H. C. (2009). Monetary policy and exchange rate overshooting: Dornbusch was right after all. *Journal of International Economics 79, 6477.*

[5] Blanchard, O. J., and Fischer, S. (1989). Lectures on Macroeconomics. *Cambridge: MIT Press.*

[6] Brooks, S. P., and Gelman, A. (1998). General methods for monitoring convergence of iterative simulations. *Journal of computational and graphical statistics, 7(4), 434-455.*

[7] Bruno, V., and Shin, H. S. (2015). Capital flows and the risk-taking channel of monetary policy. *Journal of Monetary Economics, 71, 119-132.*

[8] Brzoza-Brzezina, M., Makarski, K. (2011). Credit crunch in a small open economy. *Journal of International Money and Finance, 30(7), 1406-1428.*

[9] Carroll, C. D., Samwick, A. A. (1997). The nature of precautionary wealth. *Journal of monetary Economics, 40(1), 41-72.*

[10] Cetorelli, N., Goldberg, L. S. (2012). Banking globalization and monetary transmission. *The Journal of Finance, 67(5), 1811-1843.*

[11] Devereux, M. B., Yu, C. (2014). International Financial Integration and Crisis Contagion. *NBER Working Papers No. w20526.*

[12] Freixas, X., and Rochet, J. C. (1997). Microeconomics of banking (Vol. 2). *Cambridge, MA: MIT press.*

[13] Gali, J., Monacelli, T. (2005). Monetary policy and exchange rate volatility in a small open economy. *The Review of Economic Studies, 72(3), 707-734.*

[14] Gerali, A., Neri, S., Sessa, L., Signoretti, F.M. (2010). Credit and banking in a DSGE model of the euro area. *Journal of Money, Credit, and Banking, 42 (s1), 107141.*

[15] Gertler, M., Karadi, P. (2011). A model of unconventional monetary policy. *Journal of Monetary Economics, 58 (1), 1734.*

[16] Gertler, M., Karadi, P. (2015). Monetary Policy Surprises, Credit Costs, and Economic Activity. *American Economic Journal: Macroeconomics, 7(1), 44-76.*

[17] Gertler, M., Kiyotaki, N. (2010). Financial intermediation and credit policy in business cycle analysis. *Handbook of monetary economics, 3(3), 547-599.*

[18] Ghironi, F. (2000). Alternative monetary rules for a small open economy: The case of Canada. *Boston College Econ. Dept. WP, 466.*

[19] Goldberg, L. S. (2013). Banking globalization, transmission, and monetary policy autonomy. *NBER Working Papers, No. w19497.*

[20] Ha, J., So, I. (2013). Influence of the Banks' Money Mediation Behavior on the Monetary Policy: A Study of Korean Case. *Global Economic Review, 42(4), 396-424.*

[21] Hamilton, J. D. (1994). Time Series Analysis. *Princeton University Press, Princeton, NJ.*

[22] Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American economic review, 739-764.*

[23] Iacoviello, M. (2015). Financial business cycles. *Review of Economic Dynamics, 18(1), 140163.*

[24] Kang, T. and Dao, T. (2012). International financial business cycles. *manuscript*

[25] Kim, S. (2001). International transmission of U.S. monetary policy shocks: Evidence from VAR's. *Journal of Monetary Economics, 48, 339372.*

[26] Kiyotaki, N., Moore, J. (1997). Credit cycles. *The Journal of Political Economy, 105(2), 211-248.*

[27] Kalemli-Ozcan, S., Papaioannou, E., and Perri, F. (2013). Global banks and crisis transmission. *Journal of International Economics, 89(2), 495-510.*

[28] Kollmann, R. (2002). Monetary policy rules in the open economy: effects on welfare and business cycles. *Journal of Monetary Economics, 49(5), 989-1015.*

[29] Kollmann, R. (2013). Global banks, financial shocks, and international business cycles: Evidence from an estimated model. *Journal of Money, Credit and Banking, 45(s2), 159-195.*

[30] Levine, R. (2004). Finance and growth: Theory and evidence. *NBER Working Papers No. 10766*

[31] Lewis, K. (1995). Puzzles in international financial markets. In: Grossman, G., Rogoff, K. (Eds.) *Handbook of International Economics, Vol. 3. 19131971.*

[32] Lombardo, G., Vestin, D. (2008). Welfare implications of Calvo vs. Rotemberg-pricing assumptions. *Economics Letters, 100(2), 275-279.*

[33] Matheson, T. (2010). Assessing the fit of small open economy DSGEs. *Journal of Macroeconomics, 32(3), 906-920.*

[34] Obstfeld, M., and Rogoff, K. (1995). Exchange Rate Dynamics Redux. *Journal of Political Economy, 624-660.*

[35] Obsfeld, M. (2014). Trilemmas and Tradeoffs: Living with Financial Globalization. *manuscript*

[36] Passari, E., Rey, H. (2015). Financial Flows and the International Monetary System. *The Economic Journal, 125(584), 675-698.*

[37] Rosenberg, C. B., Tirpak, M. (2008). Determinants of foreign currency borrowing in the new member states of the EU. *IMF Working Papers, 1-24.*

[38] Rotemberg, J. J. (1982). Monopolistic price adjustment and aggregate output. *The Review of Economic Studies, 49(4), 517-531.*

[39] Schmitt-Grohe, S., and M. Uribe. (2003). Closing Small Open Economy Models. *Journal of International Economics, 61(1), 163-185.*

[40] Schnabl, P. (2012). The international transmission of bank liquidity shocks: Evidence from an emerging market. *Journal of Finance, 67(3), 897-932.*

[41] Smets, F., and Wouters, R. (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *The American Economic Review, 97(3), 586-606.*

[42] Tille, C. (2008). Financial integration and the wealth effect of exchange rate fluctuations. *Journal of International Economics, 75(2), 283-294.*

[43] Van den Heuvel, S.J. (2008). The welfare cost of bank capital requirements. *Journal of Monetary Economics, 55 (2), 298320.*

[44] Woodford, M. (2007). Globalization and Monetary Control. In: International Dimensions of Monetary Policy. *NBER Chapters. National Bureau of Economic Research, 13-77.*

