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Essays on Monetary Policy
in Small Open Economies

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Abstract

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This dissertation studies the effects of monetary policy in small open economies. In Chapter 1, I investigate how the openness of banking sector influences the transmission channels of home and international monetary policy shocks in small open economies. For the analysis, I construct a small open economy DSGE model enriched with a globalized banking sector. I consider two forms of bank globalization: international bank capital finance and foreign loan account import. By comparing the effect of each type of bank globalization on monetary policy transmission, the analysis delivers the following results. First, bank globalization leads to a significant attenuation of domestic monetary policy transmission. This is because, in response to home monetary shocks, banks' global activities allow them to maintain bank rates and demands on deposit to some extent compared to those in financial autarky. On the other hand, opening of the banking sector intensifies the impact of foreign interest rate shocks on the local bank activities. In addition to the conventional channel of international monetary transmission through interest-parity condition, global bank operation opens a new channel which makes bank rates more responsive to foreign monetary shock.

Chapter 2¹ investigates the nature of monetary policy transmission in four small open economies - Australia, Canada, South Korea, and the U.K. - and the U.S. (the benchmark)

¹Coauthored with Jongrim Ha, Department of Economics, Cornell University, Ithaca, NY 14853, U.S.A

by estimating structural vector autoregressive models using the external instrument identification method. Differing from related studies on U.S. monetary policy, which mostly employ high-frequency futures data on monetary policy operating instruments (federal fund futures rates) to identify monetary policy shocks, we propose and test alternative sets of external instruments for the four focal open economies that do not yet have well-established futures markets in monetary policy instruments. The empirical results obtained by applying this data-oriented method yield important messages from both the econometric and macroeconomic perspectives. First, U.S. monetary policy plays an important role in monetary transmission in SOEs, presumably hampering the effectiveness of domestic monetary policy. In particular, the effect of domestic monetary policy shocks on medium- and long-term interest rates is quite weak and short-lived, while U.S. monetary innovation significantly and persistently influences domestic financial variables. Second, the paper provides some evidence that foreign exchange rates in this process respond to monetary shocks as Dornbusch (1976)[24]’s overshooting hypothesis.

Chapter 3² studies the wedge between the interest rate implied by Euler equation and money market rate in five small open economies – Australia, Canada, Finland, Korea, and the U.K. Standard Euler equation predicts strongly positive relationship between the two interest rates. However, data shows significantly large wedge between them, which causes negative correlation. We explore the systemic link between the wedge and two possible influencing factors – monetary policy and net foreign asset position. The empirical results from our analysis deliver the important message that the wedge is closely related to net foreign asset position in open economies, while its relationship to the stance of monetary policy has mixed results.

²Coauthored with Daisoon Kim, Department of Economics, University of Washington, Seattle, WA 98195-3330, U.S.A

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Dedication

To my dear wife, Jihyun Song, my son, Yejoon, and daughter, Yewon (Ellie).

Chapter 1

BANK GLOBALIZATION AND MONETARY POLICY TRANSMISSION IN SMALL OPEN ECONOMIES

1.1 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)[4], Cetorelli and Goldberg (2012)[14], Bruno and Shin (2015)[9]).

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 1.1 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

¹Throughout the chapter, I refer to such international banking activities as bank globalization.

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)[32]). 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.

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)[50]. 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

²For instance, Woodford (2007)[94] and Tille (2008)[90] 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.

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)[73] 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

³A burgeoning literature sheds light on the conditions from the supply side (i.e. financial intermediaries) of credit markets (Van den Heuvel (2008)[92], Gerali et al. (2010)[36]). 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*).

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)[14] and Goldberg (2013)[43], 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 an analysis by subdividing and quantitatively assessing 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 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 perspective for understanding the overall features of change caused by bank globalization (e.g., *quantity side*: Kollmann (2013)[59], Kang and Dao (2012)[53], *price side*: Brzoza-Brzezina and Makarski 2011[10]).

⁴See recent work on the international transmission of crises by Schnabl (2012)[82], Kalemli-Ozcan, Pappaioannou and Perri (2013)[52], Devereux and Yu (2014)[23], Kang and Dao (2012)[53] and others.

⁵For instance, in the open banking market, banks do not necessarily rely on the domestic credit in their operation. This may change their strategies on interest rate setting and capital position.

The rest of this chapter is organized as follows. Section 1.2 presents empirical evidence on bank globalization using a VAR model. Section 1.3 describes the baseline SOE DSGE model. Section 1.4 discusses the calibration/estimation procedure. Section 1.5 provides an overview of the transmission mechanism of MP shocks through the banking sector and the results of domestic and foreign MP restriction. Section 1.6 concludes the paper.

1.2 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 1.1. 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 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)[54] and Bjørnland 2009[7]).

⁶The variables are specified in levels to implicitly determine any potential co-integrating relationship between them. See Hamilton (1994)[48].

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

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 1.2. The shaded area plotted in the graph is the 90% bootstrap probability band of loan rate response. 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 except Canada. 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. 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)[36], Ha and So (2013)[47]). However, as we shall see in Section 1.5, the attenuation of MP transmission in banking could also appear due to the bank's global activity.

Figure 1.3 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)[71], Kim (2001)[54]). 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 framework. Loan rates in SOEs respond to foreign MP shock as much as policy rates except 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.

⁸I 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)[38], Bjørnland 2009[7]). The results remain robust to these variations.

1.3 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 take out one-period 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 entrepreneurs, and obtain funding via deposits and foreign liquidity borrowing.

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 face credit constraints in how much they can raise from home depositors 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.

⁹I consider heterogeneity in households to apply financial frictions to both firms and households (e.g. Iacoviello (2005)[50], Gerali et al. (2010)[36]). 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).

1.3.1 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 utility of a representative patient household is given as:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_P^t [\ln c_{P,t} + j_t \ln h_{P,t} - (n_{P,t})^\eta / \eta] \quad (1.1)$$

where \mathbb{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 (1.2):

$$\ln j_t = (1 - \theta_j) \ln j + \theta_j \ln j_{t-1} + \varepsilon_{j,t} \quad (1.2)$$

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 $R_{d,t-1}d_{t-1}/\pi_t$ ¹⁰ to finance its consumption, housing expenditure and new deposits. The patient household's budget constraint is (in real terms):

$$c_{P,t} + q_t h_{P,t} + d_t \leq w_{P,t}n_{P,t} + q_t h_{P,t-1} + \frac{R_{d,t-1}}{\pi_t} d_{t-1} + \Pi_{P,t}^E + \Pi_{P,t}^B \quad (1.3)$$

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:

¹⁰Similar to Iacoviello (2005)[50], I assume that deposit and loan contracts are set in nominal terms. Here, $R_{d,t}$ is a gross return and π_t is the price change between $t-1$ and t ($= P_t/P_{t-1}$).

$$\frac{1}{c_{P,t}} = \mathbb{E}_t \left[\frac{\beta_P R_{d,t}}{c_{P,t+1} \pi_{t+1}} \right] \quad (1.4)$$

$$\frac{q_t}{c_{P,t}} = \frac{j_t}{h_{P,t}} + \mathbb{E}_t \left[\beta_P \frac{q_{t+1}}{c_{P,t+1}} \right] \quad (1.5)$$

$$w_{P,t} = (n_{P,t})^{\eta-1} c_{P,t} \quad (1.6)$$

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 ¹¹:

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

where a and $\omega > 0$ are the home bias parameter and intra-temporal elasticity of substitution (EOS) between home and import consumption goods, respectively. Given the CES aggregator, the demand for domestic goods and the demand for imports are represented as follows:

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

where the corresponding price index is:

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

1.3.2 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.

¹¹Composites for domestic and foreign goods are defined as $c_t^H = \left[\int_0^1 (c_t^H(z))^{\frac{\varepsilon^H-1}{\varepsilon^H}} dz \right]^{\frac{\varepsilon^H}{\varepsilon^H-1}}$ and $c_t^F = \left[\int_0^1 (c_t^F(z))^{\frac{\varepsilon^F-1}{\varepsilon^F}} dz \right]^{\frac{\varepsilon^F}{\varepsilon^F-1}}$ 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)[71]).

The impatient households maximize the following expected lifetime utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_I^t [\ln c_{I,t} + j_t \ln h_{I,t} - (n_{I,t})^\eta / \eta] \quad (1.7)$$

However, they use labor income and loans $b_{I,t}$ to finance consumption, housing and the real interest cost of loans in the previous period $R_{b_{I,t-1}} b_{I,t-1} / \pi_t$. In addition, they can borrow only up to the expected real value of their housing stock. The budget constraint and the borrowing constraint are:

$$c_{I,t} + q_t h_{I,t} + \frac{R_{b_{I,t-1}}}{\pi_t} b_{I,t-1} \leq w_{I,t} n_{I,t} + q_t h_{I,t-1} + b_{I,t} \quad (1.8)$$

$$R_{b_{I,t}} b_{I,t} \leq m_I \mathbb{E}_t [q_{t+1} h_{I,t} \pi_{t+1}] \quad (1.9)$$

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:

$$\frac{1}{c_{I,t}} = \mathbb{E}_t \left[\frac{\beta_I}{c_{I,t+1}} \frac{R_{b_{I,t}}}{\pi_{t+1}} \right] + \lambda'_{I,t} R_{b_{I,t}} \quad (1.10)$$

$$\frac{q_t}{c_{I,t}} = \frac{j_t}{h_{I,t}} + \mathbb{E}_t \left[\beta_I \frac{q_{t+1}}{c_{I,t+1}} + \lambda'_{I,t} m_I q_{t+1} \pi_{t+1} \right] \quad (1.11)$$

$$\frac{w_{I,t}}{c_{I,t}} = (n_{I,t})^{\eta-1} \quad (1.12)$$

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

1.3.3 Entrepreneurs

Entrepreneurs only care about their consumption $c_{E,t}$, and they maximize the following expected utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_E^t \ln c_{E,t} \quad (1.13)$$

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 (1.14). Here A_t is total factor productivity, which follows an exogenous AR(1) process.¹²

$$y_{W,t} = A_t (k_{t-1})^\mu (h_{E,t-1})^v \left[(n_{P,t})^\alpha (n_{I,t})^{1-\alpha} \right]^{1-\mu-v} \quad (1.14)$$

Entrepreneurs' expenditure on consumption, real estate, labor services, capital accumulation and reimbursement of loans is financed by the revenue from their intermediate goods sales and new loans $b_{E,t}$:

$$c_{E,t} + i_t + w_{P,t} n_{P,t} + w_{I,t} n_{I,t} + q_t h_{E,t} + \frac{R_{bE,t-1}}{\pi_t} b_{E,t-1} + \xi_{K,t} \leq \frac{y_{W,t}}{x_t} + q_t h_{E,t-1} + b_{E,t} \quad (1.15)$$

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 intermediate 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

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$$R_{bE,t} b_{E,t} \leq m_E \mathbb{E}_t [q_{t+1} h_{E,t} \pi_{t+1}] \quad (1.16)$$

Entrepreneurs' first-order conditions are the consumption Euler equation, capital de-

¹²The autoregressive coefficient is θ_A , and the standard deviation is σ_A .

¹³I assume that firms also use housing stock as collateral as in Iacoviello (2005)[50], noting that firms in SOEs are usually requested to provide real estate, including housing and land, to banks as collateral rather than capital. For example, as of late 2008 in Korea, real estate comprised 88% of the total collateral value used by firms and 94% of that used by households (See Ha and So (2013)[47]).

mand, real estate demand and labor demands:

$$\frac{1}{c_{E,t}} = \mathbb{E}_t \left[\frac{\beta_E}{c_{E,t+1}} \frac{R_{bE,t}}{\pi_{t+1}} \right] + \lambda'_{E,t} R_{bE,t} \quad (1.17)$$

$$\begin{aligned} & \frac{1}{c_{E,t}} \left(1 + \frac{\kappa_i}{\delta} \left(\frac{i_t}{k_{t-1}} - \delta \right) \right) \\ &= \mathbb{E}_t \left[\frac{\beta_E}{c_{E,t+1}} \left(1 - \delta + \mu \frac{y_{W,t+1}}{x_{t+1}} \frac{1}{k_t} + \frac{\kappa_i}{\delta} \left(\frac{i_{t+1}}{k_t} - \delta \right) \left(\frac{1}{2} \left(\frac{i_{t+1}}{k_t} + \delta \right) + 1 - \delta \right) \right) \right] \end{aligned} \quad (1.18)$$

$$\frac{q_t}{c_{E,t}} = \mathbb{E}_t \left[\frac{\beta_E}{c_{E,t+1}} \left(q_{t+1} + \frac{y_{W,t+1}}{x_{t+1}} v \frac{1}{h_{E,t}} \right) \right] + \lambda'_{E,t} m_E \mathbb{E}_t [q_{t+1} \pi_{t+1}] \quad (1.19)$$

$$w_{P,t} = \alpha(1 - \mu) \frac{y_{W,t}}{x_t} \frac{1}{n_{P,t}} \quad (1.20)$$

$$w_{I,t} = (1 - \alpha)(1 - \mu) \frac{y_{W,t}}{x_t} \frac{1}{n_{I,t}} \quad (1.21)$$

1.3.4 Firms

There are two sets of firms. As in Galí and Monacelli (2005)[34], for example, firms in the import goods sector purchase foreign intermediate goods at given world prices P_t^* and transform them into differentiated import goods y_t^F , whereas firms in the home goods sector produce differentiated goods y_t^H using domestic intermediate goods purchased at the wholesale price $P_{W,t}$ from entrepreneurs at no cost. Each firm z then sells their unique variety at a mark-up over world price or wholesale price. Both groups face a quadratic cost of price adjustment, following Rotemberg (1982)[78].¹⁴

¹⁴Calvo-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)[8], and Lombardo and Vestin(2008)[62] further details.

The domestic firm z would set price $P_t^H(z)$ for the domestic goods to maximize the net present value of future profits:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[P_t^H(z) y_t^H(z) - P_{W,t} y_t^H(z) - \frac{\kappa_p^H}{2} \left(\pi_t^H(z) - (\pi_{t-1}^H)^\zeta (\pi^H)^{1-\zeta} \right)^2 p_t^H y_t^H \right] \quad (1.22)$$

subject to the demand function, $y_t^H(z) = \left(\frac{P_t^H(z)}{P_t^H} \right)^{-\omega} y_t^H$.¹⁵ Here, $\Lambda_{0,t}$ is an inter-temporal discount rate.¹⁶ I assume that the price of home goods is indexed to a combination of past and steady-state inflation, with relative weights equal to ζ and $1 - \zeta$, respectively. Firms in the domestic sector must pay a quadratic price adjustment cost (parameterized by κ_p^H) when they change their prices beyond indexation. After imposing symmetry, the first-order condition yields the following hybrid Phillips curve in the home goods market:

$$1 - \omega + \frac{\omega}{x_t} - \kappa_p^H \left(\pi_t^H - (\pi_{t-1}^H)^\zeta (\pi^H)^{1-\zeta} \right) \pi_t^H + \beta_P \frac{c_{P,t}}{c_{P,t+1}} \kappa_p^H \mathbb{E}_t \left[\left(\pi_{t+1}^H - (\pi_t^H)^\zeta (\pi^H)^{1-\zeta} \right) (\pi_{t+1}^H)^2 \frac{y_{t+1}^H}{y_t^H} \right] = 0 \quad (1.23)$$

Log-linearizing Eq (1.23) (with hat denoting the log deviation from the steady state) yields:

$$\hat{\pi}_t^H = -\frac{\omega - 1}{\kappa_p^H (1 + \beta_P \zeta)} \hat{x}_t + \frac{\beta_P}{1 + \beta_P \zeta} \mathbb{E}_t \hat{\pi}_{t+1}^H + \frac{\zeta}{1 + \beta_P \zeta} \hat{\pi}_{t-1}^H \quad (1.24)$$

where $\hat{\pi}_t^H$ is the inflation of home goods defined as the price change of domestic goods between t and $t - 1$, i.e. $\hat{\pi}_t^H \equiv \hat{P}_t^H - \hat{P}_{t-1}^H$. Domestic inflation is thus driven by past and future 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

¹⁵I assume that an index for the aggregate output for each country is analogous to the index introduced for consumption.

¹⁶Note that the firm is owned by patient households so that intertemporal discount rate is taken from the problems of patient households.

maximize the profit:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[P_t^F(z) y_t^F(z) - e_t P_t^*(z) y_t^F(z) - \frac{\kappa_p^F}{2} \left(\pi_t^F(z) - (\pi_{t-1}^F)^\zeta (\pi^F)^{1-\zeta} \right)^2 p_t^F y_t^F \right] \quad (1.25)$$

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 first-order condition for the import goods market is obtained as Eq (1.26), or log-linearized expression (1.27):

$$1 - \omega + \omega \psi_t - \kappa_p^F \left(\pi_t^F - (\pi_{t-1}^F)^\zeta (\pi^F)^{1-\zeta} \right) \pi_t^F + \beta_P \frac{c_{P,t}}{c_{P,t+1}} \kappa_p^F \mathbb{E}_t \left[\left(\pi_{t+1}^F - (\pi_t^F)^\zeta (\pi^F)^{1-\zeta} \right) (\pi_{t+1}^F)^2 \frac{y_{t+1}^F}{y_t^F} \right] = 0 \quad (1.26)$$

$$\hat{\pi}_t^F = \frac{\omega - 1}{\kappa_p^F (1 + \beta_P \zeta)} \hat{\psi}_t + \frac{\beta_P}{1 + \beta_P \zeta} \mathbb{E}_t \hat{\pi}_{t+1}^F + \frac{\zeta}{1 + \beta_P \zeta} \hat{\pi}_{t-1}^F \quad (1.27)$$

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 $\hat{\pi}_t^F$ is the inflation of imported goods denominated in home currency. Import goods inflation is thus determined by past and future inflation, and deviations from LOP.

1.3.5 Inflation, Real Exchange Rate and Terms of Trade

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

$$\hat{\pi}_t = a \hat{\pi}_t^H + (1 - a) \hat{\pi}_t^F \quad (1.28)$$

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:

$$\hat{\pi}_t = \hat{\pi}_t^H - (1 - a)\Delta\hat{S}_t \quad (1.29)$$

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

$$\hat{Q}_t = a\hat{S}_t + \hat{\psi}_t \quad (1.30)$$

1.3.6 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 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.

Loan and Deposit Demand

I model market power in the banking industry with a Dixit-Stiglitz framework after Gerali et al (2010)[36]. 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 :¹⁷

¹⁷For simplicity, I treat the EOSs between deposits and between loans as exogenously determined.

$$d_t = \left[\int_0^1 d_t(j)^{\frac{\varepsilon_d - 1}{\varepsilon_d}} dj \right]^{\frac{\varepsilon_d}{\varepsilon_d - 1}} \quad (1.31)$$

Minimizing over $d_t(j)$ the gross interest payment given by the formula (1.32) subject to (1.31) yields the demand for deposits of patient households:¹⁸

$$\int_0^1 \frac{1}{R_{d,t}(j)} d_t(j) dj \quad (1.32)$$

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 .

$$b_{s,t} = \left[\int_0^1 b_{s,t}(j)^{\frac{\varepsilon_{bs} - 1}{\varepsilon_{bs}}} dj \right]^{\frac{\varepsilon_{bs}}{\varepsilon_{bs} - 1}} \quad (1.33)$$

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

$$\int_0^1 R_{bs,t}(j) b_{s,t}(j) dj \quad (1.34)$$

subject to (1.33).

The demand for deposits and the demand for loans are:

$$d_t(j) = \left(\frac{R_{d,t}(j)}{R_{d,t}} \right)^{\varepsilon_d} d_t \quad (1.35)$$

$$b_{s,t}(j) = \left(\frac{R_{bs,t}(j)}{R_{bs,t}} \right)^{-\varepsilon_{bs}} b_{s,t} \quad (1.36)$$

¹⁸Banks sell deposit contracts at the price $1/R_d$. Note that this formulation is equivalent to a formulation where banks maximize profit from taking deposits defined as $\frac{1}{R_{d,t}} d_t - \int_0^1 \frac{1}{R_{d,t}(j)} d_t(j) dj$.