Table 1: Calibrated Parameters

Parameter	Description	Value
β_P	Patient Households' discount factor	0.99
β_I	Impatient Households' discount factor	0.94
β_E	Entrepreneurs' discount factor	0.94
β_B	Banks' discount factor	0.96
μ	Capital share in the production function	0.36
α	Patient/Impatient household ratio in the production function	0.70
υ	Real estate share in the production function	0.04
ω	Elasticity of substitution between home and foreign goods	6.0
a	Share of home consumption component in the consumption index	0.7
ε_d	Elasticity of substitution between deposit	1442.29
ε_{bI}	Elasticity of substitution between loans for impatient households	139.40
ε_{bE}	Elasticity of substitution between loans for entrepreneurs	211.48
m	Share of home loan component in the loan index	0.85
m_I	LTV on loans to households	0.5
m_E	LTV on loans to entrepreneurs	0.8
m_F	Foreign capital regulation ratio	0.5
γ	Capital adequacy ratio	0.85
δ	Capital depreciation rate	0.025
η	Weight on leisure	1.01
ρ	Policy rate inertia in Taylor rule	0.75
ϕ_y	Weight on output in Taylor rule	1.9
ϕ_π	Weight on inflation in Taylor rule	0.4

Table 2: Prior and Posterior Distribution of Parameters : Structural Parameters

Parameter	Prior Distribution			Posterior Distribution		
	Distribution	Mean	St.dev.	Median	Mean	St.dev.
κ_d	Gamma	10.0	2.5	4.29	4.30	0.130
κ_{bI}	Gamma	10.0	2.5	22.65	23.34	0.506
κ_{bE}	Gamma	10.0	2.5	7.51	7.66	0.585
ϕ_d	Beta	0.25	0.1	0.24	0.24	0.001
ϕ_{bI}	Beta	0.25	0.1	0.26	0.26	0.001
ϕ_{bE}	Beta	0.25	0.1	0.25	0.25	0.001
ϕ_l	Beta	0.25	0.1	0.24	0.24	0.001
κ_p^H	Gamma	50.0	10.0	41.74	41.91	2.765
κ_p^F	Gamma	50.0	10.0	44.70	45.23	0.875
κ_K	Gamma	2.5	1.0	1.60	1.60	0.044

Table 3: Prior and Posterior Distribution of Parameters : Exogenous Processes

Parameter	Prior Distribution			Posterior Distribution		
	Distribution	Mean	St.dev.	Median	Mean	St.dev.
AR coefficients						
θ_A	Gamma	0.8	0.01	0.80	0.80	0.010
θ_j	Gamma	0.8	0.01	0.81	0.81	0.010
Standard deviations						
σ_A	Inv. Gamma	0.01	0.05	0.01	0.01	0.005
σ_j	Inv. Gamma	0.01	0.05	0.24	0.25	0.034
$\sigma_{R^{IB}}$	Inv. Gamma	0.01	0.05	0.04	0.04	0.003
σ_{UIP}	Inv. Gamma	0.01	0.05	0.06	0.06	0.006
$\sigma_{R^{IB*}}$	Inv. Gamma	0.01	0.05	0.04	0.04	0.004
σ_{y^*}	Inv. Gamma	0.01	0.05	0.02	0.02	0.002
σ_{π^*}	Inv. Gamma	0.01	0.05	0.05	0.05	0.005

Table 4: Steady State Ratios of the Model

Variable	Description	Model	Data
$\frac{c_P+c_I}{y}$	Households' consumption to GDP	0.68	0.68
$\frac{i}{y}$	Facility investment to GDP	0.08	0.09
$\frac{b_E}{y}$	Loans to entrepreneur to GDP	1.02	1.12
$\frac{b_I}{y}$	Loans to household to GDP	1.55	0.88
$\frac{d}{y}$	Deposit to GDP	1.80	2.59
$\frac{h}{y}$	Housing stock to GDP	1.98	1.77
$\frac{k}{y}$	Capital stock to GDP	3.35	3.78

Table 5: Decomposition of MP Transmission Channels

	Baseline Model	Alternative Models	
	(BM)	(AM1)	(AM2)
Foreign liquidity channel (A)	◯	◯	$\times$
Foreign interest rate channel (B)	◯	$\times$	$\times$
Identify		(A)	(B)

Notes: ◯−Existing in the model, $\times$−Not existing in the model.

Table 6: Comparison of the Impacts of MP Tightening (25bp) through Each Channel

(%, %p)

	y	R_{bI}	R_{bE}	R_d	b_I	b_E	d	MP shocks
BM	-0.20	0.02	0.02	0.12	-0.26	-0.11	-0.29	-
AM1	-0.27	0.13	0.09	0.13	-0.42	-0.18	-0.46	-
AM2	-0.30	0.13	0.09	0.14	-0.45	-0.20	-0.41	-
Foreign interest rate channel (BM-AM1)	+0.07	-0.11	-0.07	-0.01	0.16	0.07	0.18	Weakened
Foreign liquidity channel (AM1-AM2)	+0.03	-0.01	-0.01	-0.01	0.03	0.01	-0.05	Weakened

Notes: Average impulse responses in the first year

Table 7: Comparison of the Impacts of Foreign MP Tightening (25bp)

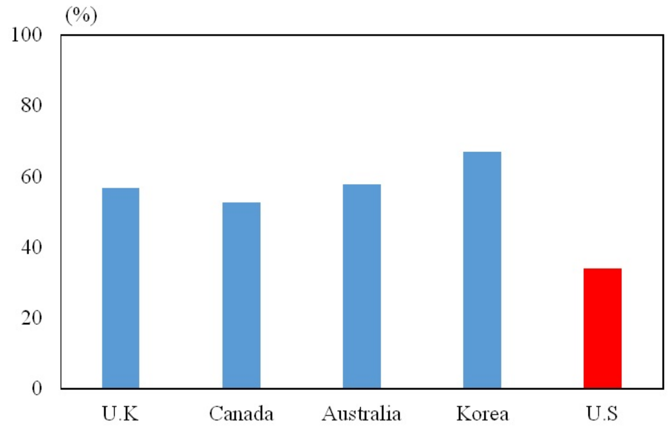
(%, %p)

	R^{IB}	R_d	R_{bI}	R_{bE}	$R_d - R^{IB}$	$R_{bI} - R^{IB}$	$R_{bE} - R^{IB}$
AM1	0.04	0.04	0.04	0.03	-0.0001	-0.0030	-0.0143
	Indirect transmission				*Friction*		
BM	0.01	0.01	0.05	0.05	-0.0000	0.0335	0.0381
	Indirect transmission		*Indirect/Direct transmission*		*Friction*		