Wholesale Branch

The perfectly competitive wholesale branch manages the capital position of the bank. On the liability side, the wholesale branch takes wholesale deposits d_t from patient households and raises foreign funds l_t^F on the international interbank market. On the asset side, the branch gives out wholesale loans $b_{I,t}^H$ and $b_{E,t}^H$.

A wholesale unit maximizes:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_B^t \ln c_{B,t} \quad (1.37)$$

subject to budget constraint:

$$\begin{aligned} c_{B,t} + \frac{R_{t-1}^{IB}}{\pi_t} d_{t-1} + b_{I,t}^H + b_{E,t}^H + Q_t \frac{R_{t-1}^{IB*}}{\pi_t} l_{t-1}^F \\ \leq d_t + \frac{R_{t-1}^{IB}}{\pi_t} (b_{I,t-1}^H + b_{E,t-1}^H) + Q_t l_t^F - \xi_{d,t} - \xi_{bI,t} - \xi_{bE,t} - \xi_{l,t} \end{aligned} \quad (1.38)$$

where $c_{B,t}$ is the wholesale bank's consumption, R_t^{IB} and R_t^{IB*} are domestic and international interbank rates,¹⁹ and $\xi_{d,t} \equiv \frac{\phi_d}{2} (\Delta d_t)^2$, $\xi_{bI} \equiv \frac{\phi_{bI}}{2} (\Delta b_{I,t}^H)^2$, $\xi_{bE} \equiv \frac{\phi_{bE}}{2} (\Delta b_{E,t}^H)^2$, and $\xi_l \equiv \frac{\phi_l}{2} (\Delta l_t^F)^2$ are quadratic portfolio adjustment costs.²⁰ 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 (1.39). 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 (1.40).²¹

¹⁹I 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.

²⁰Although the introduction of portfolio adjustment costs in the model helps to characterize real world financial frictions and distinguish from each other, it simultaneously resolves the nonstationarity problem of the SOE model with incomplete financial markets. See Schmitt-Grohe and Uribe (2003)[81] for details.

²¹Similar assumptions on bank constraints are adopted by Iacoviello (2015)[51] and Kang and Dao (2012)[53].

$$d_t + Q_t l_t^F \leq \gamma (b_{I,t} + b_{E,t}) \quad (1.39)$$

$$Q_t l_t^F \leq m_F (b_{I,t} + b_{E,t} - d_t) \quad (1.40)$$

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

$$\frac{1 - \phi_d (d_t - d_{t-1})}{c_{B,t}} = \mathbb{E}_t \left[\frac{\beta_B}{c_{B,t+1}} \left(\frac{R_t^{IB}}{\pi_{t+1}} - \phi_d (d_{t+1} - d_t) \right) \right] - \lambda'_{B,t} - \lambda''_{B,t} m_F \quad (1.41)$$

$$\frac{1 + \phi_{bI} (b_{I,t} - b_{I,t-1})}{c_{B,t}} = \mathbb{E}_t \left[\frac{\beta_B}{c_{B,t+1}} \left(\frac{R_t^{IB}}{\pi_{t+1}} + \phi_{bI} (b_{I,t+1} - b_{I,t}) \right) \right] - \lambda'_{B,t} \gamma - \lambda''_{B,t} m_F \quad (1.42)$$

$$\frac{1 + \phi_{bE} (b_{E,t} - b_{E,t-1})}{c_{B,t}} = \mathbb{E}_t \left[\frac{\beta_B}{c_{B,t+1}} \left(\frac{R_t^{IB}}{\pi_{t+1}} + \phi_{bE} (b_{E,t+1} - b_{E,t}) \right) \right] - \lambda'_{B,t} \gamma - \lambda''_{B,t} m_F \quad (1.43)$$

$$\frac{1 - \phi_l (l_t^F - l_{t-1}^F)}{c_{B,t}} = \mathbb{E}_t \left[\frac{\beta_B}{c_{B,t+1}} \left(Q_{t+1} \frac{R_t^{IB*}}{\pi_{t+1}^*} - \phi_l (l_{t+1}^F - l_t^F) \right) \right] - \lambda'_{B,t} Q_t - \lambda''_{B,t} Q_t \quad (1.44)$$

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

Retail Branch

Retail branches operate in a monopolistically competitive manner with the demand function given by (1.35) and (1.35). 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 takes deposit $d_t(j)$ from patient households at the interest rate $R_{d,t}(j)$ and transfers them to the wholesale unit at rate R_t^{IB} . The retail branch sets deposit rates to maximize the profit from deposit taking:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^B \left[R_t^{IB} d_t(j) - R_{d,t}(j) d_t(j) - \frac{\kappa_d}{2} \left(\frac{R_{d,t}(j)}{R_{d,t-1}(j)} - 1 \right)^2 R_{d,t} d_t \right] \quad (1.45)$$

subject to demand (1.35). 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 .²² The first-order condition for deposit rate setting reads:

$$1 - \varepsilon_d + \varepsilon_d \frac{R_t^{IB}}{R_{d,t}} - \kappa_d \left(\frac{R_{d,t}}{R_{d,t-1}} - 1 \right) \frac{R_{d,t}}{R_{d,t-1}} + \beta_P \mathbb{E}_t \left[\frac{c_{P,t}}{c_{P,t+1}} \kappa_d \frac{d_{t+1}}{d_t} \left(\frac{R_{d,t+1}}{R_{d,t}} - 1 \right) \left(\frac{R_{d,t+1}}{R_{d,t}} \right)^2 \right] = 0 \quad (1.46)$$

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

$$\hat{R}_{d,t} = \frac{1 + \varepsilon_d}{1 + \varepsilon_d + (1 + \beta_P) \kappa_d} \hat{R}_t^{IB} + \frac{\kappa_d}{1 + \varepsilon_d + (1 + \beta_P) \kappa_d} \hat{R}_{d,t-1} + \frac{\beta_P \kappa_d}{1 + \varepsilon_d + (1 + \beta_P) \kappa_d} \mathbb{E}_t \hat{R}_{d,t+1} \quad (1.47)$$

This equation highlights how the retail unit sets deposit rate 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 $1/\varepsilon_d$.

Similar to the deposit taking, the retail branch of bank j receives wholesale loans $b_{s,t}(j)$ from the wholesale unit ($b_{s,t}^H(j)$) at rate R_t^{IB} or in the international interbank market ($b_{s,t}^F(j)$) at rate R_t^{IB*} for $s = I, E$, and sales them to impatient households and entrepreneurs. As in Brzoza-Brzezina and Makarski (2011)[10], 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:

²²Note that the bank is owned by patient households so that discount factor is taken from the problem of patient households.

$$b_{s,t}(j) = b_{s,t}^H(j) + Q_t b_{s,t}^F(j) \quad (1.48)$$

Formally, the profit maximization problem from loan issuance can be stated as follows:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^B [R_{bs,t}(j) b_{s,t}(j) - R_t^{IB} b_{s,t}^H(j) - R_t^{IB*} Q_t b_{s,t}^F(j) - \frac{\kappa_{bs}}{2} \left(\frac{R_{bs,t}(j)}{R_{bs,t-1}(j)} - 1 \right)^2 R_{bs,t} b_{s,t}] \quad (1.49)$$

subject to demand (1.36), and with a technology (1.48) for $s = I, E$. Solving the problem yields the first-order conditions for loan rates as (1.50) or their log-linearized versions (1.51):

$$1 - \varepsilon_{bs} + \varepsilon_{bs} \frac{m R_t^{IB} + (1-m) Q_t R_t^{IB*}}{R_{bs,t}} - \kappa_{bs} \left(\frac{R_{bs,t}}{R_{bs,t-1}} - 1 \right) \frac{R_{bs,t}}{R_{bs,t-1}} + \beta_P \mathbb{E}_t \left[\frac{c_{P,t}}{c_{P,t+1}} \kappa_{bs} \frac{b_{s,t+1}}{b_{s,t}} \left(\frac{R_{bs,t+1}}{R_{bs,t}} - 1 \right) \left(\frac{R_{bs,t+1}}{R_{bs,t}} \right)^2 \right] = 0 \quad (1.50)$$

$$\begin{aligned} \hat{R}_{bs,t} = & \underbrace{\frac{\varepsilon_{bs} m R^{IB}}{R_{bs} (\varepsilon_{bs} - 1 + \kappa_{bs} (1 + \beta_P))}}_{\text{domestic interbank rate}} \hat{R}_t^{IB} \\ & + \underbrace{\frac{\varepsilon_{bs} (1-m) R^{IB*}}{R_{bs} (\varepsilon_{bs} - 1 + \kappa_{bs} (1 + \beta_P))}}_{\text{foreign interbank rate}} \hat{R}_t^{IB*} + \underbrace{\frac{\varepsilon_{bs} (1-m) R^{IB*}}{R_{bs} (\varepsilon_{bs} - 1 + \kappa_{bs} (1 + \beta_P))}}_{\text{real exchange rate}} \hat{Q}_t \\ & + \underbrace{\frac{\kappa_{bs}}{\varepsilon_{bs} - 1 + \kappa_{bs} (1 + \beta_P)}}_{\text{past loan rate}} \hat{R}_{bs,t-1} + \underbrace{\frac{\beta_P \kappa_{bs}}{\varepsilon_{bs} - 1 + \kappa_{bs} (1 + \beta_P)}}_{\text{future loan rate}} \mathbb{E}_t \hat{R}_{bs,t+1} \end{aligned} \quad (1.51)$$

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.²³

Additionally, the bank's problem originates the uncovered interest parity condition (UIP)

²³Note that in financial autarky, the dynamics of the loan rate are formulated based only on domestic interbank rates and past and future rates.

because banks can obtain resources on the international interbank market. UIP shock ($\varepsilon_{e,t}$ and its standard deviation σ_e) is assumed, as in Kollmann (2002)[58], given the empirical evidence that the exchange rates have shown a strong and persistent deviation from the UIP condition after the Bretton Woods era.

$$R_t^{IB} = R_t^{IB*} \mathbb{E}_t \left(\frac{e_{t+1} \varepsilon_{e,t}}{e_t} \right) \quad (1.52)$$

where e_t denotes the nominal exchange rate.

1.3.7 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)[41].²⁴ The data used for estimation is between 1980.Q1 and 2008.Q2 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

$$R_t^{IB} = (R_{t-1}^{IB})^\rho \left[(R^{IB}) \left(\frac{\pi_t}{\pi} \right)^{\phi_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{\phi_y} \right]^{1-\rho} \varepsilon_{R^{IB},t} \quad (1.53)$$

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.

²⁴Another popular way to model the exogenous rest-of-the-world is to assume that foreign variables are AR processes. See Matheson (2010)[63] for example.

1.3.8 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:

$$y_t = c_{P,t} + c_{I,t} + c_{E,t} + c_{B,t} + i_t \quad (1.54)$$

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

$$\bar{h} = h_{P,t} + h_{I,t} + h_{E,t} \quad (1.55)$$

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

$$\frac{P_t^H}{P_t} y_{W,t} - y_t = Q_t \frac{R_t^{IB*}}{\pi_t^*} (b_{I,t-1}^F + b_{E,t-1}^F + l_{t-1}^F) - Q_t (b_{I,t}^F + b_{E,t}^F + l_t^F) \quad (1.56)$$

1.4 Calibration and Estimation

Data from Korea are used for the estimation of the model because Korea is a typical small open economy where the financial system largely depends on the banking sector.²⁵ 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)[1].

²⁵The Korean financial market shows high dependency on banking, but low portion of direct financing such as bonds and stocks. In particular, financing through banking sector occupied 90% and 54% for households and firms, respectively, whereas the portion of corporations depending on the direct financing market was only 20% (as of 2008). For more details on the Korean financial institutions, see Ha and So (2013)[47].

1.4.1 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)[13]. The discount factor of patient households (β_P) is set to 0.99 to match the long-term average of the 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)[53] to ensure positive financial flow in the steady state.²⁶ The technology parameters (μ , ν and α) are chosen as 0.36, 0.04 and 0.70 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)[50] and Gerali et al. (2010)[36].

1.4.2 Data and Estimation

To estimate the remaining parameters, i.e., adjustment cost parameters and the standard error and autoregressive coefficients of all of the shocks, seven quarterly macroeconomic and financial time-series data are 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.²⁷ The sample period is chosen as 1999.Q3 ~ 2014.Q4 to correspond to a period of

²⁶Home 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 banks charge must be low enough for borrowers, i.e. $\frac{1}{\beta_I} > R_{bI}$ and $\frac{1}{\beta_E} > R_{bE}$.

²⁷There are seven exogenous shocks in the model. As in the usual practice for the estimation, I use as many observable variables as shocks.

a homogeneous monetary policy regime.²⁸ The data are detrended using an HP-filter with a smoothing parameter of 1,600. The detrended data are plotted in Figure 1.5.

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 by Brooks and Gelman (1998)'s diagnostics as shown in Figure 1.6.²⁹

Tables 1.2 and 1.3 report the summary statistics of prior and posterior distributions. Similar to Gerali et al. (2010)[36] 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)[51] and Kang and Dao (2012)[53], I also set the prior means of banks' adjustment cost parameters (ϕ_d , ϕ_{bI} and ϕ_{bE}) at 0.25.³⁰ I impose priors for the standard deviations of the above parameters 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.

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 in line with Gerali et al. (2010)[36]. 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,

²⁸The 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.

²⁹Markov 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.

³⁰These parameters are linked to the elasticity of loan and deposit supplies. The derivatives of loan adjustment cost functions, for instance, can be written as $\frac{d\xi_{bs}}{db_s} = \phi_{bs}(b_{s,t} - b_{s,t-1})$. 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 parameter 0.25 implies an increase of the loan supply by 1% responding to a 1% rise in loan rates. See Iacoviello (2015)[51] for the details.

which is somewhat lower than Smets and Wouters' (2007)[86] estimate. The shocks following AR(1) processes are persistent.

1.4.3 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 (1998.Q1~2014.Q4). Table 1.4 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.³¹

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)[51]). Figure 1.7 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.

1.5 The Transmission Mechanism of MP Shocks

As in existing studies, the model suggests several channels that explain the transmission of local MP shocks: the real rate, nominal debt, financial accelerator, bank attenuator and bank lending channel (mainly closed economy model; see Iacoviello (2005)[50], Gerali et al. (2010)[36] and Van den Heuvel (2008)[92] for instance).³² Additionally, foreign interest rate

³¹Steady 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.

³²In 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

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 (2015)[70], Passari and Rey (2015)[73]).

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.

1.5.1 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.³³

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)[36], Ha and So (2013)[47]). 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.

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 contractions of bank deposit, banks tighten their lending standards, which worsen credit conditions (*bank lending 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*).

³³As proposed by Gerali et al. (2010)[36], 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.

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 tighten 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 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.³⁴ Table 1.5 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.

Figure 1.8 exhibits the impacts of policy tightening on key macroeconomic and financial

³⁴To 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 $s = I, E$).

variables through each transmission channel, and Table 1.6 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 the output (-0.20%) and inflation (-0.04%) fall because the productive sector of the economy relies on bank credit.³⁵

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, 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).³⁶ 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

³⁵For 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.

³⁶Consumption and investment also react less in BM than in AM1 by 0.07%p and 0.04%p respectively.

drops by less than 0.03%p in AM1 compared to AM2. The responses of the variables confirm the existence of a foreign liquidity channel in line with much of the available literature (e.g., Cetorelli and Goldberg (2012)[14]).

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.

1.5.2 *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 responses coming from BM and AM1, as illustrated in the previous section.³⁷ Figure 1.9 shows the impulse responses from an unanticipated 25bp increase in the foreign policy

³⁷In the model, the relationship between foreign monetary policy and foreign loan conditions is not clearly defined for simplicity (see Section 1.3.7 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.

rate. Table 1.7 summarizes the average impulse response of key variables in the first year.

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)[36]. 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 the 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 those 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 (1.50) and (1.51). This situation adds a stronger propagation mechanism: in addition to indirect transmission channel through policy rate adjustment (0.01%p on average in the first year), foreign monetary shocks can also directly influence the loan rates 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 1.10 plots the responses of both loan rates and domestic policy rates to a foreign monetary shock. In Panel A, which describes the responses of variables in AM1, loan rates react to foreign monetary surprises by a lower amount than to 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.

1.6 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.

1.7 Tables and Figures

Table 1.1: 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
v	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 1.2: 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 1.3: Prior and Posterior Distribution of Parameters : Exogenous Processes

Parameter	Prior Distribution			Posterior Distribution		
	Distribution	Mean	St.dev.	Median	Mean	St.dev.
<i>AR coefficients</i>						
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
<i>Standard deviations</i>						
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
σ_{RIB}	Inv. Gamma	0.01	0.05	0.04	0.04	0.003
σ_e	Inv. Gamma	0.01	0.05	0.06	0.06	0.006
σ_{RIB^*}	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 1.4: 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
$\frac{b_H}{y}$	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 1.5: Decomposition of MP Transmission Channels

	Baseline Model	Alternative Models	
	(BM)	(AM1)	(AM2)
Foreign liquidity channel (A)	○	○	×
Foreign interest rate channel (B)	○	×	×
Identify		(A)	(B)

Notes: ○—Existing in the model, ×—Not existing in the model.

Table 1.6: 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

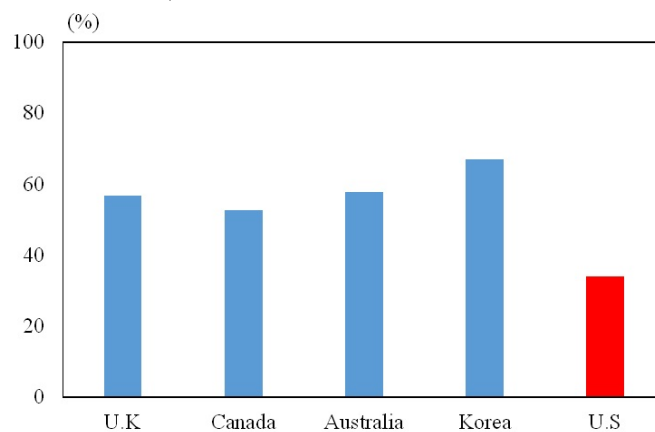
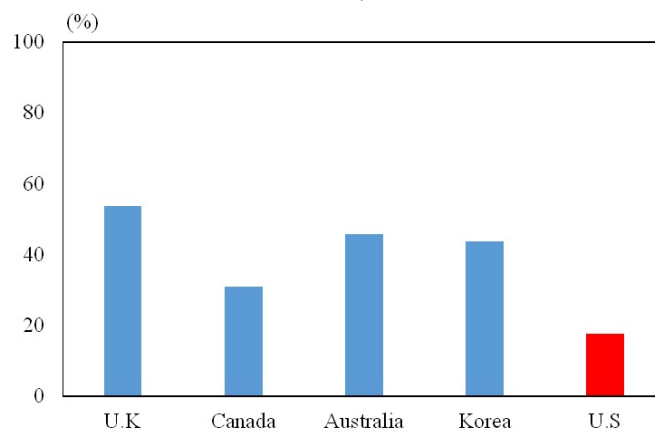
Notes: Average impulse responses in the first year

Table 1.7: 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

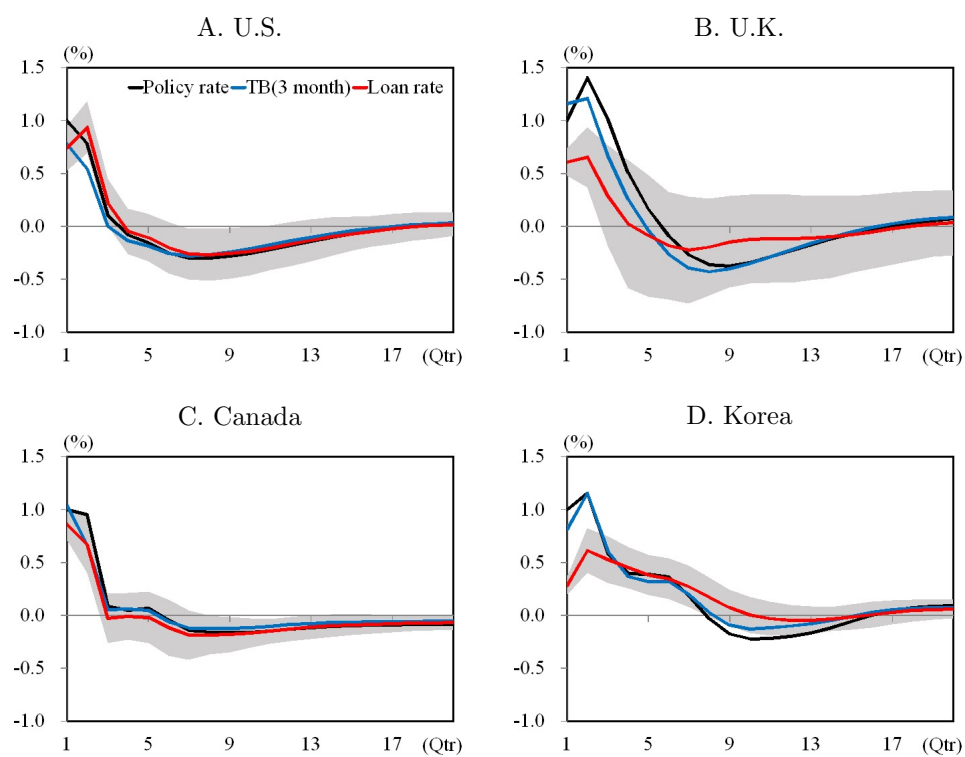
Figure 1.1: Bank Credit to Private Sector and Bank External Debt

A. Bank¹ credit/total credit To Private Non-financial Sector²B. Bank¹ external debt/gross external debt

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

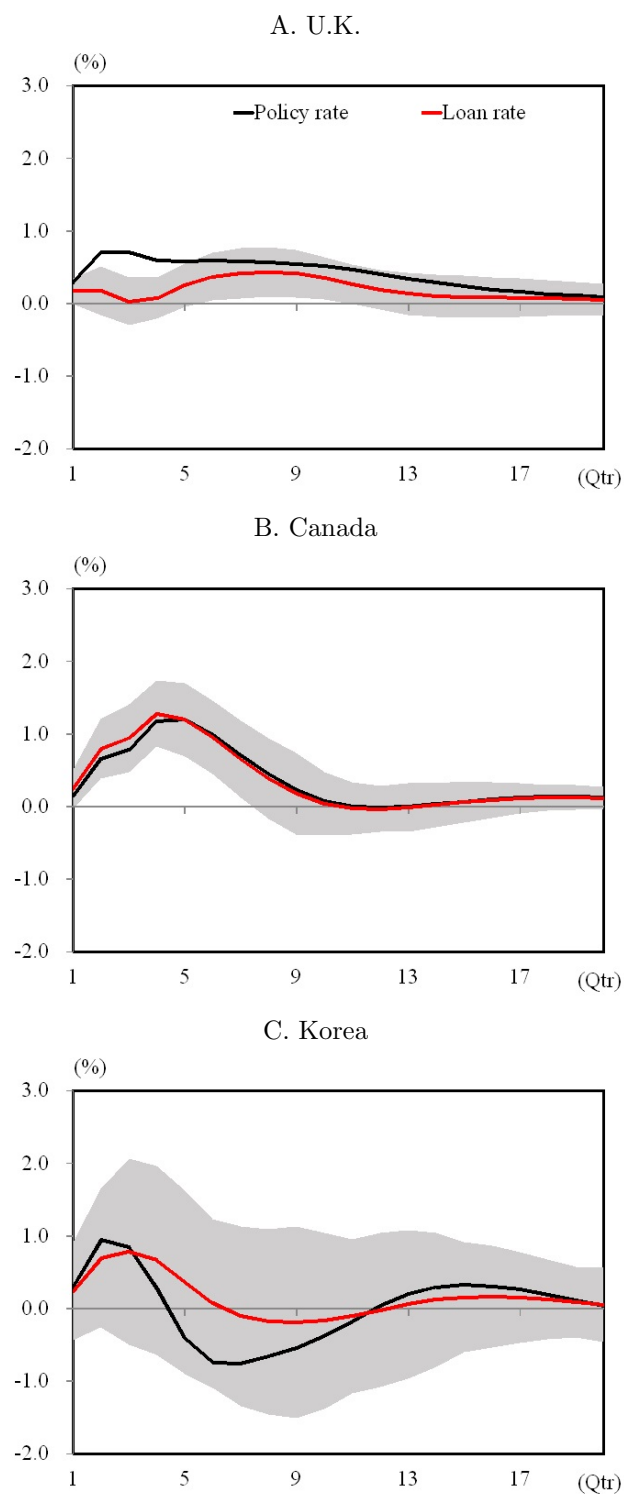
Sources: BIS, World Bank (as of the end of 2014)

Figure 1.2: Impulse Responses of Interest Rates to Domestic MP Shock (1%p)



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

Figure 1.3: Impulse Responses of Interest Rates to Foreign MP Shock (1%p)



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

Figure 1.4: Model Structure

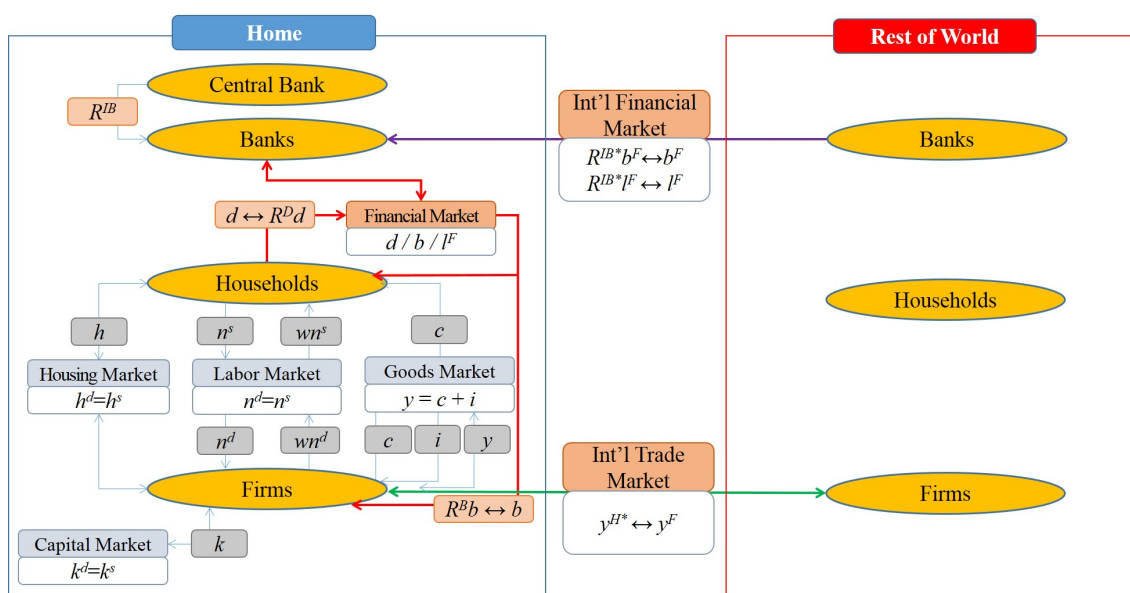
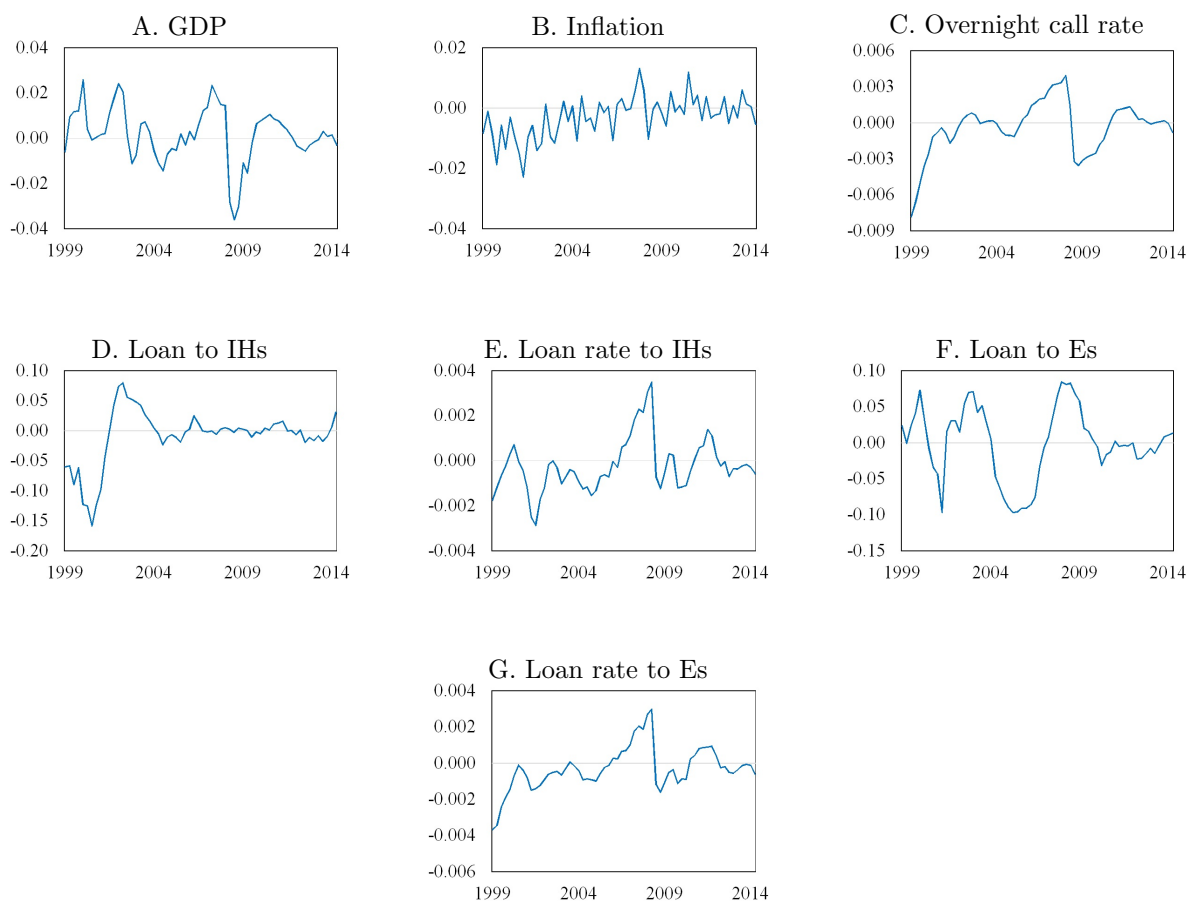
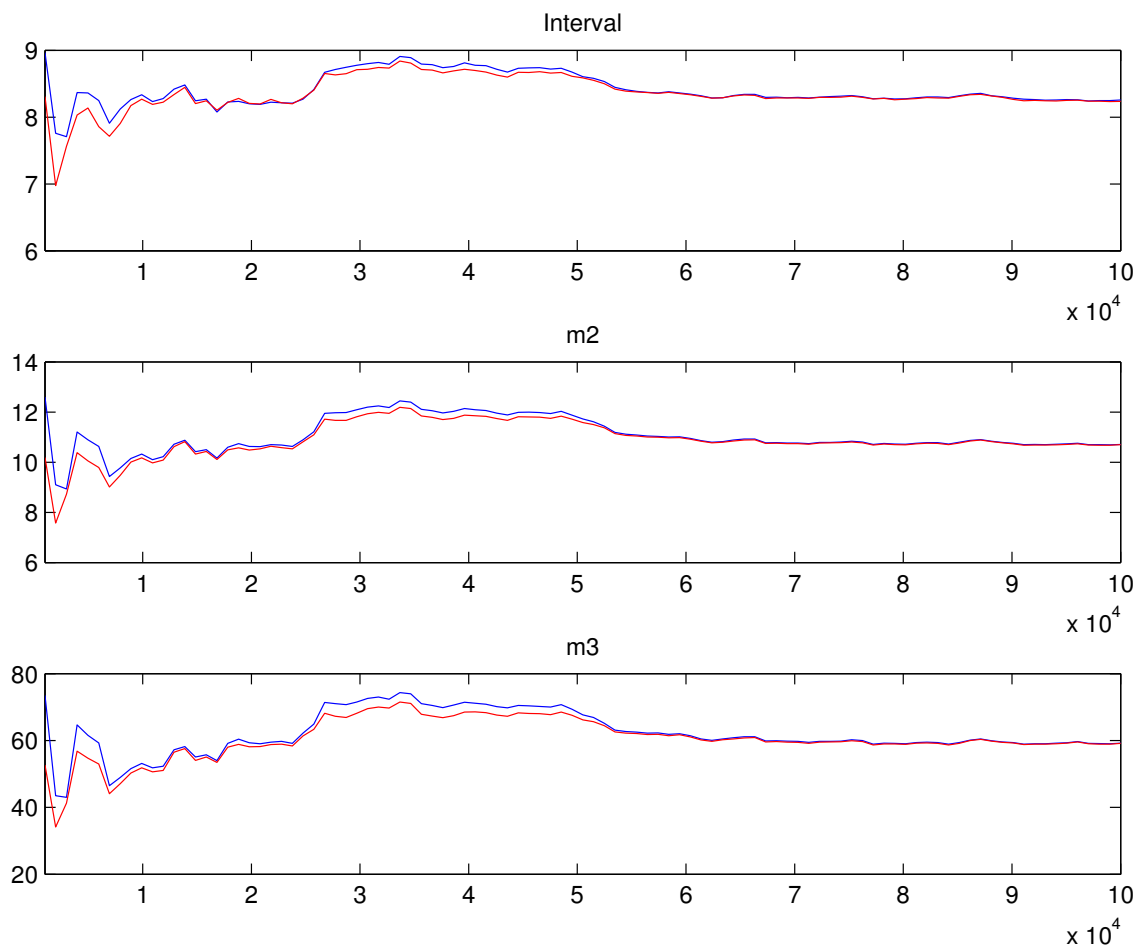


Figure 1.5: Data Used in Estimation



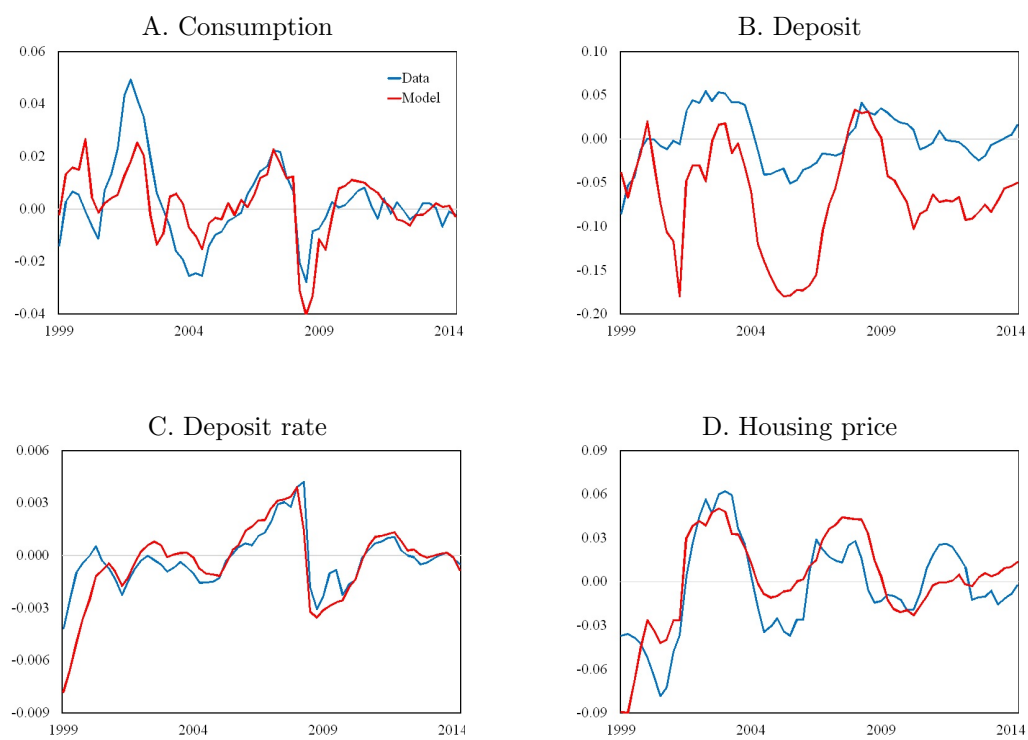
- Notes:*
1. The model parameters are estimated using data from 1999Q3 to 2014Q4. All of the variables are expressed as log deviations from the HP-filter trend.
 2. IHs: Impatient households, Es: Entrepreneurs

Figure 1.6: Multivariate MH Convergence Diagnosis



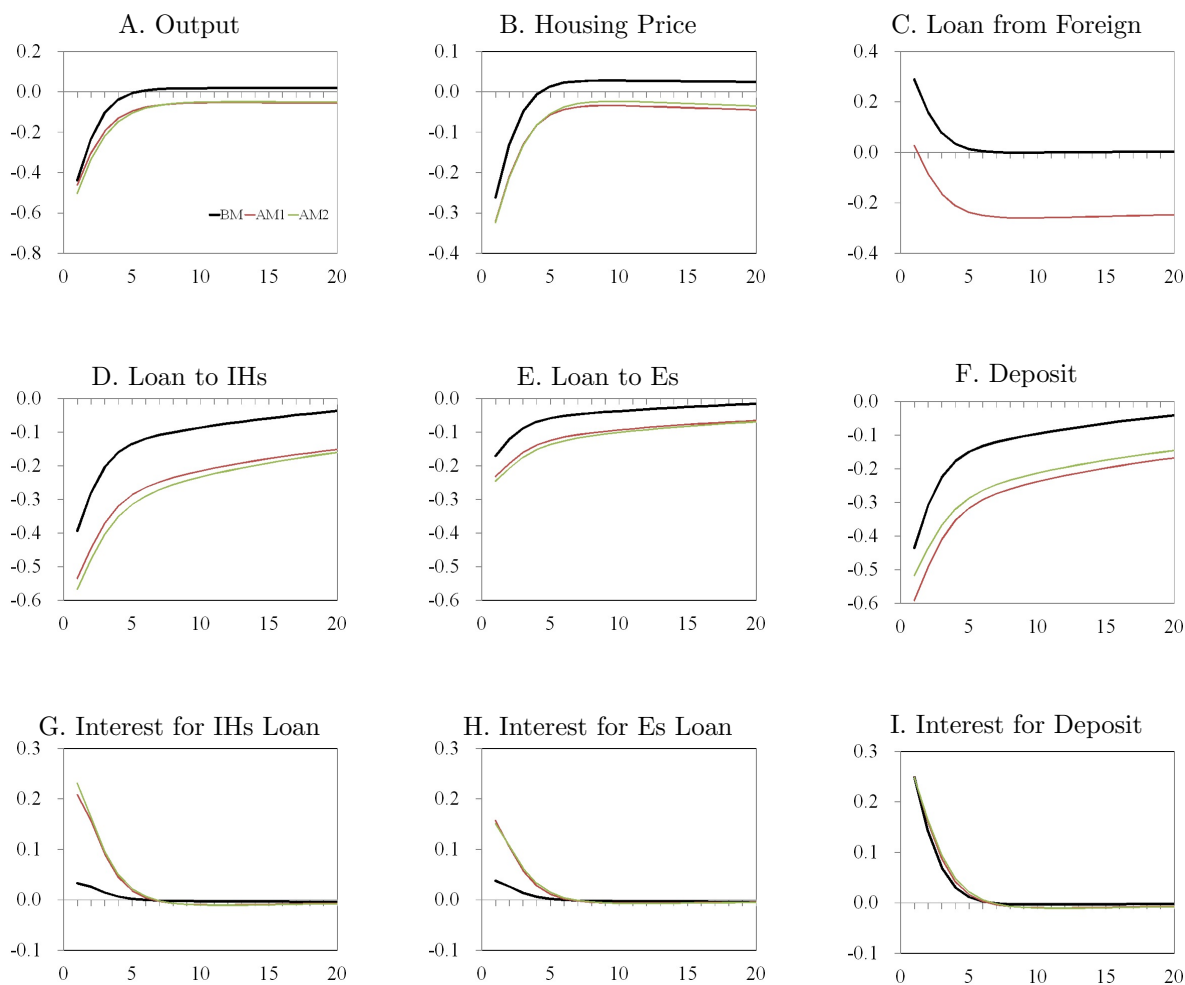
- Notes:
1. The results are based on 10 chains, each with 100,000 draws from the MH algorithm.
 2. Red line: Within-chain measure, Blue line: Within- and between-chain measure for each moment
 3. Interval: First moment, m2: Second moment, m3: Third moment