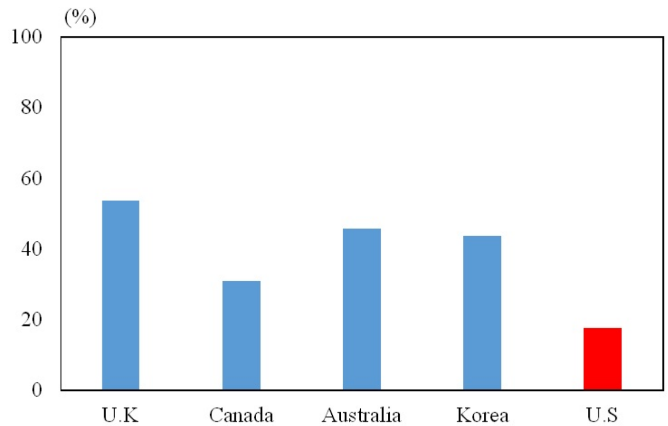
Notes: Average impulse responses in the first year

Figure 1: Bank Credit to Private Sector and Bank External Debt

A. Bank[1] credit/total credit To Private Non-financial Sector[2]



B. Bank[1] external debt/gross external debt



Notes: 1. Domestic depository corporations (except central banks)
2. Non-financial corporations, households, and non-profit institutions serving households

Sources: BIS, World Bank (as of the end of 2014)

Figure 2: Impulse Responses of Interest Rates to Domestic MP Shock (1%p)

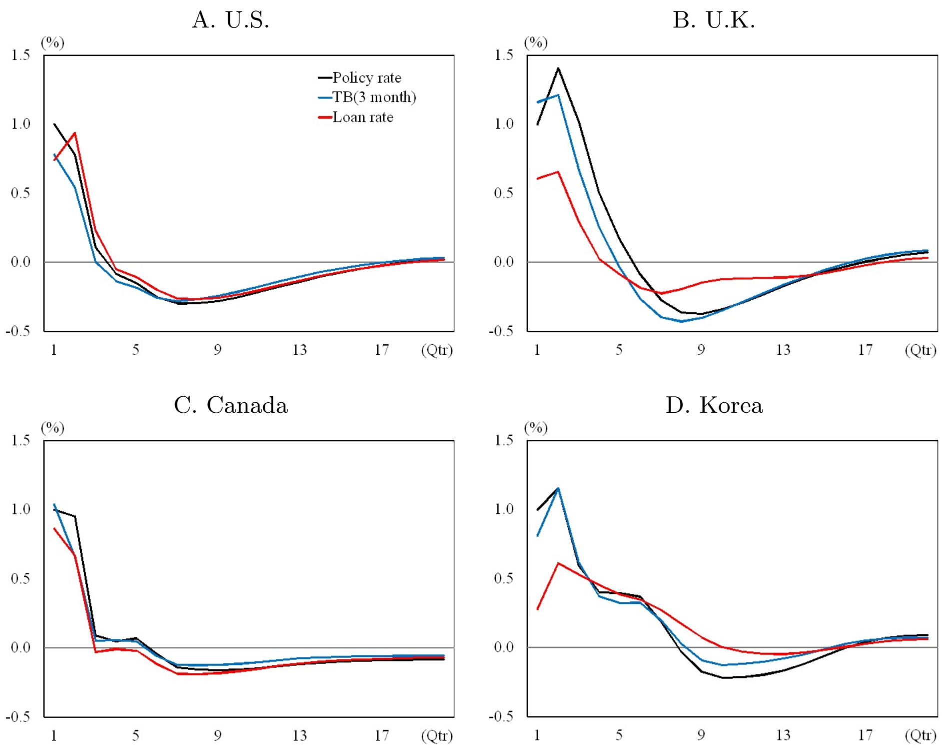
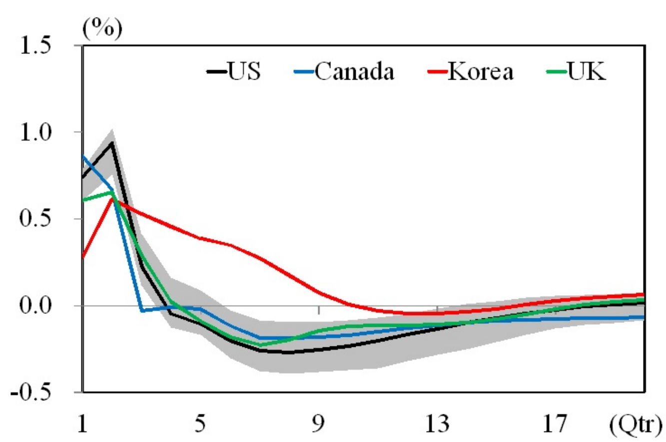


Figure 3: Comparison of Impulse Responses of Loan Rates to Domestic MP Shock (1%p)



Notes: Shaded area is 90% bootstrap interval (based on 5,000 draws) of U.S loan rate response.

Figure 4: Impulse Responses of Interest Rates to Foreign MP Shock (1%p)