Figure 1.7: Historical Decomposition of Model Series and Actual Data



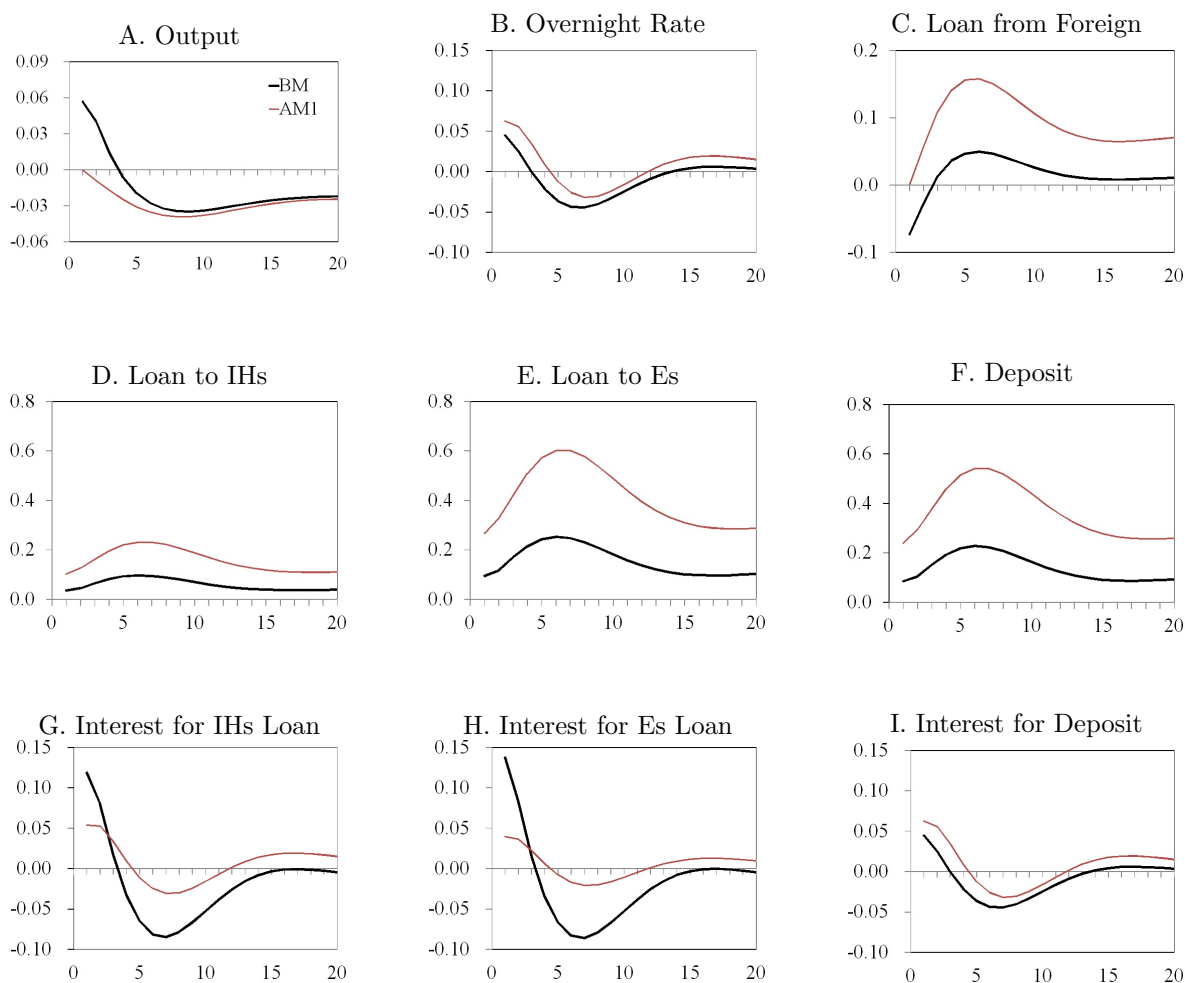
Notes: All of the variables are expressed as log deviations from the HP-filter trend.

Figure 1.8: Impulse Response to Contractionary Domestic MP Shock (25bp)



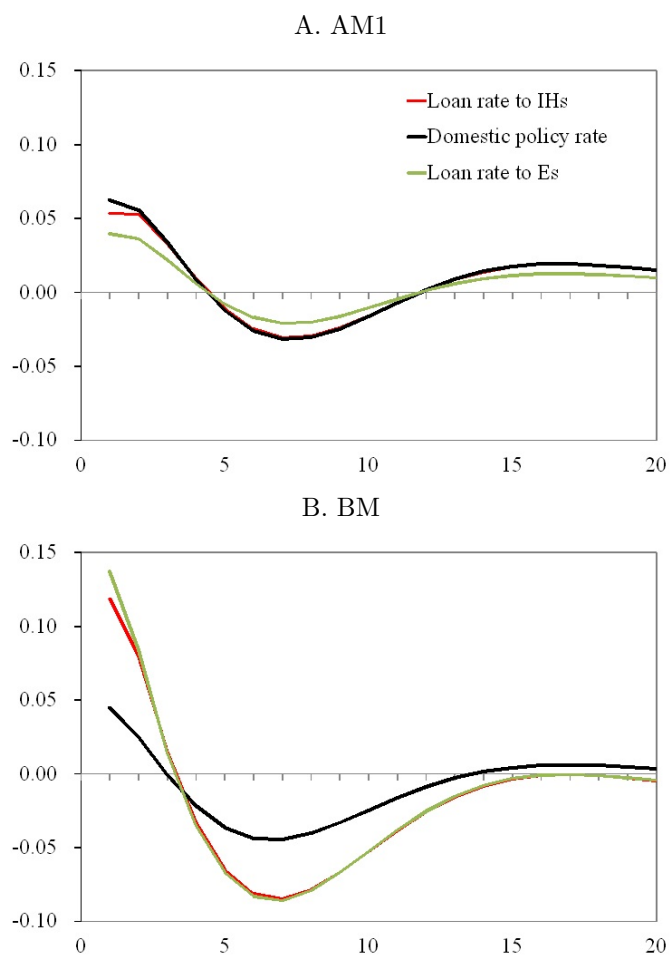
- Notes:*
1. BM: Baseline model,
AM1: Alternative model 1(no foreign interest rate channel),
AM2: Alternative model 2(AM1 + no foreign liquidity channel)
 2. IHs: Impatient households, Es: Entrepreneurs
 3. Horizontal axis: Quarters from the shock;
Vertical axis: Percentage deviation from steady state.

Figure 1.9: 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 1.10: 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.

Chapter 2

**WHICH MONETARY SHOCKS MATTER IN SMALL
OPEN ECONOMIES? EVIDENCE FROM SVARS****2.1 Introduction**

A frictionless transmission of monetary policy (hereafter ‘MP’) shocks through financial markets is a key assumption in conventional macroeconomics as well as in practical policy discussions. The central banks in many advanced countries currently choose overnight interest rates as a MP operating instrument, based on the belief that short-term interest rates, among other candidate instruments, are the most directly related to their macroeconomic target. They attempt to steer inflation and/or output gaps towards targets via market interest rates at all maturities. Transmission of policy effects to other financial market asset prices are, in this sense, a crucial prerequisite for successful MP implementation.¹

It is, however, yet to be determined whether, in a world of open financial markets, MP decisions transmit through a variety of financial markets effectively and in a timely way. U.S. financial markets, for instance, confronted *Greenspan’s conundrum* in the mid-2000s, during which a global savings glut kept long-term rates low even as the Federal Reserve raised short-term rates. This phenomenon is not confined to the U.S. To the extent that interest rate movements in small open economies (hereafter ‘SOEs’) are heavily influenced by international monetary and financial spillovers, their movements are more likely to deviate from a central bank’s policy stance (Turner (2013)[91], Obstfeld (2015)[70]).² As a result,

¹As we discuss in section 2.2, conventional models of monetary policy transmission regard financial markets as frictionless, thereby predicting long-term rates which rely entirely on the expected path of short-term rates in reaction to MP actions.

²South Korea, for example, has experienced such a conundrum, with long-lasting, low levels of long-term rates despite consecutive MP tightening in 2010~11, and this was attributed to the influence of a strong surge in foreign investments into national bond markets.

central banks are faced with a dilemma in their efforts to achieve macroeconomic stability because focusing only on short-term rates can bias the assessment of a given policy stance.

Existing empirical studies on MP transmission in SOEs nevertheless have paid less attention to the transmission through financial markets and focused mainly on direct relationship between MP shocks and macroeconomic variables, typically assuming no frictions in capital and financial markets (e.g. Obstfeld, Shambaugh and Taylor (2005)[72], Frankel, Schmukler and Serven (2004)[31]). Specifically, few studies explicitly deal with how well market interest rates, e.g. long-term bond yields, respond to local MP shocks, under the belief that the traditional interest rate channel performs well as theory expects.³ ⁴ Besides, there is still no conclusive consensus on the dynamic relationship between MP and foreign exchange (FX) rates in the literature. Despite many preceding results on the puzzling movements of exchange rates in response to MP shocks, e.g. *foreign exchange rate* and *forward premium puzzles*,⁵ a few of recent studies reconcile the empirical results with theories by adopting new identification strategies.⁶ Moreover, to the extent that foreign MP shocks play an important role in explaining the movements of domestic financial asset prices under financial integration, transmission mechanism of foreign MP shocks must be equally considered as the studies on domestic MP transmission.

Taking account of those issues, we seek to investigate the channels of MP transmission in SOEs *within* and *across* border. To this end, we use an open-economy SVAR model - a main workhorse in the field of empirical MP transmission studies - with various financial market variables as well as macroeconomic variables. Identification of structural monetary policy

³The studies about U.S. market have been progressed well. For instance, seminal studies including Cochrane and Piazzesi (2002)[20] and Gürkaynak et al. (2005)[46] provide evidence that unanticipated MP shocks significantly influence long-term bond yields and other financial asset prices in the U.S. Another group of studies, including Evans and Marshall (1998)[27] and Rudebush et al. (2006)[80], do not, however, find strong evidence of a close relationship attributing the relationship to other factors, including appetite for risk.

⁴As we discuss in section 2.2, however, the capacity of SOEs to influence movements of long-term rates can be limited in a world of large capital flow across border and financial integration.

⁵See Christiano and Eichenbaum (1995)[16] for the puzzles.

⁶See Kim and Roubini (2000)[55], Bjørnland (2009)[7] for example.

shocks in SVAR can be problematic, however, especially in a model with multiple financial variables, because of simultaneity issues. Most studies with an open-economy setting impose arbitrary relationships on endogenous variables (e.g. a recursive structure or *Cholesky restriction*), which specify that some structural shock has no contemporaneous effect on one or more financial variables, thereby facing difficulties in sorting out the contemporaneous movements of MP shocks, exchange rates, long-term yields, etc (Faust, Rogers, Swanson, Wright (2003)[28], Gertler and Karadi (2015)[38]). In addition, identified monetary structural shocks in such a model can be quite different from each other depending on assumptions regarding the identification of such shocks (Rudebush (1998)[79]). This may work as a critical limitation when interpreting empirical results pertaining to the dynamic relationship between structural shocks and endogenous variables, e.g., impulse response functions (IRFs) and decomposition of forecast error variances.

The identification scheme proposed by Stock and Watson (2012)[85] and Mertens and Ravn (2013)[65], which we refer to as the *external instrument identification scheme*, has considerable appeal because it exploits the attractive features of SVARs while addressing the identification issues raised above by using information from external instruments. In the area of MP transmission studies, Gertler and Karadi (2015)[38] combine a SVAR set-up with such an identification scheme, exploiting high-frequency external instrument variables, federal funds, and euro dollar futures rates. Contrary to findings in the literature on U.S. markets, this identification method has not yet been applied to related studies for other economies. One critical reason for this omission may be that there are no futures markets with active trading in such monetary policy operating targets in those countries, and thus external data for MP shocks are not easily obtainable.

Given these circumstances, we contribute to the literature in the following respects. This paper revisits the conventional topic of MP transmission in SOEs, but focuses on how well domestic MP shocks propagate through financial markets and on whether such transmission is distorted by international monetary spillovers. To that end, the SVAR models in this paper explicitly test and compare the impact of domestic as well as foreign (for which the U.S. is the

proxy) MP shocks on multiple market interest rates at a variety of maturities. Furthermore, we test MP transmission in national currency markets, in light of prior theoretical and empirical findings that foreign exchange rates play an important role in domestic and foreign MP transmission in open countries.

In addition, we avoid a simultaneity problem involving MP actions and other macroeconomic or financial variables (e.g., Bjørnland (2009)[7]) by identifying monetary shocks using external instruments identification instead of making direct arbitrary assumptions about contemporaneous interaction between variables. Specifically, we exploit a variety of high-frequency financial data in the focal SOE countries as well as other measures obtained from econometric methods as external instruments to identify domestic and foreign MP shocks, and we provide a parsimonious characterization of MP shock transmission mechanisms in SOEs.

Our empirical findings are as follows. First, medium- and long-term interest rates in the SOEs under study respond quite weakly to domestic MP shocks, and these effects are short-lived, which represents a more readily discernible response than estimates for the U.S. suggest. Meanwhile, foreign MP shocks have significant and persistent effects on domestic financial and macroeconomic variables, indicating that MP implementations in our sample SOEs may have been either hampered or strengthened by international monetary spillovers. Second, foreign exchange rates in this process are seen to respond significantly to MP shocks, as Dornbusch (1976)[24] predicted. Contrary to the findings of existing studies that reported counterevidence for overshooting hypothesis (e.g. Eichenbaum and Evans (1995)[26], Grilli and Roubini (1995)[45], Cushman and Zha (1997)[22]), we find that an increase in the policy rates causes the nominal exchange rate to appreciate instantaneously and then depreciates gradually in line with uncovered interest parity (UIP) with few exceptions. Finally, a group of external instrument variables for the identification are tested and selected, among which movements of overnight spot rates on MP decision dates turn out to be the most suitable instrument for such identifications.

The rest of this paper is organized as follows. In section 2.2 we provide an overview of

theoretical relationships between endogenous variables in the context of open-economy structural models. In section 2.3 we specify SVAR models and identifying restrictions. Section 2.4 summarizes the empirical results and section 2.5 concludes.

2.2 *Theoretical Motivation and Hypotheses*

Standard New-Keynesian models with sticky prices and frictionless financial markets indicate that MP transmission to credit costs and thus to aggregate spending operates via yield curves assuming price rigidity. Given the expectation hypothesis of the term structure, the effect of MP decisions on the paths of current and expected short-term interest rates is summarized in Eq (2.1):

$$R_t^m = m^{-1} E_t \left[\sum_{i=0}^{m-1} R_{t+i} \right] + \xi_t^m \quad (2.1)$$

where R_t^m is an m -period zero-coupon government bond yield at time t , R_t is a short-term interest rate (e.g., the central bank policy rate), and ξ_t^m is a yield term premium. The term premium captures additional compensation for the interest rate (duration) risk inherent in medium- or long-term bond positions as well as residual effects of idiosyncratic market factors. If the premium is assumed to be constant over time, changes in the path of short-term policy rates will dominate changes in long-term rates and this allows central banks to influence movements of output and inflation (Gertler and Karadi (2015)[38]).

The extent of a central bank's control, especially in SOEs, over macroeconomic developments, however, is controversial because policy and other monetary shocks migrate from other countries under international financial integration, possibly causing monetary spillovers even when exchange rates float freely (Obstfeld (2015)[70]). The international monetary transmission mechanism can be considered as operating with the following, direct and indirect, channels through the short- and long- term yield structure.

In integrated capital markets, a country's manipulation of short-term rates (R_t^*), especially if it is a large open economy such as the U.S., inevitably directly affects short-term rates (R_t) in other open countries following the interest-parity relationship represented in

(2.2):

$$R_t = R_t^* + \mathbb{E}_t \Delta(e_t) + \rho_t \quad (2.2)$$

where e_t is the nominal exchange rate vis-à-vis the US dollar and ρ_t is the currency risk premium in SOEs.

Although changes in the interest rate difference between two countries are absorbed mainly by adjustments in exchange rates, market interest rates in an open country are significantly influenced by foreign MP shocks, depending on the behavior of the exchange rate and the risk premium. If the Federal Reserve cuts its policy rates but SOEs maintain the path of the short-term interest rate constant in response, for instance, the resulting decrease in the foreign short-term rate causes the nominal exchange rate and, accordingly, macroeconomic variables in SOEs, to fluctuate.⁷ In order to avoid sharp exchange rate movements, SOE central banks are likely to enhance the correlation between the domestic policy rate and the federal fund rate (FFR).

MP actions abroad can also influence domestic market interest rates indirectly through the combination of domestic MP transmission and international spillovers. Equations (2.1) and (2.2) are combined to show the linkage between international long-term rates of the form (2.3):

$$R_t^m = R_t^{*m} + m^{-1} E_t \left[\sum_{i=0}^{m-1} (\Delta e_{t+i} + \rho_{t+i}) \right] + \xi_t^m - \xi_t^{*m} \quad (2.3)$$

Equation (2.3) implies that unexpected MP shocks in a foreign country at first adjust movements of market interest rates for a variety of maturities in the country and then lead to the correlated movement of market rates in SOEs as long as the change in the expected exchange rates tends to be slow over time and term premiums are internationally correlated

⁷Dornbusch's (1976)[24] exchange rate overshooting hypothesis predicts that an increase in the interest rate should make the nominal exchange rate appreciate sharply at first and then depreciate. An initial sharp exchange rate adjustment may have a negative effect on the economy.

across countries (e.g., Turner (2014)[74], Hellerstein (2011)[49]).⁸

Overall, these theoretical channels of international monetary transmission through integrated financial markets indicate that foreign MP adjustment can directly and/or indirectly have a significant impact on the movement of market interest rates in SOEs, and thereby influence the effectiveness of their domestic MP. Our empirical analysis leads to three implications of the MP transmission in SOEs that we can test. First, domestic MP shocks transmit through bond yields of multiple maturities instantaneously, with little response reflected in the term premium, based on the *expectation hypothesis*. We then investigate the role of U.S. MP shocks, as second MP shocks in the focal SOEs, by testing the second and third hypotheses: U.S. MP shocks transmit into overnight rates (MP instruments) in SOEs (direct international transmission), and U.S. MP shocks influence other market interest rates, e.g. medium- and long-term rates in non-U.S. open countries (indirect international transmission).

2.3 Estimation of SVAR Model

2.3.1 SVAR Modeling

We assume the economy is described by a structural form equation (2.4):

$$AX_t = \sum_{i=1}^p B_i X_{t-i} + \varepsilon_t \quad (2.4)$$

where X_t is an $n \times 1$ vector of macroeconomic and financial variables, A and $B_i (\forall i \geq 1)$ are

⁸Foreign as well as domestic MP shocks also operate through the term premium and the currency risk premium. For example, consider first the case discussed above, an SOE central bank's effort to mitigate a sharp change in the exchange rate following a U.S. MP contractionary shock. Even when there is no monetary intervention such as synchronizing MP actions, consequential capital flows may occur, and thus affect the term premiums in SOE asset markets. Variations in term premiums on long-term assets caused by capital flow at times offset the impact of changes in short-term rates. In addition, SOE bond and currency risk premiums may fluctuate with changes in U.S. monetary policy. Tighter U.S. monetary policy, for example, may raise perceived risk and uncertainty, which will compress capital inflows and boost risk premiums, thereby leading to potential unintended pro-cyclical dynamics in SOE bond markets (Bruno and Shin (2015)[9]).

nonsingular coefficient matrices, and ε_t is an $n \times 1$ structural disturbances vector. ε_t is serially uncorrelated and $\mathbb{E}(\varepsilon_t \varepsilon_t') = I$ where I is the identity matrix; therefore, structural disturbances are assumed to be mutually uncorrelated. For notational brevity, the specification in (2.4) omits deterministic terms and exogenous regressors.

By pre-multiplying each side of the equation by A^{-1} , we obtain a reduced form representation (2.5):

$$X_t = \sum_{i=1}^p \alpha_i X_{t-i} + e_t \quad (2.5)$$

where $\alpha_i = A^{-1}B_i$, and e_t are the reduced form residuals which are related to the structural shocks by (2.6):

$$e_t = \begin{bmatrix} e_t^p \\ e_t^q \end{bmatrix} = S \varepsilon_t = [s^p \ s^q] \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^q \end{bmatrix} \quad (2.6)$$

with $S = A^{-1}$. e_t^p are the residuals of domestic and foreign MP instruments (i.e., $e_t^p = [e_t^{MP*} \ e_t^{MP}]'$) and e_t^q is a vector for the residuals of the other variables, and the analogous definition applies to structural shocks ε_t^p and ε_t^q . s^p and s^q denote the column in matrix S that corresponds to the impact on each element of the vector of reduced-form residuals e_t of structural policy shocks ε_t^p and ε_t^q . The variance-covariance matrix of the reduced-form VAR is $\Sigma = E[e_t e_t'] = E[SS']$.

Next, the structural moving average (or Wold) representation as a function of structural shock is given as (2.7):

$$X_t = \sum_{j=0}^{\infty} C_j S \varepsilon_{t-j} = \sum_{j=0}^{\infty} C_j s^p \varepsilon_{t-j}^p + \sum_{j=0}^{\infty} C_j s^q \varepsilon_{t-j}^q \quad (2.7)$$

where C_j denotes the coefficients of the structural MA form. Accordingly, if the interest rate responds to MP innovations, the IRF, which is the dynamic response of the k -th element of vector X (X_k) to a unit shock of ε_t^p at time $t + j$, can be obtained by (2.8):

$$IRF_{k,j} = \frac{\partial X_{k,t+j}}{\partial \varepsilon_{k,t}^p} = C_{k,j} s^p \quad (2.8)$$

where $C_{k,j}$ is the k -th row of C_j . Forecast error variance decomposition (FEVD) for X_k at time $t + j$ can also be calculated from structural MA representation by (2.9):

$$VD_{k,j} = \frac{\text{var} \left(\sum_{l=0}^j C_{k,l} s^p \varepsilon_{t-l}^p \right)}{\text{var} \left(\sum_{l=0}^j C_{k,l} e_{t-l}^p \right)} \quad (2.9)$$

2.3.2 Identification Scheme in SVAR Analyses

The identification strategy should be deliberately chosen since it considerably affects model specification results, most importantly the identification of structural shocks.⁹ In the monetary VAR literature, exogenous MP shocks are typically obtained by a surprise component from the regression of a policy rate on suggested explanatory variables, e.g., its lags and/or other financial and macroeconomic variables. Dynamic responses of endogenous variables in the VAR to the identified structural shocks, i.e., IRF and FEVD results, therefore vary depending on the assumptions imposed on relationships between endogenous variables.¹⁰

In addition, if identification restrictions are assumed without modeling the relationships between variables correctly, the model may generate biased results. For purposes of ease and convenience, for instance, short-run zero restrictions on the impact matrix are conventionally assumed, which orthogonalize reduced-form disturbances by Cholesky decomposition. In the literature on MP transmission as well, the short-run zero restriction has been widely used on the assumption that MP transmission is occasionally uni-directional, i.e., MP shocks do

⁹Obtaining identified ‘exogenous’ MP shocks is crucial in monetary VAR analyses because the response of variables to endogenous policy actions cannot distinguish the movement of the economy due to the policy action itself and to the variable that spurred that action.

¹⁰In this respect, Rudebusch (1998)[79] criticizes the limitations of applying VAR methodology in MP analyses. He showed that structural shocks stemming from a recursively identified VAR may not be identical to MP shocks identified outside the VAR.

not affect macroeconomic variables while the latter affect MP decisions, and propagation of MP surprises in the financial market flows only in one direction, from the short-term to the long-term rate. Such a restriction, however, may be distorting because within a given period policy shifts not only influence financial variables but may also be responding to them. Even if the central bank does not directly respond to financial indicators, it may respond to underlying correlated variables left out of the VAR.¹¹ Furthermore, there is a growing body of literature, including Carlstrom, Fuerst, and Paustian (2009)[12], in which findings indicate that MP can influence economic variables simultaneously and that Cholesky identification can distort the results, producing price puzzles or muted responses of inflation and output.¹²

In order to avoid possible identification problems, an identification strategy should avoid direct assumptions regarding elements of the impact matrix while it produces robust exogenous MP shocks regardless of structural identifying assumptions. In this respect, the identification method proposed by Stock and Watson (2012)[85] and Mertens and Ravn (2013)[65] offers attractive features for measuring the effects of structural shocks because it utilizes an information set pertaining to exogenous shocks that are identified outside the VAR and it does not assume direct restrictions on relationships between variables. Gertler and Karadi (2015)[38], who adopt this approach, show that it can be extended to monetary VAR analyses by exploiting information about external MP shocks from the HFI to test whether MP and other macroeconomic and financial variables have simultaneous relationships.

¹¹For instance, the results derived from our model with Cholesky identification show that residual series of most financial variables from the proposed VAR model interact simultaneously. Cross-correlations between short- and long-term rates are very high, up to 0.4~0.9.

¹²Since the 1990s, the Federal Reserve and central banks in other developed countries have increasingly relied on communication to influence market beliefs about the expected paths of policy rates and economic conditions, and in this way MP may have immediate effects on macroeconomic variables. If central banks have more information on the future economic situation, e.g., on aggregate demand and inflation, than the public, an announcement by central banks may change agents' expectations and thereby economic activity. A statement that causes economic agents to expect accommodative future aggregate demand, for example, may lead to a spontaneous increase in current consumption and output.

2.3.3 External Instrument Identification Scheme

We recover structural parameters related to domestic and foreign MP shocks by using external instrument identification. The main idea behind this identification scheme is to complement the required restrictions for recovering structural parameters from reduced-form VAR residual covariance and the moment conditions that external instruments can be considered orthogonal to other structural shocks but correlated with MP shocks. This scheme enables us to exploit information contained in external instruments and to avoid arbitrary assumptions about structural parameters. The procedures are summarized as follows. The relationship between residuals of reduced-form VAR (e_t) and structural shocks (ε_t) in equation (2.6) can be rearranged as (2.10):

$$\begin{bmatrix} e_t^p \\ e_t^q \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^q \end{bmatrix} = \begin{bmatrix} s_{11}\varepsilon_t^p + s_{12}\varepsilon_t^q \\ s_{21}\varepsilon_t^p + s_{22}\varepsilon_t^q \end{bmatrix} \quad (2.10)$$

where s_{11} represents the response of the residuals of the MP instrument to its own shock and s_{21} represents the responses of residual series of the other variables to the structural MP shock. Since we are interested in how variables respond to MP shocks, s_{11} and s_{21} are the only two parts of the impact matrix (S) to be identified. Next, VAR residuals e_t^p and e_t^q can be expressed by the other reduced-form residuals and structural shocks ε_t^p or ε_t^q because those are composites of structural shocks:

$$e_t^p = \eta e_t^q + C_1 \varepsilon_t^p \quad (2.11)$$

$$e_t^q = \theta e_t^p + C_2 \varepsilon_t^q \quad (2.12)$$

where $\eta = s_{12}s_{22}^{-1}$, $\theta = s_{21}s_{11}^{-1}$, $C_1 = s_{11} - s_{12}s_{22}^{-1}s_{21}$, and $C_2 = s_{22} - s_{21}s_{11}^{-1}s_{12}$. In particular, the 2×2 matrix C_1 represents variance-covariance between two structural MP shocks, and it has the following relationship with s_{11} and s_{21} :¹³

¹³ C_1 can be rearranged as $C_1 = s_{11} - s_{12}s_{22}^{-1}s_{21} = (I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1})s_{11}$ and thus $s_{11}C_1^{-1} =$

$$\begin{bmatrix} s_{11} \\ s_{21} \end{bmatrix} = \begin{bmatrix} (I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1})^{-1} \\ s_{21}s_{11}^{-1}(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1})^{-1} \end{bmatrix} C_1 \quad (2.13)$$

$$C_1 C_1' = (I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1}) s_{11}s_{11}' (I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1})' \quad (2.14)$$

Thus, obtaining s_{11} and s_{21} requires identification of two parts: One is $s_{21}s_{11}^{-1}(= \theta)$, which can be estimated by two-stage least squares (2SLS) estimation, and the others are $s_{11}s_{11}'$ and $s_{12}s_{22}^{-1}$, which can be calculated by restrictions from the covariance matrix.

(Restriction from 2SLS estimation: $s_{21}s_{11}^{-1}(= \theta)$)

Consider first the regression of equation (2.12). Since the reduced-form residual for MP instrument ($e_t^p(= s_{11}\varepsilon_t^p + s_{12}\varepsilon_t^q)$) is correlated with $C_2\varepsilon_t^q$, denoting it as u_t hereafter, we can obtain consistent estimates of θ of regression e^q on e^p from 2SLS, employing appropriate IVs that satisfy the following moment conditions:

$$\mathbb{E}[Z_t u_t] = 0 \quad \text{or} \quad \mathbb{E}[Z_t \varepsilon_t^q] = 0 \quad (2.15)$$

$$\mathbb{E}[Z_t e_t^p] = \pi(\pi \neq 0) \quad \text{or} \quad \mathbb{E}[Z_t \varepsilon_t^p] = \phi(\phi \neq 0) \quad (2.16)$$

(Restriction from covariance matrix: $s_{11}s_{11}'$ and $s_{12}s_{22}^{-1}$)

In addition to the restrictions derived from IV estimation, identification of s_{11} and s_{21} requires the additional restrictions from the covariance matrix. Consider the following reduced form variance-covariance and its partitioning:

$$\Sigma = E[SS'] \Rightarrow \begin{bmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{bmatrix} = \begin{bmatrix} s_{11}s_{11}' + s_{12}s_{12}' & s_{11}s_{21}' + s_{12}s_{22}' \\ s_{21}s_{11}' + s_{22}s_{12}' & s_{21}s_{21}' + s_{22}s_{22}' \end{bmatrix} \quad (2.17)$$

$(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1})^{-1}$. Similarly, C_2 can be expressed in terms of partitions of S matrix as the following form: $s_{21}C_1^{-1} = s_{21}s_{11}^{-1}s_{11}C_1^{-1} = s_{21}s_{11}^{-1}(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1})^{-1}$.

Then, $s_{11}s'_{11}$, $s_{12}s_{22}^{-1}$ is obtained by the following closed-form solution:

$$s_{11}s'_{11} = \Sigma_{11} - s_{12}s'_{12} \quad (2.18)$$

$$s_{12}s_{22}^{-1} = \left(s_{12}s'_{12}\theta' + (\Sigma_{21} - \theta\Sigma_{11})' \right) \left(s_{22}s'_{22} \right)^{-1} \quad (2.19)$$

where $s_{12}s'_{12} = (\Sigma_{21} - \theta\Sigma_{11})' Q^{-1} (\Sigma_{21} - \theta\Sigma_{11})$, $s_{22}s'_{22} = \Sigma_{22} + s_{21}s_{11}^{-1} (s_{12}s'_{12} - \Sigma_{11}) (s_{21}s_{11}^{-1})'$ and $Q = \Sigma_{22} - (\Sigma_{21}\theta' + \theta\Sigma_{21}) + \theta\Sigma_{11}\theta'$.¹⁴

These restrictions from 2SLS and VAR residual covariance allow for the identification of C_1C_1' and the covariance of $C_1\varepsilon_t^p$. If structural shocks to domestic MP are uncorrelated with foreign MP shocks and vice versa, C_1 is a diagonal and can be directly identified up to a sign convention from equation (2.18).¹⁵ However, if we cannot impose zero cross-correlations between structural shocks, we must make an arbitrary assumption regarding how domestic MP shocks respond contemporaneously to unanticipated movements in foreign MP instruments and vice versa in order to disentangle the causal effects of shocks on both MP shocks. To the extent that the model considers two countries, the U.S. and an SOE, Cholesky decomposition of C_1C_1' , supposing that the foreign MP shock is ordered before the domestic MP shock, permits economically meaningful results in this analysis. Finally, by plugging the identified C_1 back into (2.13), s_{11} and s_{21} are uniquely pinned down.

¹⁴Consider first the fact that $\Sigma_{21} - \theta\Sigma_{11} = C_2s'_{12}$ because $\Sigma_{21} - \theta\Sigma_{11} = s_{21}s'_{11} + s_{22}s'_{12} - s_{21}s_{11}^{-1}(s_{11}s'_{11} + s_{12}s'_{12}) = s_{22}s'_{12} - s_{21}s_{11}^{-1}s_{12}s'_{12} = (s_{22} - s_{21}s_{11}^{-1}s_{12})s'_{12}$.

The derivation of $s_{12}s_{22}^{-1}$ is straightforward, noticing that $s_{12}s_{22}^{-1} = s_{12}s'_{12}\theta' + (\Sigma_{21} - \theta\Sigma_{11})'$. $Q = Q'$ because Q is symmetric, and it is same as u_tu_t' or C_2C_2' . Using this fact, $s_{12}s'_{12}$ can be obtained by the following form: $s_{12}s'_{12} = s_{12}C_2'C_2^{-1}C_2^{-1}C_2s'_{12} = s_{12}C_2'Q^{-1}C_2s'_{12} = (\Sigma_{21} - \theta\Sigma_{11})' Q^{-1} (\Sigma_{21} - \theta\Sigma_{11})$. And from the covariance matrix, $s_{22}s'_{22} = \Sigma_{22} - s_{21}s'_{21}$, and it can be expressed as the above because $s_{21}s'_{21} = s_{21} \left(s_{11}^{-1} s_{11} s'_{11} s_{11}^{-1} \right) s'_{21} = (s_{21}s_{11}^{-1}) \left(\Sigma_{11} - s_{12}s'_{12} \right) \left(s_{11}^{-1} s'_{21} \right)$.

¹⁵If so, a simpler identification approach, such as Gertler and Karadi (2015)[38] employ, can be directly applied to identify s_{11} and s_{21} .

2.3.4 Data

Endogenous Variables in the VAR System

We choose nine monthly (except for Australia, for which it is quarterly)¹⁶ macroeconomic and financial variables in the VAR, reflecting the theoretical set-up described in section 2.2. In particular, the VAR model comprises logs of the domestic consumer price index (P , ‘price’ hereafter), logs of seasonally adjusted industrial production (Y , ‘output’ hereafter), domestic and foreign policy interest rates (MP and MP^*), three-month, three-year and ten-year government bond yields ($R3m$, $R3y$, and $R10y$), bank lending rates ($Lend$), and logs of the foreign exchange rate against one unit of the U.S. dollar (FX).¹⁷ In addition, following procedures employed in prior 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)[54] and Bjørnland (2009)[7], among many others).

The four focal open countries represent open economies that depend heavily on foreign economies, especially the U.S., from both real economic and financial market perspectives. These countries have employed inflation targeting as an MP regime and used short-term interest rates as an MP operating instrument. Moreover, they are also commonly equipped with well-developed financial markets with sufficient trading volume to validate our use of financial asset prices to identify IVs. And, for the purpose of comparing the empirical results, we also estimate a SVAR model with U.S. data as well as a benchmark. Table 2.1 summarizes the detailed description of the data.

¹⁶Since Australia reports macroeconomic variables (output, price, etc.) only in the quarterly base, we employ quarterly averages of its financial data.

¹⁷The variables are specified in levels to implicitly determine any potential co-integrating relationship between them; see Hamilton (1994)[48].

Instrumental Variables (IVs)

Prior studies on U.S. MP use mostly high-frequency movements of Federal Fund futures rates around FOMC meetings as ideal instruments for identifying MP shocks. Other economies, however, are not yet equipped with derivative markets for MP instruments. Given this limitation, we propose various sets of alternative IVs for external instrument identification based on prior theoretical and empirical findings, including short-term spot rates, futures rates under financial instruments, and surprise in overnight rates estimated by statistical method and Taylor rule assumption. See the details in Appendix B.1.

IVs tested for focal SOEs and the U.S. are summarized in Table 2.2. For the U.S., we use IV data proposed by Gertler and Karadi (2015)[38] and Gürkaynak et al (2005)[46], and FFFR changes within a narrow (thirty-minute) window around FOMC meetings. In addition, we test some daily movements of financial instruments for comparison.

2.4 Empirical Analysis Results

IV Selection

To apply external instrument identification, we first turn to the issue of instrument choice in our VAR models. We select suitable instruments in our analysis based on the following conditions:

$$\begin{aligned}
 & \text{(relevancy)} && \text{rank}(E[Z_t \varepsilon_t^p]) = L \\
 & \text{(orthogonality or validity)} && E[Z_t \varepsilon_t^q] = 0
 \end{aligned} \tag{2.20}$$

where L is the number of endogenous variables. In particular, we use the F -statistic of the first-stage regression residual of a particular policy indicator regressed on various instrument sets to test the relevance of IVs.¹⁸ Moreover, considering that we choose a combination of

¹⁸Staiger and Stock (1997)[87] suggest that the F -statistics of the IVs should be greater than 10 to ensure that the maximum bias in the IV estimators is less than 10%. If we are willing to accept maximum bias in

multiple IVs, we test the over-identification restriction for selected IVs with each first-stage residual series using Hausman-Sargan (hereafter, ‘Sargan’)¹⁹ statistics.²⁰

In estimating open-economy SVAR models for the selected SOEs, following the test results as well as those of prior studies, including Gertler and Karadi (2015)[38], we use intraday movements of Federal fund futures rates and Eurodollar futures rates for some maturities (IV5a, IV5b, IV5d, IV5e, and IV5f) as IVs for U.S. MP shocks. In addition, as for IVs of SOEs’ local MP shocks, we use movements of overnight rates (IV1), overnight-rate surprises estimated by statistical method (IV10) and Taylor rule assumption (IV11) which are found to be most suitable, in terms of relevancy and exogeneity. Those instruments are comparable to the traditional IVs (high frequency FFFR movements) for the US. IV test results for the U.S. and the focal SOEs are summarized in Appendix B.2.

2.4.1 Results from SVAR: Impulse Response Functions (IRFs)

To show how the MP transmission mechanism works in the focal SOEs, we first present the IRFs of interest rates at various maturities for domestic MP innovation. Contrary to conventional theory, the increase in long-term interest rates following monetary tightening proved to be much smaller and short-lived than those of short-term rates. We then show how the interest rates responded to U.S. MP shocks to address the other central question of this paper: namely, how foreign MP shocks influence domestic interest rates, directly or indirectly. In response to surprise foreign monetary tightening policy moves, interest rates at all maturities exhibit significant and persistent increases of several basis points. We also find that nominal exchange rates respond to monetary policy shocks in line with overshooting hypothesis in this process, contrary to the existing literature which reports exchange rate

IV estimators of less than 20%, the threshold for the F -statistics would be 5. If the IV number is one, the F -statistics should be replaced by t -statistics.

¹⁹We can test for endogeneity of the IVs using Sargan’s statistics only if we have more IVs than potentially endogenous explanatory variables (over-identification).

²⁰If the Sargan’s statistic, which follows the chi-squared, is significantly different from zero, then at least some of the instruments are not exogenous.

puzzle or delayed overshooting (e.g. Cushman and Zha (1997)[22]).

Effects of MP Shocks on the Interest Rates

When a domestic MP shock occurs, market interest rate responses weaken with longer maturity, contrary to what the conventional New Keynesian framework predicts. The first column in Figure 2.1 displays the effect of a contractionary MP shock on short-term interest rates, with the shock normalized to an initial one-percentage-point increase, while the second and third columns show the corresponding effects on medium- and long-term bond yields, respectively. Clearly, short-term rates respond spontaneously to the shock, increasing one to two percentage points at a maximum. However, medium- and long-term bond yields respond much more weakly and these responses are shorter-lived than those of short-term rates. Especially in Canada, market rates do not seem to react significantly to an MP tightening shock, even showing negative movement in the early stages of such shocks.