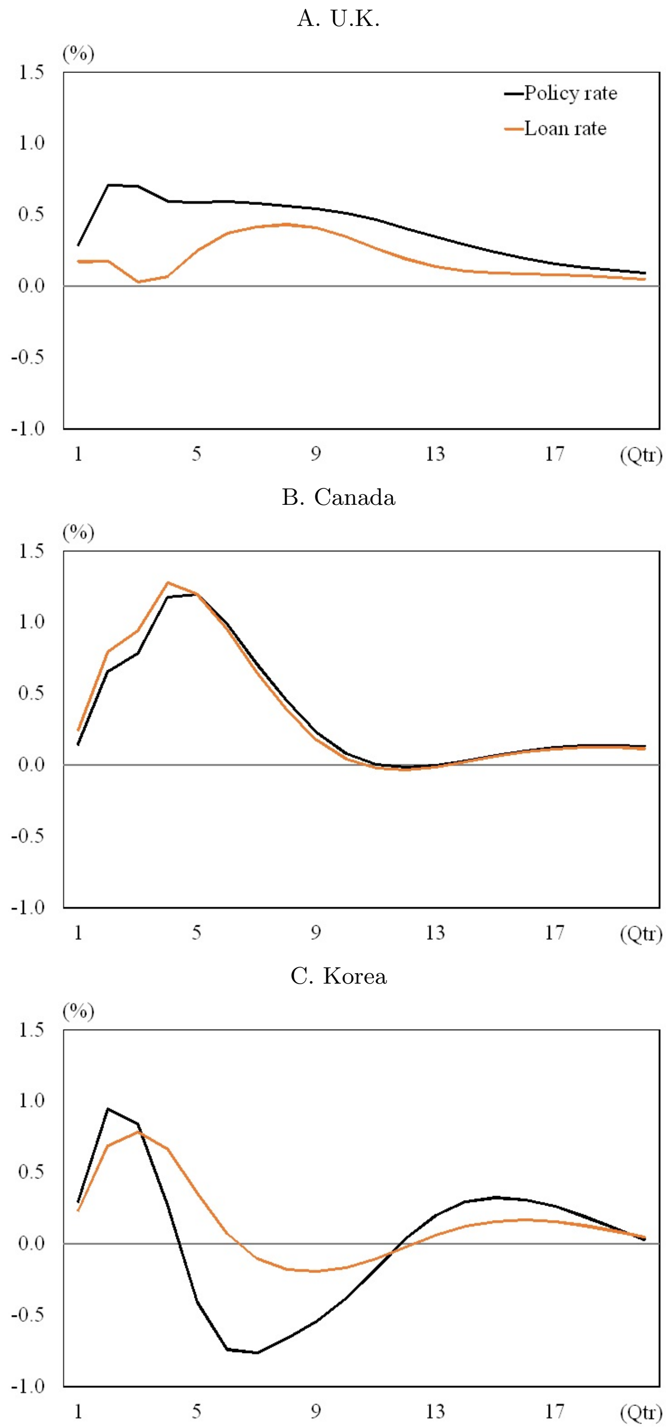


Figure 5: Model Structure

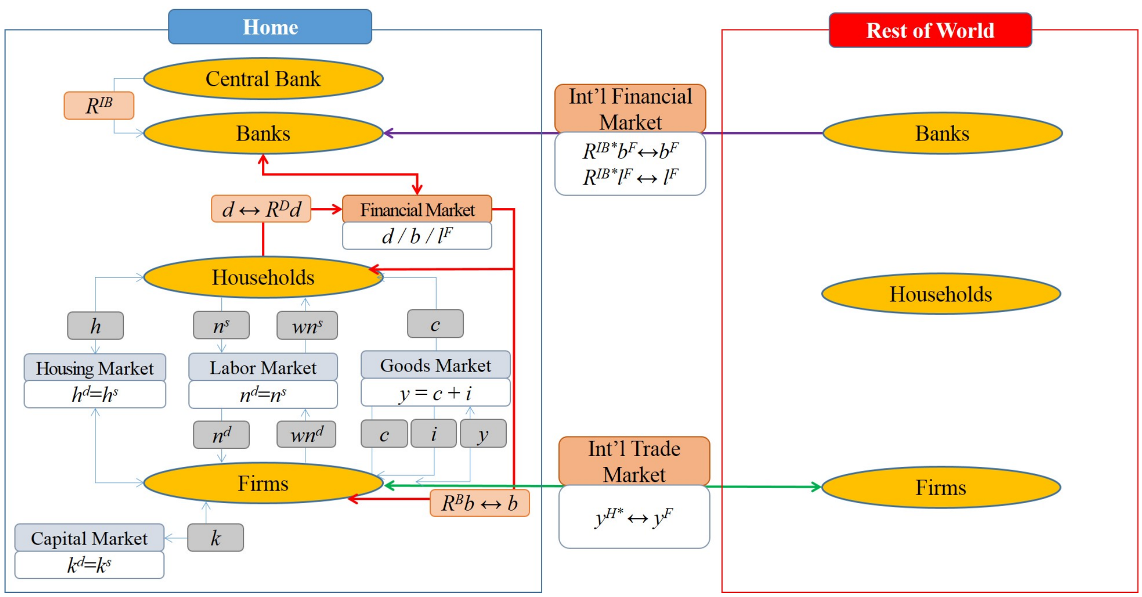
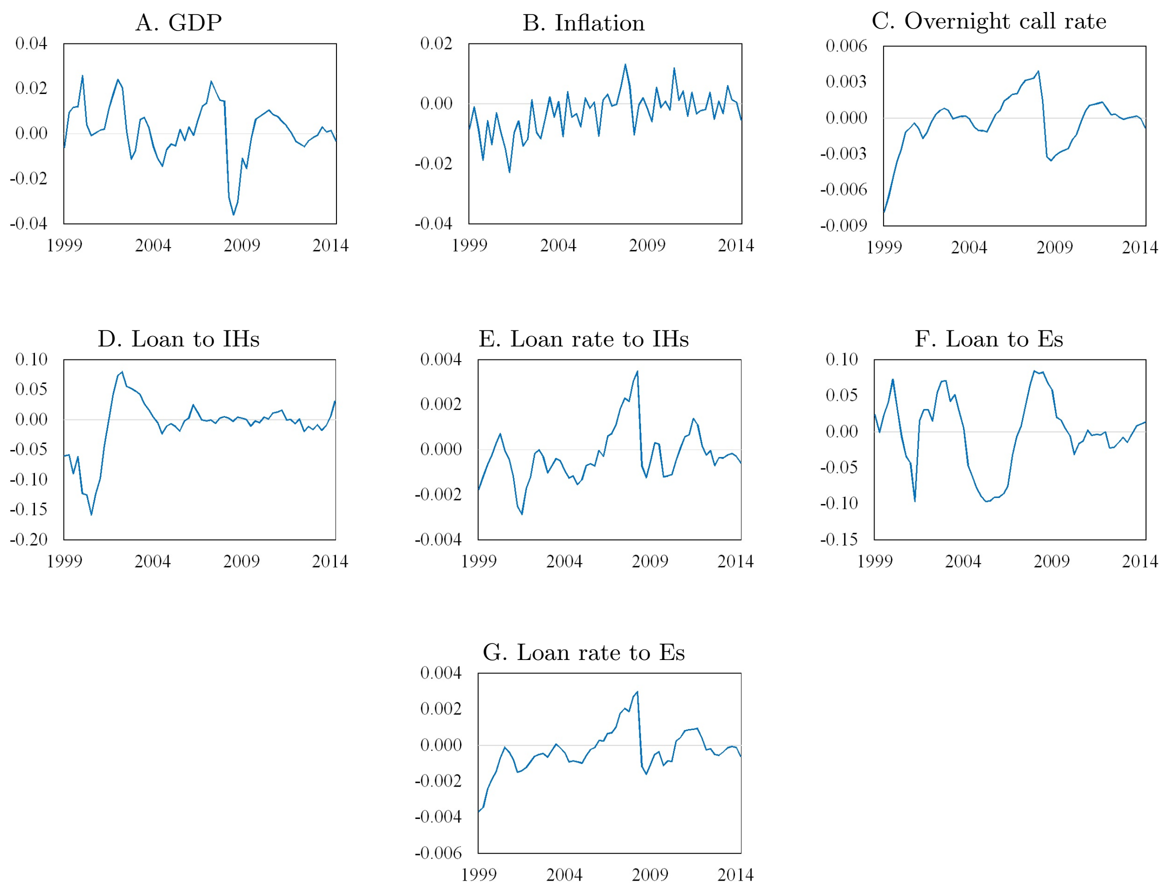
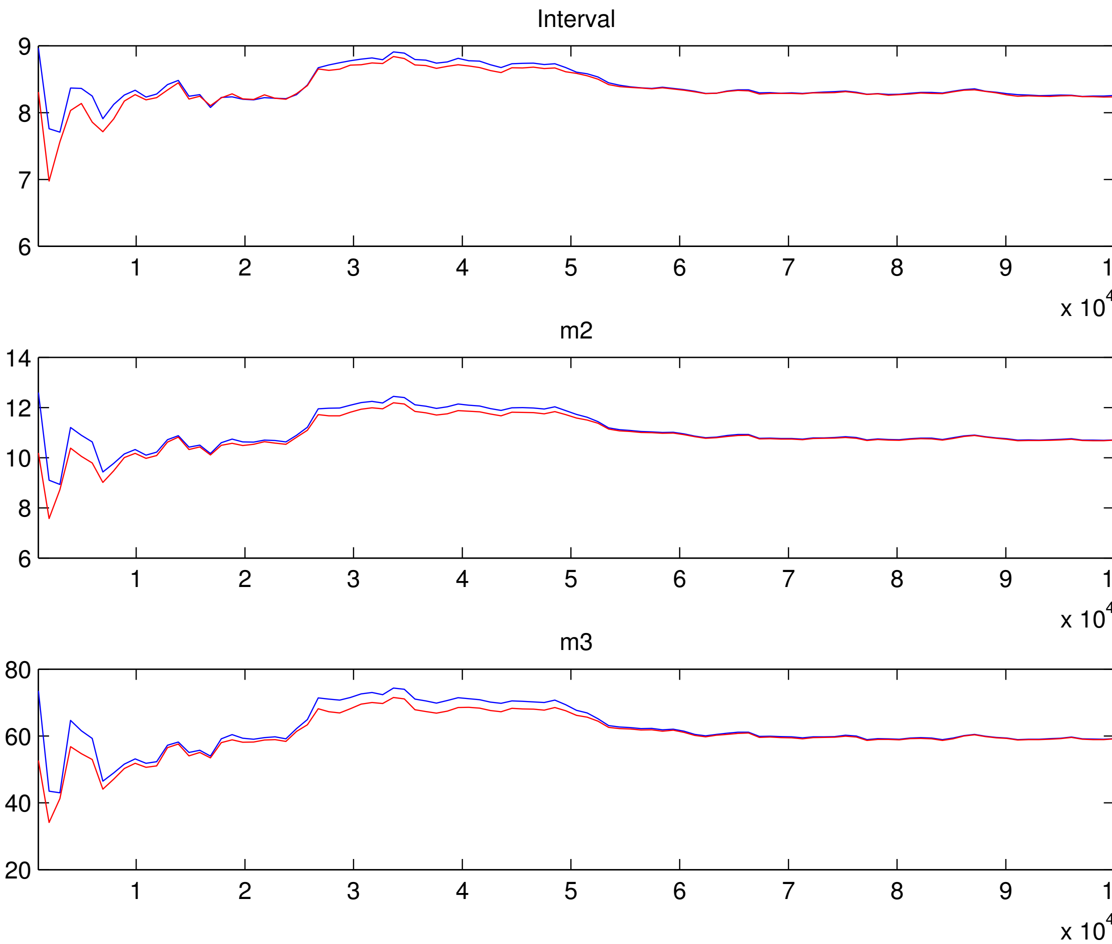


Figure 6: Data Used in Estimation



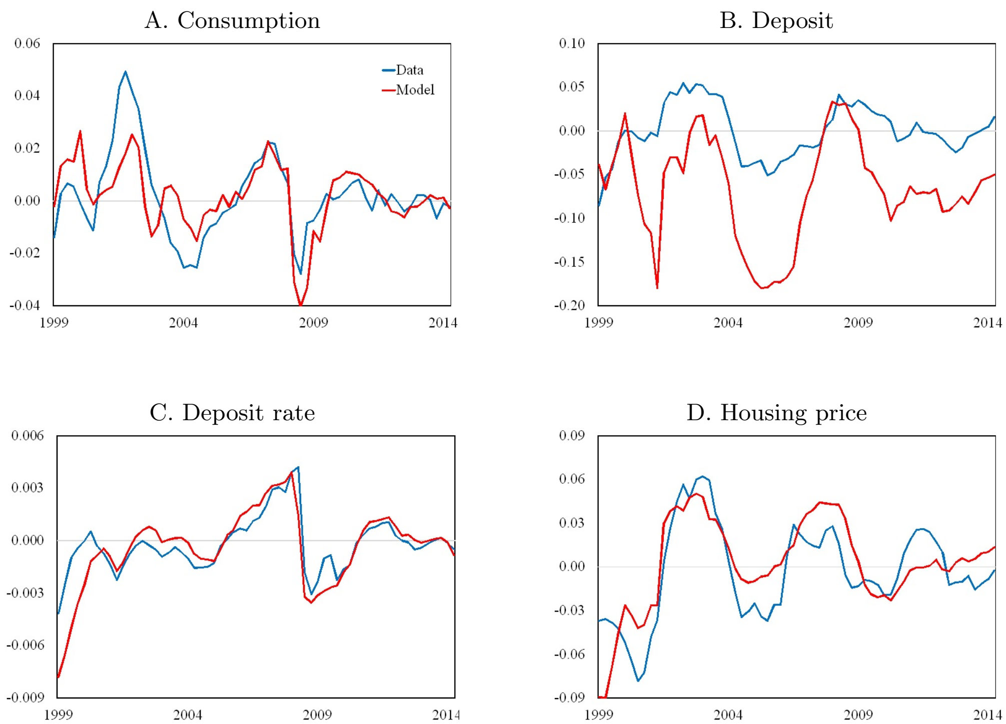
Notes:
1. The model parameters are estimated using data from 1999Q3 to 2014Q4. All of the variables are expressed as log deviations from the HP-filter trend.
2. IHs: Impatient households, Es: Entrepreneurs