The above-reported empirical results indicate that domestic MP does not propagate sufficiently and quickly enough from short-term rates to medium- or long-term rates or, finally, to real sectors. To shed light on this aspect of MP, Figure 2.2 displays the responses of interest rate spreads to a contractionary MP shock of (1%p). Compared with the benchmark (U.S.) case, the responses of spreads between medium- or long-term rates and short-term rates in the focal SOEs are distinctively shorter. Considering the characteristics of SOEs, the above disturbance in the MP transmission mechanism may more or less result from the influence of international monetary and financial spillovers, such as the flow of global liquidity or movements of the exchange rate caused by changes in domestic or foreign MP stances.

To infer further details of the transmission mechanism for MP shocks, we examine the effects of U.S. MP shocks on market interest rates in each focal country. In Figure 2.3, market rates show positive and persistent responses to a contractionary U.S. MP shock. Overall, two results stand out concerning our hypotheses that test international monetary transmissions. First, overnight and short-term interest rates in the focal SOEs show significantly positive responses of up to 1%p to the shock in most non-U.S. countries. One possible interpretation of

this result is that contractionary U.S. MP shocks lead to international synchronization of MP, or of the corresponding market expectations, which helps absorb the impact of a dramatic change in the exchange rate that applies to direct cross-border monetary transmission.

Second, we also investigate the reactions of longer-term yields to examine the indirect channel of foreign MP transmission. Medium- and long-term rates react to foreign MP shocks similarly to short-term rates; in the UK and Canada the shock has negative effects at first but the confidence intervals suggest that these initial reactions are not significantly different from zero. Combining our findings of the linkage between U.S. MP shocks and U.S. market rates and prior results in the literature, which documented significant co-movements among long-term bond yields in multiple countries (e.g., Ehrmann, Fratzscher and Rigobon (2011)[25]), this result may indicate that U.S. MP shocks also transmit indirectly to domestic long-term bond markets through the linkage between the U.S. and the focal SOE long-term bond markets (indirect cross-border monetary transmission).

To illustrate the characteristics of the IRFs of each MP shock, Figure 2.4 compares the influence of domestic and foreign MP shocks on market interest rates in each country. This confirms our conclusion that foreign MP shocks seem to have weaker but much more persistent effects on the focal SOEs' market interest rates.

The above-reported results contradict the findings of previous studies such as Kim (2001) [54], who suggests that non-U.S. G-6 countries do not react strongly to U.S. MP by documenting that negative U.S. FFR innovations do not lead to a significant and substantial decrease in non-U.S. short-term interest rates. However, those past studies may be limited significantly in their ability to isolate exogenous U.S. MP shocks. In particular, their identified MP structural shocks depend largely on the questionable assumption of a simultaneous relationship among the variables.²¹ After identifying the shocks based on external information outside the VAR framework, we conclude that the endogenous reaction of focal SOE MP and interest rates to U.S. MP surprises is substantial and lasts longer than domestic

²¹For example, Kim (2001)[54] assumes in some models that the central banks in non-US countries do not respond contemporaneously to changes in any foreign interest rate.

shocks, consistently with what Faust et al. (2003)[28], who study the U.K. and Germany cases, find.

Effects of MP shocks on the Nominal Foreign Exchange rates

Turning now to consider the effect of MP shocks on the exchange rate, there is no evidence of a puzzle, which is consistent with the overshooting hypothesis of Dornbusch (1976)[24]. This is surprising insofar as most empirical VAR studies that have found that, following a contractionary MP shock, the exchange rate either depreciates (this is the exchange rate puzzle; see Grilli and Roubini (1995)[45]; Sims (1992)[84]), or, if it appreciates, it does so for a prolonged period of up to three years, thereby exhibiting hump-shaped behavior that violates the UIP condition (delayed overshooting; see Eichenbaum and Evans (1995)[26]; Cushman and Zha (1997)[22]).

In particular, as shown in the first columns of Figure 2.5, the initial appreciation of the focal SOE currencies following a contractionary monetary shock is not followed by long and persistent appreciation as found in previous studies. Except for Australia, which shows a puzzling response (a drop) after the initial appreciation, the exchange rates start to depreciate (rise) gradually after a few quarters. Note that, while the exchange rates do not depreciate immediately following the impact appreciation,²² the confidence intervals also suggest that there is no clear, persistent appreciation. Meanwhile, in response to U.S. MP tightening, the currencies of the focal SOEs appreciate gradually, thus depreciating the US dollar, followed by initial depreciation in line with the overshooting hypothesis (except in Korea, whose currency appreciates without initial depreciation). Such a response is quite consistent with previous IRF results regarding domestic MP shocks. In line with several studies (e.g., Bjørnland (2009)[7], Kim and Roubini (2000)[55], Cushman and Zha (1997)[22]), this result suggests that the inappropriate identification of MP shocks may account for the puzzles observed in

²²One possible explanation of this is that, as compared with the other focal countries, the Australian economy as a major commodity-exporting country has become less dependent on the US while the impact of the export activity of other trading partners, such as China and the EU, has strengthened more over the period.

the prior literature.²³

Effects of MP shocks on the macroeconomic variables

Finally, it is also important to verify whether output and prices react to MP shocks as expected given available theories, because we cannot say that our identified structural shocks are valid if any puzzles in their responses persist. In all countries, output and the price levels decline smoothly over a given horizon following monetary contraction, consistently with conventional theory. The output of the focal SOEs decreases by one to two percent maximum after 1~2 years, and the effect on prices is also negative and reaches a minimum after 1~1.5 years.

Another notable finding is that the macroeconomic variables show a positive simultaneous response to the shock, although the response is in some cases not statistically significant. This is quite at odds with the conventional belief that MP transmission is a long and complicated mechanism and thereby has uncertain time lags for feasible effects on macroeconomic variables to manifest. We can explain this by noting that MP decisions can significantly influence market expectations regarding future economic situations.²⁴ Central banks have been influencing market expectations by forward guidance since the 1990s, and in this channel MP may have an immediate effect on macroeconomic variables under the belief that central banks have better information regarding future economic situations through earlier access to data or superior economic analysis, and thus statements by central banks somehow reveal private information pertaining to future paths of economic activities and inflation. The direction that responses of macroeconomic variables to news of expectation shocks takes may be depend on which news regarding future economic situations is disseminated.²⁵

²³For comparison purpose, we compare IRFs from Cholesky restrictions with ordering as $[MP^*, Y, P, FX, MP, R3m, R3y, R10y, Lend]$ in Figure 2.5. Contrary to the results from external instrument identification scheme, the responses of exchange rate produce puzzles under Cholesky scheme as the previous studies.

²⁴According to Ravenna and Walsh (2006)[75], a cost channel for interest rates, through which the increased interest rate increases borrowing costs for firms and therefore prices, can also account for an initial price puzzle.

The responses of focal SOE outputs to U.S. MP shocks are mixed. Korea shows a significant negative impact of contractionary shocks, while the other focal SOEs respond positively but less significantly.²⁶ Meanwhile, the responses of prices to U.S. MP shocks are persistently negative with a time lag, except in Australia. This result may be explained by an import price decrease due to appreciation of the domestic exchange rate relative to the U.S. dollar and a decrease in domestic aggregate demand.

2.4.2 Forecast Error Variance Decomposition (FEVD) Results

How much do foreign MP shocks affect the overall variability in the process of domestic MP transmission? To shed some light on this issue, we quantify the contributions of each MP shock to the variance in market interest rates on the impact for the first four years.²⁷

As reported in Table 2.3, on a short-run forecast horizon, domestic MP shocks seem to have greater influence on market interest rates than foreign MP shocks, but this relationship reverses on the longer-run horizon; the effect of domestic shocks fade quickly while that of foreign shocks decreases (or even increases in some cases) gradually. In particular, domestic MP shocks explain from (based on a long-run forecast horizon) 10~30% of the variation in focal SOE market interest rates. Domestic shocks have greater explanatory power for short-term and bank lending rates than for medium- or long-term rates. The effect of foreign (U.S.) MP also explains a substantial portion of market interest rate movements. In particular, the contribution of foreign MP shocks to the variation in medium- and long-term rates is greater than that of domestic MP.

²⁵If economic agents believe, for example, that an MP decision to tighten a central bank's supply of money is based on future accommodative economic activities, outputs will respond positively impact to the shock.

²⁶Mixed economic channels seem to explain these mixed results. US monetary contraction can decrease export demand from the U.S. Countries whose economies rely greatly on external demand, such as Korea, may experience a strong negative impact from such a shock. A rise in interest rates caused by international monetary spillover to bond markets may also curb domestic aggregate spending. The initial nominal exchange rate depreciation will, on the other hand, feed into deteriorating terms of trade, which may play an increasingly strong role in domestic income and output.

²⁷Note that only the columns related to MP shocks, i.e., the first and fourth columns of the S matrix, are identified, so we can quantify the contribution of only domestic and foreign MP shocks.

Of the four focal open countries, Australia displays a relatively greater share of domestic MP effects on medium- and long-term rates compared with those of foreign MP shocks. But foreign MP shocks also play a non-negligible role in explaining variations in market rates. In Canada and the U.K., the variation in short- and medium-term rates is affected mainly by foreign MP.²⁸ For long-term rates, foreign MP shocks are still important for explaining the variation in rates in the U.K., but not in Canada. In Korea, U.S. MP shocks play a slightly stronger role in explaining market rates than domestic MP.

These results emphasize that the short-term rates respond systematically to domestic monetary surprises, but on the long-run horizon they react more strongly to foreign MP shocks. However, domestic monetary shocks do not play an important role in explaining the variation in longer-term bond yields in the focal SOEs, while the other factors, including U.S. MP shocks, do.

Table 2.4 exhibits FEVD results for macroeconomic variables (output, prices, and exchange rates). Consistently with the FEVD results for market interest rates, U.S. MP shocks show substantial influence on movements of the focal SOE macroeconomic variables as well. The two MP shocks, in sum, account for 5~20% of the forecast error regarding the output and price variables of the focal SOEs, among which the U.K. shows the greatest impact of U.S. MP shocks. Around 20~30% of the movement in the exchange rates of the focal SOEs is explained by the domestic and foreign MP shocks in all the countries.

2.5 Conclusion

This paper revisits the conventional topic of MP transmission in SOEs, but focuses on how easily MP shocks propagate through financial markets and on whether such transmission is hampered by international monetary spillover. To that end, the SVAR model in this paper explicitly tests the impact of domestic and foreign MP shocks, as proxied by U.S. MP shocks, on multiple financial variables including market interest rates at a variety of

²⁸These results are overall consistent with Cushman and Zha (1997)[22], who found a weak role of domestic MP shocks and strong impacts of foreign factors.

maturities, which other studies implicitly assume to be ideally strong. Furthermore, this paper tests MP transmission in national currency markets in light of the findings in the literature that foreign monetary shocks and exchange rates play an important role in MP transmission in open countries.

The study's empirical findings are threefold. First, responses to MP shocks of medium- and long-term interest rates in the focal SOEs are weak and sluggish, discernibly more so than estimates for the U.S., while foreign MP shocks have statistically significant and persistent impacts on domestic financial and macroeconomic variables. Second, foreign exchange rates are seen to respond significantly to MP shocks, consistently with Dornbusch's (1976)[24] prediction. Finally, a group of external instrument variables for the identification are tested and selected, among which IVs, movements of overnight spot rates on MP decision dates, turn out to be the most suitable instrument for identification.

The empirical results indicate that market interest rates do not always react in the way that central banks intend. Other structural shocks, most likely external shocks, may lead them in different directions from domestic MP and thereby attenuate the effects of domestic MP. In our analysis, movements of domestic variables are indeed substantially influenced by foreign MP shocks. VD results, which show a non-negligible contribution of foreign MP shocks to the variation in medium- and long-term rates, also support this idea. Recalling the conundrum that occurred in the US during the 1990s and 2000s, and the vulnerability of the focal SOEs' financial markets to external factors, the empirical results in this paper may serve to warn central banks that MP implementations in the focal SOEs may be hampered by external influences.

2.6 Tables and Figures

Table 2.1: List of Variables in the VAR Model

Variable	Category	U.S.	Australia	Canada	Korea	U.K.
MP^*	US MP	-	Effective FFR			
Y	Output	Industrial production (Seasonally Adjusted)				
P	Price	Consumer Price Index				
MP	Overnight rate	Effective FFR	Overnight cash rate	Money market financing rate	Overnight call rate	Bank rate
$R3m$	Short-term rate	TB (3-month) rate (Korea: CD 91-days rate)				
$R3y$	Medium-term rate	TB (3-year) rate				
$R10y$	Long-term rate	TB (10-year) rate (Korea TB 5-year rate)				
$Lend$	Lending	Overall lending rate including loan rates to households and firms				
FX	FX rate	-	Foreign exchange rates per US dollar			
Control Variable		Commodity price index, Crisis dummy variable with 1 for the period between Sep 2008 ~ June 2009, CBOE volatility index, US dollar index				

Notes: Sample periods: U.S. (1980~2008), Korea(1999~2013), Canada (1996~2013), Australia (1990~2013), U.K. (1997~2013).

Source: Bloomberg, IFS, CEIC database

Table 2.2: IVs for the US and SOEs

Category	IVs	Country	Financial instruments
Short-term spot rates	IV1 (overnight rates)	AU	Overnight cash rates
		CA	Overnight MMF rates
		KO	Overnight call rates
		UK	Average 4 UK bank's rates
		US	Effective FFR rates
	IV2 (1 month spot rates)	AU	Bank accepted bills rates (1-month)
		CA	Bank deposit rates (1-month)
		KO	Not available
		UK	TB (1-month) rates
		US	Euro-dollar deposit (1-month) rates
	IV3 (3 month spot rates)	AU	Bank accepted bills rates (3-month)
		CA	Bank deposit rates (3-month)
KO		CD rates (3-month)	
UK		Deposit rates (3-month)	
US		US TB (3-month) yield	
IV4 (exchange rate)	SOEs	exchange rate per US dollar	
Futures rates under financial instruments	IV5 (short-term futures)	AU	Futures under Interest rates (3-month)
		CA	-
		KO	CD rates (3-month) futures
		UK	3-month sterling interest futures rates
		US	FFFR with remaining maturity 1-month (IV5-a) and 3-month(IV5-b), Eurodollar deposit rates with remaining maturity 3-months (IV5-c), 6-month (IV5-d), 9-month (IV5-e), and 12-month (IV5-f)
	IV6 (medium-term futures)	SOEs	Futures under TB (3 year)
	IV7 (long-term futures)	SOEs	Futures under TB (10 year), (5 year for Korea)
IV8 (currency futures)	SOEs	Futures under per USD exchange rates	
IV9 (stock price futures)	SOEs	Futures under national stock price index	
BN	IV10 (BN)	SOEs	BN-decomposed overnight rates
TR	IV11 (Taylor rule)	SOEs	Residuals from Taylor rule estimation

Notes: 1) '-' indicates that the IV is not available for a given country
2) AU: Australia; CA: Canada; KO: Korea; SOEs: the selected four small open economies

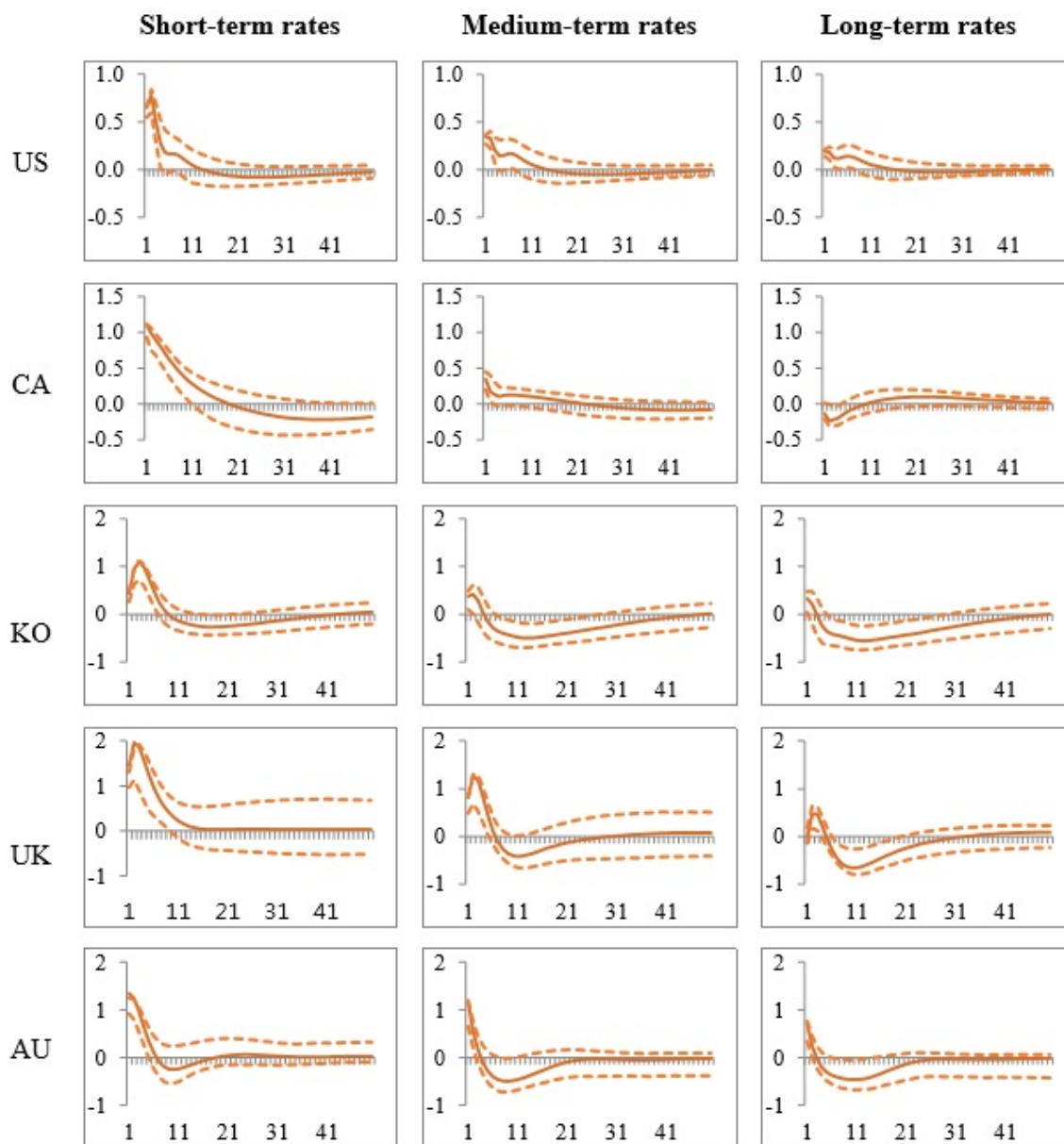
Table 2.3: Contribution of Domestic (MP) and Foreign (MP*) Shock to Market Rate Variation

Forecast horizon (month)	Canada		Korea		UK		Australia	
	MP*	MP	MP*	MP	MP*	MP	MP*	MP
(Short-term interest rates)								
1	0.7	39.0	17.5	6.9	6.6	63.2	5.1	68.5
12	5.6	16.0	15.7	13.8	7.5	25.6	7.0	33.2
24	6.9	10.2	14.4	11.7	18.3	14.4	7.9	32.3
48	10.2	10.1	13.2	9.7	24.8	8.9	7.8	32.0
(Medium-term interest rates)								
1	0.3	2.5	14.5	1.6	0.6	10.0	2.6	29.9
12	2.6	1.6	5.5	3.0	6.8	8.8	9.9	18.0
24	3.9	1.3	7.2	5.9	19.9	6.3	11.1	18.7
48	7.0	1.9	8.3	6.0	27.0	4.4	11.1	18.7
(Long-term interest rates)								
1	1.1	0.5	11.7	1.0	4.7	0.0	0.0	19.8
12	0.6	1.1	3.7	3.5	6.7	7.8	6.2	12.0
24	0.8	1.4	5.9	6.8	13.4	9.6	7.4	13.9
48	1.0	1.6	7.3	6.9	21.6	8.0	7.4	14.0
(Bank lending rates)								
1	1.4	59.7	6.7	2.0	0.5	20.9	5.8	62.4
12	5.3	20.6	12.0	14.7	5.0	25.3	8.1	34.3
24	6.7	12.3	13.5	12.7	20.2	19.3	9.0	33.1
48	10.2	11.8	13.0	9.8	27.8	14.7	9.0	32.7