Figure 7: Multivariate MH Convergence Diagnosis



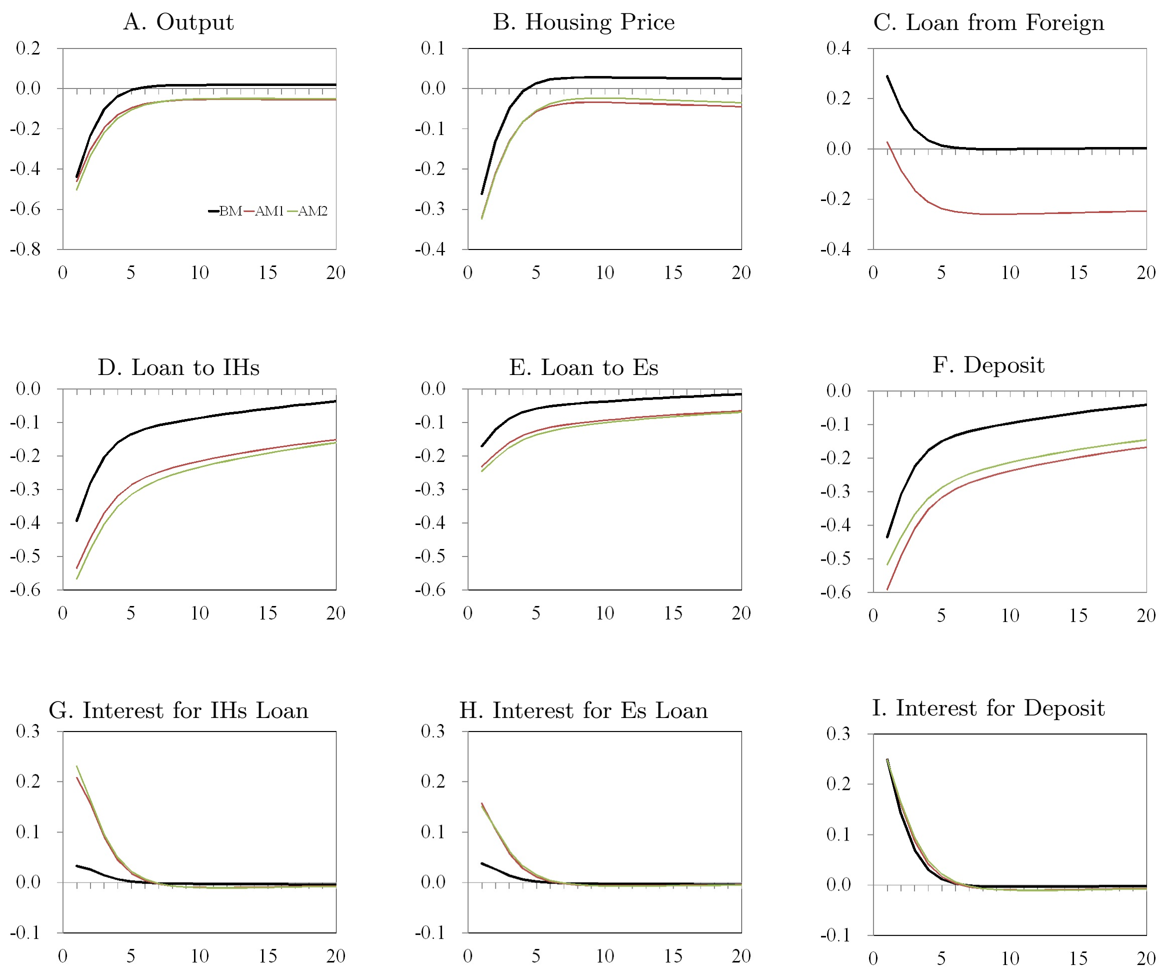
Notes: 1. The results are based on 10 chains, each with 100,000 draws from the MH algorithm.
2. Red line: Within-chain measure, Blue line: Within- and between-chain measure for each moment
3. Interval: First moment, m2: Second moment, m3: Third moment