Table 2.4: Contribution of Domestic (MP) and Foreign (MP*) Shock to Macroeconomic Variables

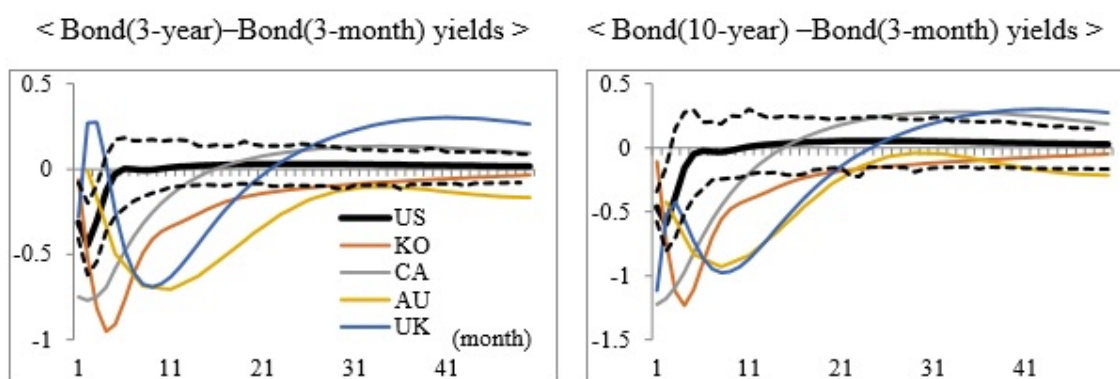
Forecast horizon (month)	Canada		Korea		UK		Australia	
	MP*	MP	MP*	MP	MP*	MP	MP*	MP
(Industrial Production)								
1	1.5	0.0	6.7	2.6	0.1	4.2	10.9	13.0
12	4.8	2.0	5.6	2.8	2.1	4.8	7.2	13.1
24	3.2	3.5	4.3	4.6	7.0	7.8	6.3	10.8
48	2.4	4.5	3.3	5.9	12.3	7.0	6.6	9.5
(Consumer price index)								
1	4.8	0.4	0.1	0.4	1.8	1.2	0.1	2.3
12	12.9	3.8	1.6	0.4	0.6	4.7	3.3	3.0
24	7.5	4.5	3.5	0.4	6.3	3.7	5.9	6.0
48	5.1	2.8	3.5	1.1	20.8	1.9	6.8	6.6
(Foreign exchange rates)								
1	7.1	1.1	2.3	1.6	10.5	14.1	0.2	4.1
12	15.3	8.0	6.5	9.6	10.5	9.2	17.6	11.9
24	16.3	12.3	7.1	11.1	9.2	9.4	17.6	12.0
48	15.4	12.7	6.4	10.4	9.5	9.3	17.6	12.0

Figure 2.1: Response of Interest Rates to a 1%p Domestic MP Shock



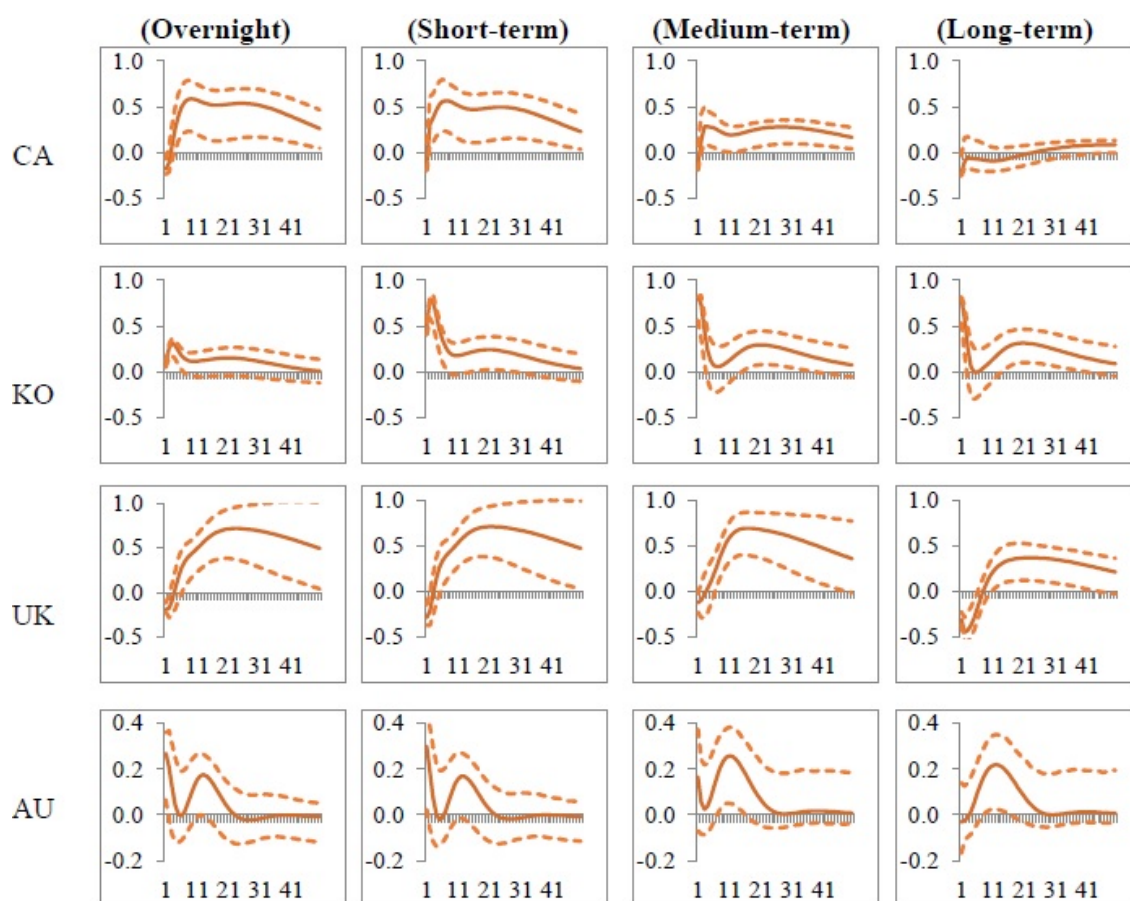
- Notes:
1. Y axis indicates % and X axis month(s) for the U.S., Canada (CA), Korea (KO), and the U.K. and quarter(s) for Australia (AU).
 2. Broken lines are the 16th and 84th quantiles of the empirical distribution of IRFs through the external instrument identification scheme based on 5,000 draws.

Figure 2.2: Response of Interest Rates Spreads to a 1%p Domestic MP Shock



Notes: Black broken lines are the 16th and 84th quantiles of the empirical distribution based on 5,000 draws for the U.S.

Figure 2.3: Response of SOE Interest Rates to a 1% U.S. MP Shock



- Notes:
1. Y axis indicates % and X axis month(s) for the U.S., Canada (CA), Korea (KO), and the U.K. and quarter(s) for Australia (AU).
 2. Broken lines are the 16th and 84th quantiles of the empirical distribution of IRFs through the external instrument identification scheme based on 5,000 draws.

Figure 2.4: Response of Domestic Interest Rates 1%p Domestic and U.S Shocks

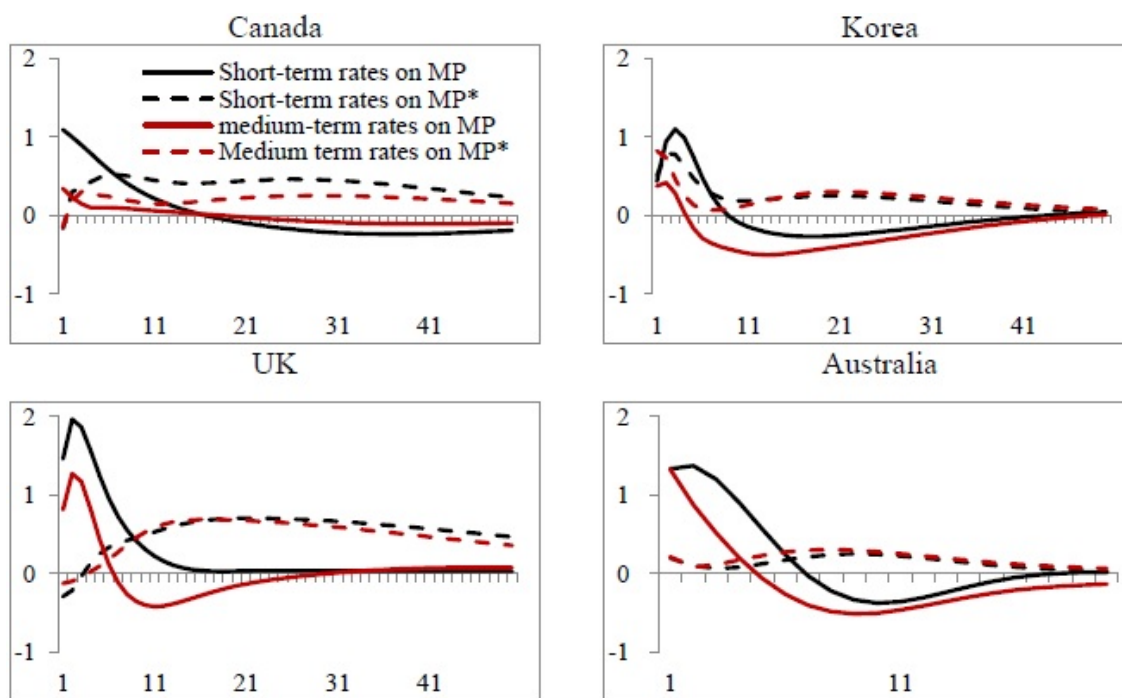
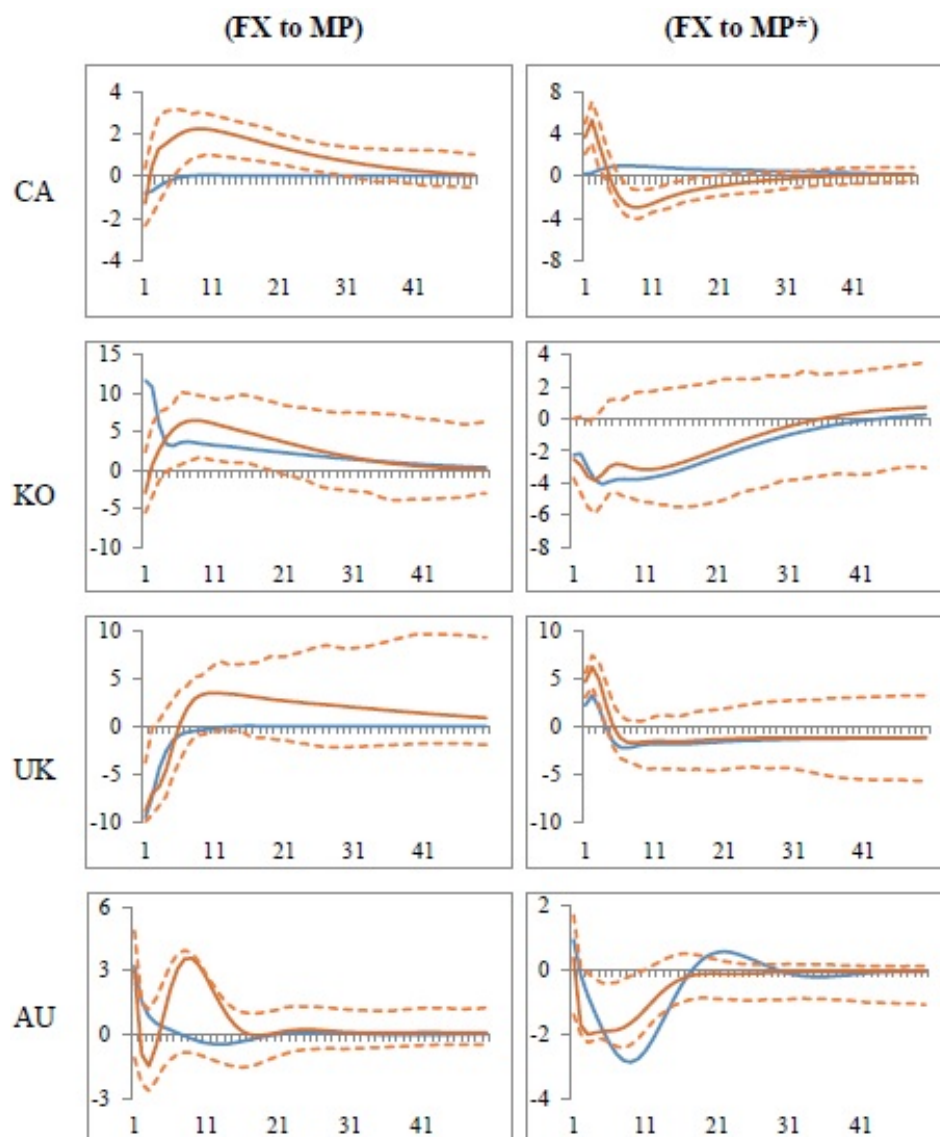
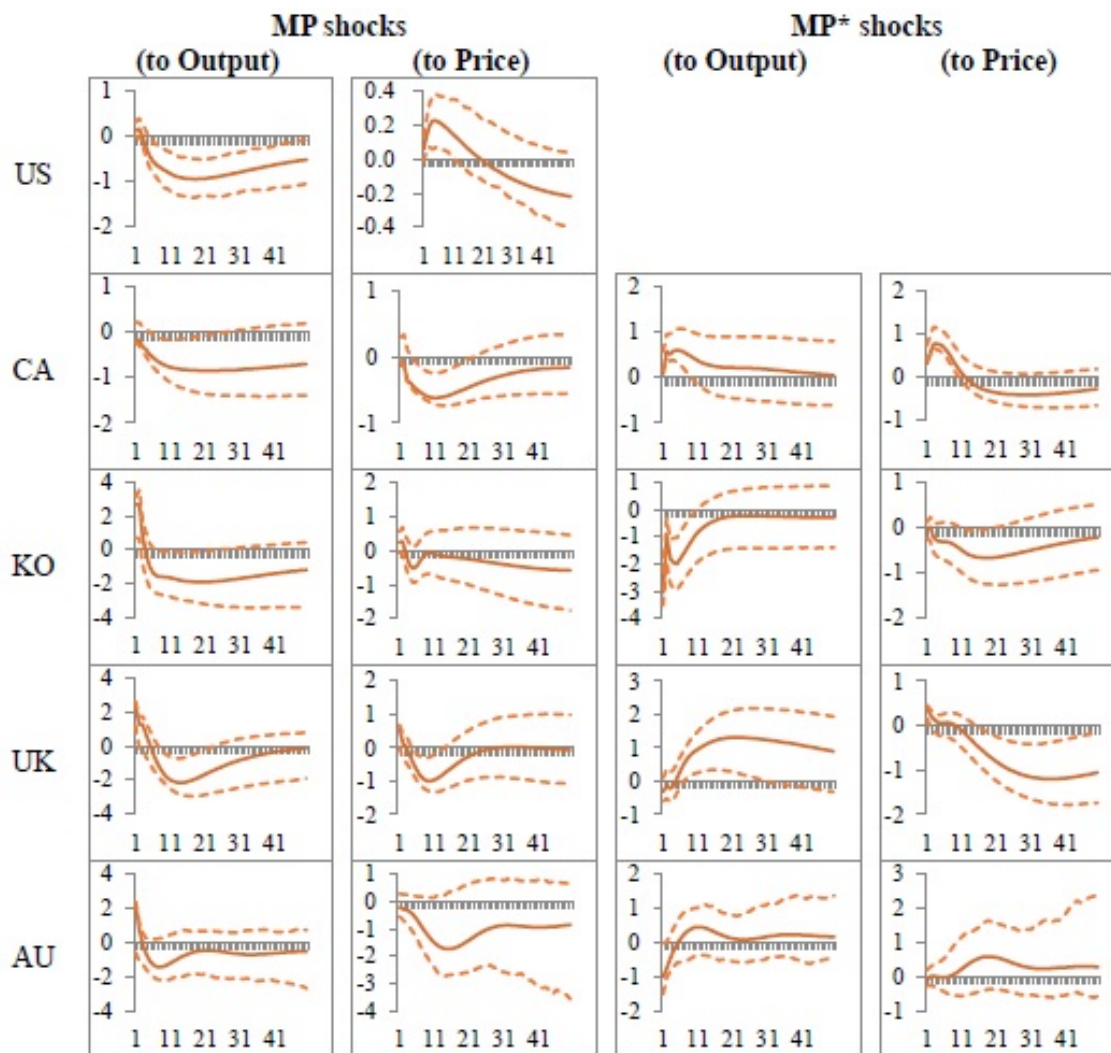


Figure 2.5: Response of FX Rates to 1%p Domestic and U.S. MP Shock



- Notes:
1. Y axis indicates % and X axis month(s) for the U.S., Canada (CA), Korea (KO), and the U.K. and quarter(s) for Australia (AU).
 2. Broken lines are the 16th and 84th quantiles of the empirical distribution of IRFs through the external instrument identification scheme based on 5,000 draws.
 3. Red lines indicate estimated IRFs with external instrument identification and blue lines indicate the results through Cholesky identification.

Figure 2.6: Response of Macroeconomic Variables to a Domestic and U.S. MP Shock (1%p)



- Notes:*
1. Y axis indicates % and X axis month(s) for the U.S., Canada (CA), Korea (KO), and the U.K. and quarter(s) for Australia (AU).
 2. Broken lines are the 16th and 84th quantiles of the empirical distribution of IRFs through the external instrument identification scheme based on 5,000 draws.

Chapter 3

WEDGE IN EULER EQUATION, MONETARY POLICY AND NET FOREIGN ASSET POSITION IN SMALL OPEN ECONOMIES

3.1 *Introduction*

Consumption Euler equation is a central building block in (open) macroeconomic models, stating that money market rate should be equated with the asset return implied by a consumption demand. When confronted with data, however, few studies have provided empirical evidence for a direct link between the implied Euler equation rate and actual interest rates. Instead, they have repeatedly reported that the actual returns are not consistent with the returns implied by standard CRRA Euler equation in the models. Despite the empirical weaknesses, however, the Euler equation remains at the center of standard modern macroeconomic theories. This paper examines whether the wedge between the two interest rate series exists in small open economies as in the literature, and investigates further the systematic relationship between the wedge and two possible influencing factors – monetary policy (‘MP’, hereafter) and net foreign asset (‘NFA’, hereafter) position.

The households’ intertemporal decisions on consumption may play a key role in aggregate demand and business cycles. Hence, a growing number of empirical studies on Euler equation have proposed a variety of approaches to explain the anomalies between the two rates. However, they have not reached the conclusive consensus yet,¹ and furthermore, relatively less attention has been paid to the studies on this issue in small open economies.

¹In the consumption-based asset pricing literature, many studies rely on the degree of elasticity of substitution to explain the discrepancy between the Euler equation interest rate and actual rate. For instance, see Mehra and Prescott (1985)[64], Giovannini and Labadie (1991)[42] and many others which document equity premium puzzle, and Weil (1989)[93] and Rose (1988)[76] for risk-free rate puzzle.

Why does not the interest rate implied by standard Euler equation and money market rate coincide? Some recent studies argue that the discrepancy between the standard Euler equation rate ('EER', hereafter) and actual market rate, specifically money market rate targeted by the central bank, is systemically linked to the stance of MP (e.g. Canzoneri et al. (2007)[11], Fuhrer (2000)[33], Collard and Dellas (2012)[21], Gareis and Mayer (2013)[35]). Euler equation with standard CRRA preference suggests that the interest rate is strongly correlated to the expected consumption growth. The empirical studies on the MP demonstrate that consumption responds in a hump-shaped manner on a monetary contraction, thereby creating a downward pressure on the expected consumption growth. In this case, the interest rate implied in the standard Euler equation declines, whereas money market rate increases. From this perspective, they argue that monetary surprise is the main source that makes the two rates move to the opposite direction.