Figure 8: Historical Decomposition of Model Series and Actual Data



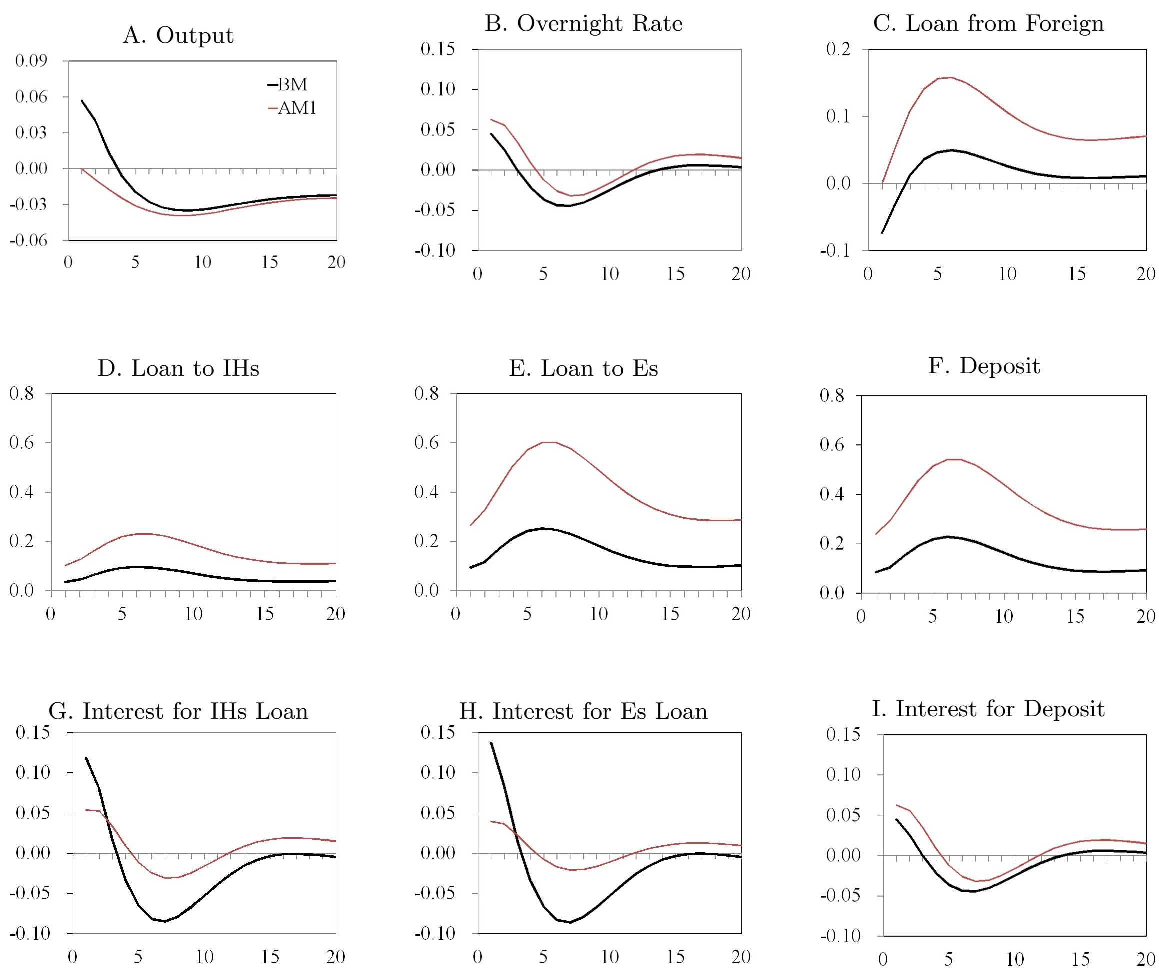
Notes: All of the variables are expressed as log deviations from the HP-filter trend.

Figure 9: Impulse Response to Contractionary Domestic MP Shock (25bp)



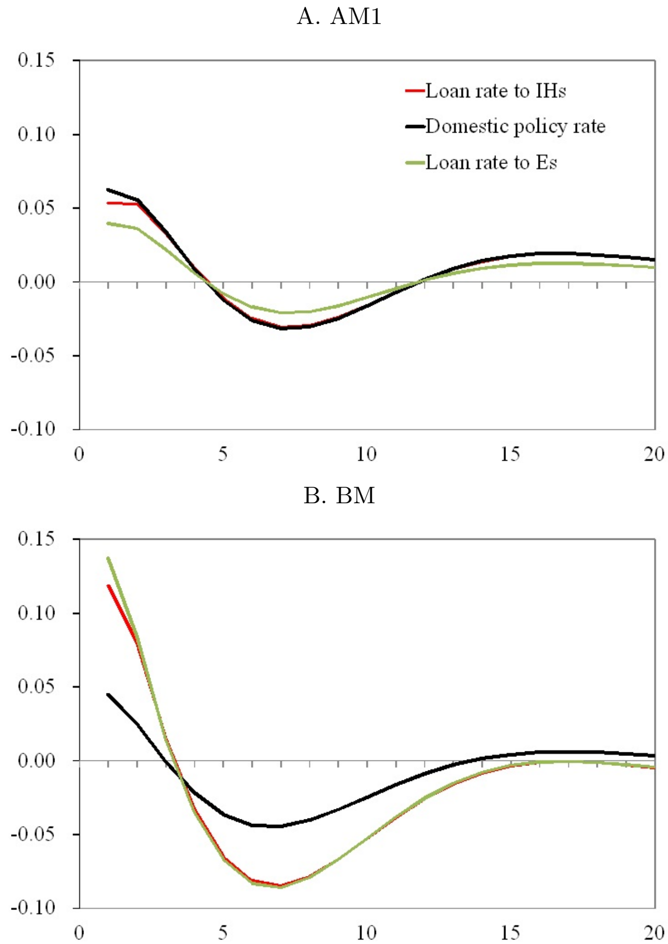
Notes:
1. BM: Baseline model,
   AM1: Alternative model 1(no foreign interest rate channel),
   AM2: Alternative model 2(AM1 + no foreign liquidity channel)
2. IHs: Impatient households, Es: Entrepreneurs
3. Horizontal axis: Quarters from the shock;
   Vertical axis: Percentage deviation from steady state.

Figure 10: Impulse Response to Contractionary Foreign MP Shock (25bp)



Notes: 1. BM: Baseline model,
AM1: Alternative model 1(no foreign interest rate channel)
2. IHs: Impatient households, Es: Entrepreneurs
3. Horizontal axis: Quarters from the shock;
Vertical axis: Percentage deviation from steady state.

Figure 11: Comparison of Impulse Responses of Interest Rates to Foreign MP Shock (25bp)



Notes:
1. BM: Baseline model,
   AM1: Alternative model 1(no foreign interest rate channel)
2. IHs: Impatient households, Es: Entrepreneurs
3. Horizontal axis: Quarters from the shock;
   Vertical axis: Percentage deviation from steady state.

Appendix

A-1 VAR Estimation Results of the Rest-of-the-World

The structural shocks of a recursive VAR model of three variables ($\widehat{\pi_t^*}$, $\widehat{y_t^*}$, $\widehat{R_t^{*IB}}$) are identified by using a standard Cholesky decomposition (ordered as listed) as in Eq (A-1). I place the federal funds rate last in the ordering as in Ghironi (2000), so that the output and inflation gap are restricted from simultaneously reacting to the interest rate shock, while the interest rate is allowed to react simultaneously to them.

$$AX_t = \sum_{i=1}^{p} B_i X_{t-i} + \varepsilon_t \tag{A-1}$$

where X_t is a state vector, A and $B_i (\forall i \geq 1)$ are nonsingular coefficient matrices, and ε_t is a structural disturbance vector.

Table A-1 reports the estimated coefficients. The results suggest that the signs and magnitude of the coefficients are in line with a generalized Taylor rule and Phillips curve.

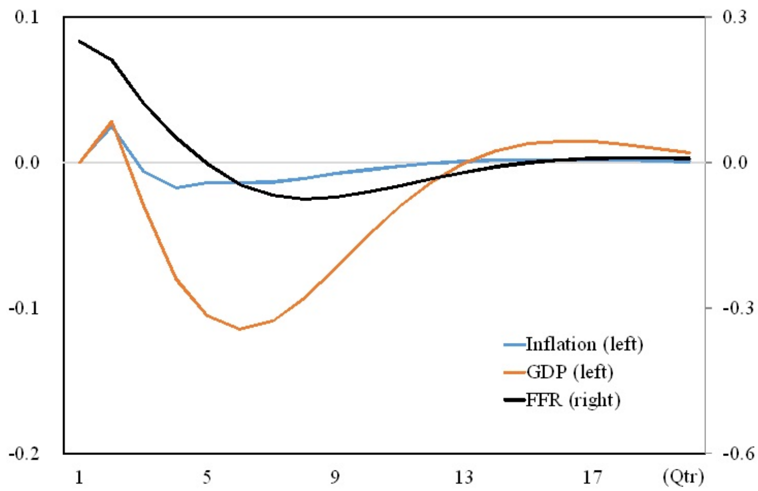
Table A-1: Estimated Coefficients of U.S VAR

	$\widehat{\pi_t^*}$		$\widehat{y_t^*}$		$\widehat{R_t^{IB*}}$	
$\widehat{y_t^*}$					0.470	(0.221)
$\widehat{\pi_t^*}$			0.183	(0.143)	0.387	(0.145)
$\widehat{\pi_{t-1}^*}$	-0.088	(0.094)	-0.165	(0.143)	-0.426	(0.233)
$\widehat{y_{t-1}^*}$	0.097	(0.058)	0.970	(0.088)	-0.109	(0.143)
$\widehat{R_{t-1}^{IB*}}$	0.098	(0.041)	0.093	(0.062)	0.756	(0.101)
$\widehat{\pi_{t-2}^*}$	-0.158	(0.096)	0.091	(0.146)	0.371	(0.237)
$\widehat{y_{t-2}^*}$	0.017	(0.057)	-0.061	(0.087)	-0.090	(0.142)
$\widehat{R_{t-2}^{IB*}}$	-0.111	(0.041)	-0.286	(0.062)	-0.036	(0.100)

Notes: The numbers in parenthesis are standard errors.

Figure A-1 illustrates the responses of U.S GDP, inflation, and federal fund rate (FFR) to a 25bp increase in FFR. The deviation of GDP and inflation from the steady state reacts with a lag of two or three quarters, of which results are in line with the literature. Over time, all variables return to the steady state.

Figure A-1: Impulse Response to Contractionary U.S FFR (25bp)

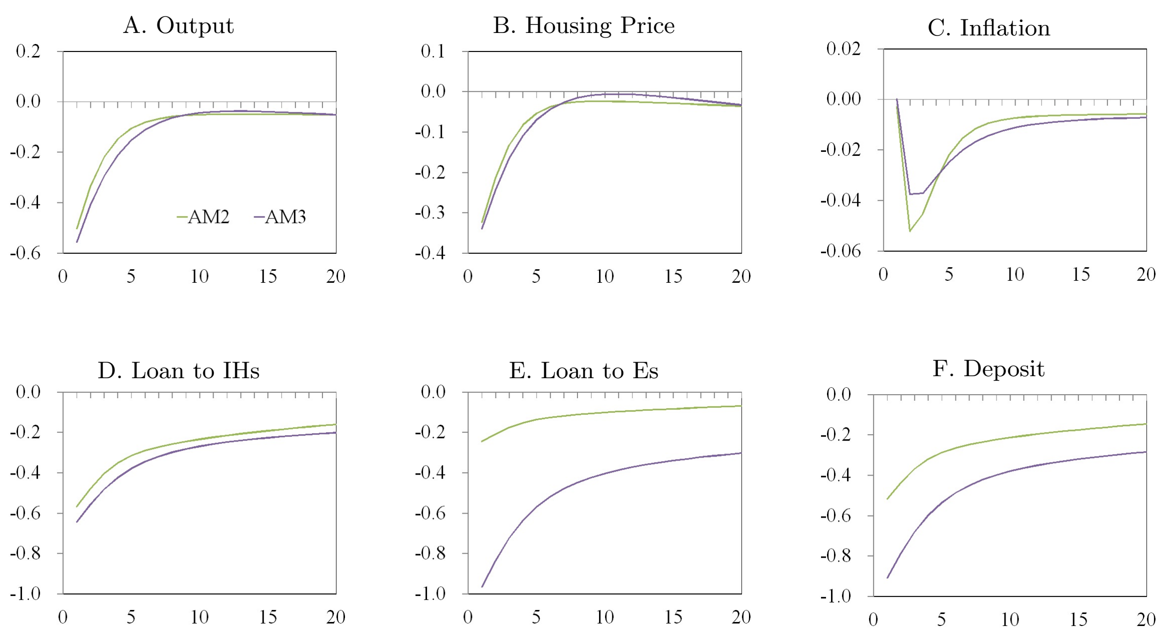


Notes: Horizontal axis : Quarters from the shock;
Vertical axis: Percentage deviation from steady state.

A-2 Market Power in the Banking Sector and MP Transmission

The monopolistic power of banks is also an important source of the attenuation of MP transmission (see Gerali et al., 2010). I set up an alternative model (AM3) that blocks the bank attenuator channel. A comparison between AM2 (green line) and AM3 (purple line) allows for capturing the bank attenuator effect. In response to a contractionary MP shock, market power in a banking industry induces financial intermediaries to adjust interest rates by a lower amount (0.02%p in deposit rate, 0.02%p in loan rate to impatient households and 0.07%p in loan rate to entrepreneurs), thereby decreasing the response of output by 0.07%p on average in the first year.

Figure A-2: Impulse Response to Contractionary Domestic MP Shock (25bp)



Notes:
1. AM2: Alternative model 2(no foreign interest rate channel and no foreign liquidity channel), AM3: Alternative model 3(AM2 + no banks' market power)
2. IHs: Impatient households, Es: Entrepreneurs
3. Horizontal axis: Quarters from the shock; Vertical axis: Percentage deviation from steady state.