However, even in this strand of literature, the determinants of the EER wedge, specifically in open economies, are far from being understood in that consumption or saving decision are likely being affected not only by the stance of monetary policy but by the movement of external factors such as NFA position. In an open economy with integrated financial markets, the effect of MP on the aggregate demand can be different from the closed economy to a certain extent due to the change of asset position. For instance, MP tightening raises domestic interest rates relative to abroad, and thereby induces capital inflows. The increased foreign capital may dampen the transmission channel of MP shocks, which would have less impact on the expected consumption than what could be observed in a closed economy (e.g. Mishkin (2009)[67]). Additionally, the foreign asset position may exert the direct influence in determining Euler equation rate and thus in explaining the gap between the EER and the perceived rates of return in small open economies. NFA position in an open economy represents total leverage of the economy, which is intimately linked to output growth, net export, and productivity (Gourinchas and Rey (2014)[44]). Hence, the asset position affects directly the aggregate return and consumption growth path in Euler equation.

Taking into account those issues, we evaluate the gap between the two rates, following

a simple wedge approach – a methodology that is standard in (open) macroeconomics (e.g. Chari, Kehoe, and McGrattan (2007)[15]). We refer to ‘EER wedge’ as the extent to which actual money market rate deviates from what the standard Euler equation with CRRA preference predicts. Then, to explore the relationships between the EER wedge and the two possible influencing sources – MP and NFA position – in small open economies, we gauge the long run and dynamic effects of each factor on the wedge by comparing the regression results and impulse responses in the vector autoregressive (VAR) model.

Our empirical findings are as follows. First, we find that significantly large EER wedge – negative correlation between EER and actual interest rate – exists in small open economies. To the extent that interest rates in small open economies can be determined by the movement of world interest rate, we also compare the EER calculated from the standard Euler equation with world interest rate. The result is robust across the type of interest rates. This finding confirms that the EER and actual interest rate do not coincide in small open economies as in a huge volume of literature which has documented well for the closed economy such as U.S.

Second, we find that the wedge is systematically related to NFA position. However, contrary to the literature on the closed economy (Canzoneri et al. (2007)[11]), the link between the wedge and the stance of MP does not seem to be strong. EER wedge does not react significantly to the monetary surprises in dynamic least square regression and VAR analysis. However, it exhibits the strong correlation with the NFA position by responding in a marked direction against NFA shock. This suggests that we need to consider NFA position additionally, for the standard Euler equation.

The rest of this paper is organized as follows. Section 3.2 presents the empirical evidence of significantly large wedge between EER and money market rate. Section 3.3 explains the possible relationship among the wedge, the stance of MP and the NFA position. Section 3.4 provides the results of empirical analysis. Section 3.5 concludes the paper.

3.2 Euler Equation Rate and Money Market Rate

In this section, we calculate the EER implied by the standard CRRA preference and compare it with actual money market rate using data in five representative small open economies – Australia, Canada, Finland, Korea and the U.K. We find that the EER is not consistent with actual rate in the focal countries, similar to many empirical studies on a closed economy, the U.S.

3.2.1 EER Calculation

To calculate the EER of standard model, we follow Canzoneri et al. (2007)[11]’s approach. We begin by assuming that a representative household has the standard additively separable CRRA preferences and he maximizes the expected lifetime utility subject to budget constraints:

$$\sum_{s=t}^{\infty} \beta^{s-t} \mathbb{E}_t \frac{C_s^{1-\alpha}}{1-\alpha} \quad (3.1)$$

where β is the discount factor, α is the coefficient of relative risk aversion, and C_s is consumption at time s . We assume that $\alpha = 2$ and $\beta = 0.993$ as in Canzoneri et al. (2007)[11].²

The first order condition (i.e. consumption Euler equation) implies that the nominal and the real EER have the relationship with consumption growth as follows:

$$\text{(Nominal Euler equation)} \quad 1 + i_t = \left\{ \beta \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\alpha} \frac{P_t}{P_{t+1}} \right] \right\}^{-1} \quad (3.2)$$

$$\text{(Real Euler equation)} \quad 1 + r_t = \left\{ \beta \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\alpha} \right] \right\}^{-1} \quad (3.3)$$

where i_t , r_t are the nominal and the real interest rate, and P_t is the consumer price index.

²For the robustness, we implement the similar exercise with the different values of elasticity of intertemporal substitution ($\alpha = 0.5$ and $\alpha = 3$). The results are robust across the value of α .

Under the assumption of conditional log-normality, equation (3.2) and (3.3) can be rewritten with log-normal terms, and nominal (\tilde{i}_t) and real EER (\tilde{r}_t) can be obtained as equation (3.4) and (3.5).

$$1 + \tilde{i}_t = \left\{ \beta \exp \left[\begin{array}{l} -\alpha (\mathbb{E}_t(c_{t+1}) - c_t) - \mathbb{E}_t(\pi_{t+1}) \\ + \frac{\alpha^2}{2} \text{var}_t(c_{t+1}) + \frac{1}{2} \text{var}_t(\pi_{t+1}) + \alpha \text{cov}_t(c_{t+1}, \pi_{t+1}) \end{array} \right] \right\}^{-1} \quad (3.4)$$

$$1 + \tilde{r}_t = \left\{ \beta \exp \left[-\alpha (\mathbb{E}_t(c_{t+1}) - c_t) + \frac{\alpha^2}{2} \text{var}_t(c_{t+1}) \right] \right\}^{-1} \quad (3.5)$$

where c_t is the logarithm of consumption, π_t is the inflation ($= \log(P_t/P_{t-1})$), and var_t , cov_t are conditional variance and covariance operator, respectively. The conditional expectations and the second moments of consumption and inflation can be obtained by assuming that the dynamics of small open economies can be described by the VAR(p) form:

$$Z_t = A_0 + A_1 Z_{t-1} + \dots + A_p Z_{t-p} + u_t \quad (3.6)$$

where Z_t is a vectors of macroeconomic variables (log of consumption, log of GDP, inflation, money market rate, NFA position)³ and u_t is a vector of i.i.d. normal error terms.

Then, we can obtain those variables from the following equations:

$$\mathbb{E}_t(Z_{t+1}) = A_0 + A_1 Z_t + \dots + A_p Z_{t-p+1} \quad (3.7)$$

$$\text{var}_t(Z_{t+1}) = \Sigma \quad (3.8)$$

where Σ is the variance-covariance matrix of VAR model.

³The details of data described in Section 3.2.2

3.2.2 Data

Five quarterly macroeconomic variables are used for the analysis following conventional VAR studies: logs of real household expenditure per capita (c_t , ‘consumption’ hereafter), logs of real GDP per capita (y_t , ‘output’ hereafter), first difference of logs of consumer price index (π_t , ‘inflation’ hereafter), money market rates (i_t), and logs of net foreign asset position (b_t).⁴ ⁵ Additionally, as in other previous literature, we include four external variables to isolate exogenous latent factors that may influence endogenous variables in the VAR system simultaneously; international commodity price index, crisis dummy, world real interest rate,⁶ and the dollar index. (e.g., Kim (2001)[54], Bjørnland (2009)[7], among many others).

The five open countries - Australia, Canada, Finland, Korea, and the U.K. - are selected to the extent that they are representative open economies of which capital markets and financial markets are in common: open and well-developed. The countries have adopted inflation targeting as a MP regime and manipulated short-term or money market rates as a MP operating instrument (except Finland). Table 3.1 summarizes the detail description of data.

3.2.3 Comparison of EER and Money Market Rate

Table 3.2 reports the summary statistics of model-generated real rate and the observed *ex post* real money market rate in each country. Standard Euler equation implies that correlation between EER and money market rate must be strongly positive.⁷ ⁸ However, the correlations

⁴We refer to NFA position as the ratio of foreign asset to foreign liability FA/FL , and use it to measure the position rather than the amount of exposure. Foreign asset and foreign liability data are obtained from international investment position data for each country.

⁵The variables are specified in levels to implicitly determine any potential co-integrating relationship between variables; See Hamilton (1994).

⁶World real interest rate are obtained from King and Low (2014)[56].

⁷The problems of nominal and real interest rates are identical. We focus on the analysis of real terms, which directly affects the agents’ intertemporal decision (e.g. consumption, saving, production).

⁸Canzoneri et al.(2007)[11] implement similar exercise for the various forms of preference, including habit persistence. They find that this anomaly between the two rates exist regardless of the forms of preference.

stay slightly negative except in U.K (U.K: 0.43, and other countries: -0.19~-0.05). One may argue that the correlation between the EER and world interest rate must be examined with consideration for the fact that the interest rate in small open economies is considerably affected by international financial market. The correlation between the EER and the world interest rate, however, shows even more negative value except in U.K (U.K: 0.65, and other countries: -0.43~-0.14). The means of spread between the two series (EER – actual rate) range from -13.23 to 10.44 in the focal countries.⁹

Figure 3.1 plots the real rate implied by standard Euler equation (red line, right axis) and ex post real money market rates (black line, left axis). Similar to the result of correlation, the behavior of the two series does not show any resemblance over the period.

The results demonstrate the existence of significantly large spread between EER and actual rate. As noted earlier, however, the fact that the two series do not comove are not surprising since this discrepancy has been well documented in the literature. We explore which factors determine the wedge between the model and the data in the following section.

3.3 Determinants of EER Wedge

The results in Section 3.2 show that the EER wedge is significantly large, indicating that some factor(s) enforces the two interest rates to move in opposite directions. In this section, we consider two possible determinants of the EER wedge in small open economies.

3.3.1 Monetary Policy and EER Wedge

Some studies explain the discrepancy between the EER and actual market rate, specifically money market rate targeted by central banks, by focusing on the role of monetary policy and the type of preference. In a frictionless economy with standard, additively separable CRRA

Considering their empirical findings, we focus on the wedge between EER from standard model with CRRA preference and money market rate in order to make the problem simple.

⁹Log-linearization of Euler equation yields: $0 = -\tilde{r}_t + r_t + \varepsilon_t$
Therefore, we can interpret the wedge between the EER and actual rate as the error term in the standard Euler equation.

preference, the consumption growth and money market rates must be strongly positively correlated according to the Euler equation. It is also empirically well-known, however, that after a contractionary monetary shock, consumption responds in a hump-shaped manner, and thus the expected consumption growth declines. Hence, money market rate rises and the EER declines on a monetary tightening shock, while, on a monetary easing shock, both rates respond in the opposite ways. As a consequence, the EER calculated from the standard CRRA utility is negatively correlated with actual money market rate.

One may argue, in this respect, that adding habit persistence (e.g. Fuhrer (2000)[33], and Christiano et al. (2005)[17]) reduces the problem stemming from the poor-behaved dynamics of spending in the model with standard Euler equation, and thus, the model with habits can perform better in fitting the model-generated rate to the money market rate. A group of recent literature, however, empirically demonstrates that the significantly large wedge or the negative correlation between the two interest rate series appears regardless of the preference specifications. For instance, Canzoneri et al. (2007)[11] show that the correlations calculated in a variety forms of specifications of preference – standard additively separable CRRA, and external or internal habits – are negative.

In an open economy, additionally, depending on the degree of integration into the international capital market, the effect of MP shock on the consumption can be less than in a closed economy. For instance, MP tightening raises domestic interest rates relative to abroad, thereby inducing capital inflows. The movement of capital triggered by MP may influence the transmission channel of MP shocks, and finally the expected consumption (Mishkin (2009)[67]).

3.3.2 Net Foreign Asset Position and EER Wedge

As the financial and capital markets become increasingly integrated, agents' consumption and saving decisions are heavily influenced by capital flow or international asset position; See Laison and Mollerstrom (2010)[60], Feldstein and Horioka (1980)[30], for instance. Additionally, the foreign asset position may exert the direct influence in determining the EER

because NFA position contains the past and future information on output growth, net export, productivity, exchange rate, and excess returns (Gourinchas and Rey (2014)[44]). Hence, the change of NFA position may affect the expected path of consumption and thus finally affect the determination of EER. in small open economies. ¹⁰

Then, how can NFA position explain the EER wedge? To answer this question, it is useful to consider how the EER wedge affects the elements in Euler equation. By doing so, one may understand intuitively the possible channels through which the EER wedge plays a role in the Euler equation, and the link between the wedge and NFA position. To this end, we rearrange the standard Euler equation with the EER wedge.

First, the EER wedge can directly affect the consumption path $(C_{t+1}/C_t)^{-\alpha} \Lambda_t$ as in (3.9):

$$1 = \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\alpha} \Lambda_t \times \beta (1 + r_t) \right] \quad (3.9)$$

where λ_t is log-normal EER wedge and $\Lambda_t = e^{\lambda_t}$. The consumption habit persistence described in the previous section can be this type of wedge. As rebutted in Canzoneri et al (2007)[11], however, the interest rates calculated from Euler equation with the external or internal habit still produce the significant wedge. The other factor which influences consumption growth may be the NFA. Positive NFA position implies the positive wealth in the economy, and thus household consumption is determined by the change of NFA position through wealth effect.

Second, as highlighted in equation (3.10), non-negligible EER wedge implies that it may affect the discount factor $\beta \Lambda_t$ in the standard Euler equation.

$$1 = \mathbb{E}_t \left[\beta \Lambda_t \times \left(\frac{C_{t+1}}{C_t} \right)^{-\alpha} (1 + r_t) \right] \quad (3.10)$$

It is note-worthy, in this respect, that existing literature (e.g. Becker and Mulligan (1997)[2])

¹⁰Note that standard Euler equation does not include NFA. This also results in the indeterminacy of non-zero long-run level of NFA. A group of literature in international macroeconomics has investigated the mechanism that pins down a steady state level of NFA. See Schmitt-Grohe and Uribe (2003)[81] for details.

empirically and theoretically demonstrates that wealth (i.e. positive asset position) is an important factor which leads to patience, thereby inducing high discount factor. Therefore, the wedge influencing the discount factor may have strong relationship with the NFA position.

Last, we may consider that the EER wedge is a gap between the aggregate return ($AR_t = (1 + r_t) \Lambda_t$) and the money market rate ($1 + r_t$) as in equation (3.11):

$$1 = \mathbb{E}_t \left[(1 + r_t) \Lambda_t \times \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\alpha} \right] \quad (3.11)$$

Standard (international) macroeconomic model typically assumes that the two returns coincide ($AR_t = 1 + r_t$). Recent literature (e.g. Moll (2014)[68]), however, indicates that rate of asset return can change depending on the asset position in an economy of which agents rely on external financing. Borrowers pay interest cost while lenders earn interest income. Therefore, the returns that borrowers and lenders receive are determined differently depending on their asset position, and so in whole-economy-wise, the asset position matters in the formation of the actual rate of return.

3.4 Empirical Analysis

In this section, we explore the relationship between the EER wedge and the possible determinants discussed in section 3.3 by using regression results and VAR analysis. From our analysis, we find the systemic relationship between the wedge and NFA position, but cannot find a strong link between the wedge and the stance of MP in the countries.

3.4.1 Regression Results

We begin with the regression that specifies the relationship among the EER wedge, the money market rate and NFA position taking the form as equation (3.12).¹¹ Regarding that these variables may have a cointegrating relationship, we employ a dynamic least square

¹¹Additionally, we test the relationship among the wedge, MP and NFA position following Canzoneri et al. (2007)[11]. The results are very similar to the DLS regression reported in this section.

(DLS) method that generates consistent estimates of θ_r and θ_b .

$$\lambda_t = \theta_0 + \theta_r r_t + \theta_b b_t + \sum_{i=-k}^k \phi_{r,i} \Delta r_{t-i} + \sum_{i=-k}^k \phi_{b,i} \Delta b_{t-i} + \varepsilon_t \quad (3.12)$$

where λ_t ($\approx \tilde{r}_t - r_t$) is the EER wedge, and Δ is the first difference operator.¹² In order for the MP shock to be effective on the wedge between the EER and money market rate, the coefficient of real money market rate (θ_r) must be significantly smaller than minus one. The negative coefficient indicates the opposite movement of the EER and money market rate on a MP shock.¹³ On the other hand, if the coefficient of NFA position θ_b is significantly different from zero, it implies that the wedge is affected by NFA position.

In Table 3.3 we present the coefficients of real interest rate and of NFA position from the DLS regression using data from each open economy. The estimates of coefficient for money market rate are negative for all of the countries, but not significantly less than minus one (-1) except Australia, indicating that the measured EER wedge does not widen greater than MP shock when MP tightens (an increase in the money market rate). This is surprising insofar as the existing literature that has found that the wedge declines on a contractionary MP shock.

Meanwhile, the estimated coefficients of θ_b show distinct pattern. As shown in Table 3.3, the rise of NFA position has increased the EER wedge from standard CRRA preference except in Canada and U.K. In Canada, the estimator is not significant, and in the U.K it declines as NFA position increases. The cross-correlation between the EER wedge and NFA position are roughly similar. As reported in Table 3.4, the correlations are positive (except the U.K), confirming the positive relationship between the EER wedge and NFA position.

In addition, we examine how the relationship between the EER and money market rate

¹²Leads and lags of the first difference of interest rate and NFA position are added to a standard OLS specification in order to exclude the possible endogeneity on the estimator. See Stock and Watson (1993)[89] for the details.

¹³On a monetary tightening shock, the real money market rate (r) always increases, thereby decreasing the wedge ($\tilde{r} - r$). In order to rule out this natural decrease of the wedge and to measure the net effect by the change of EER following a MP shock, we must test the null hypothesis $H_0 : \hat{\theta}_r = -1$ and $H_a : \hat{\theta}_r < -1$.

changes if we isolate the long run effects of NFA and interest rate from the EER. We calculate the adjusted EER after excluding the trend of the wedge as follows:

$$\tilde{r}_t^{adj} = \tilde{r}_t - \hat{\lambda}_t \quad (3.13)$$

where $\hat{\lambda}_t$ is the fitted value from the regression of λ on b . Table 3.5 summarizes that the correlation between the actual money market interest rates and the adjusted EERs. For the purpose of comparison, we also report the correlation between money market rate and the original EERs. The correlations between the two rates become positive after controlling the effects, and this result is distinguishable from the negative correlations between the EER and money market rate.

3.4.2 VAR analysis

We build a VAR model to examine the dynamic relationship between the two factors and the EER wedge. To this end, we include nominal money market rate, inflation, consumption, NFA position and the EER wedge as endogenous variables (ordered as listed).¹⁴ In addition, to exclude the latent effects of these variables on the endogenous ones, time trend, world interest rate, commodity price index, and dollar index are contained in the model as exogenous variables.

If the monetary policy is the main source of the EER wedge, on a monetary tightening shock, the wedge from the standard Euler equation must decline initially as the expected consumption growth decreases. Then, this initial drop of the wedge gradually fades away as the effect of MP shock subsides. Figure 3.2 displays the impulse response of the EER wedge to one-standard-deviation MP shock. The shaded area represents the 90% bootstrap interval, and horizontal axis is the quarters after the shock. The EER wedges in all of the countries respond negatively on a contractionary MP shock, but the responses only in

¹⁴For the robustness of the results, we compare IRFs with ordering as $[i_t \ \pi_t \ b_t \ c_t \ \lambda_t]'$. The results are similar across the ordering.

Australia, Korea, and U.K are statistically significant. After the initial drop, the response of wedge gradually reverts to zero in Australia and U.K. Meanwhile, in Korea, it quickly switches to the positive value in a few quarters, indicating that MP effects disappear within a few quarter in contrast to the conventional belief about the policy lags of MP.

Next, we examine the effects of NFA position shock on EER wedge. Positive position of NFA can produce the wealth effect, thereby increasing the expected consumption growth as well as EER. Therefore, the EER wedge increases on a positive NFA shock if this channel works. To illustrate the dynamic relationship between NFA position and the EER wedge, Figure 3.3 compares the influence of NFA position shock on the wedge from standard Euler equation in each country. Interestingly, the wedge increases significantly for about one year on a positive (one-standard-deviation) NFA position shock except in U.K, of which the EER wedge immediately drops in response to NFA position shock. On a NFA position shock, consumption reacts positively as depicted in Figure 3.4. The responses of consumption reach to the peak around one year after the shock, and then gradually decrease to zero (except in the U.K). This movement of consumption following NFA position shock matches to the reaction of the wedge, providing the evidence of the wealth effect of NFA position to consumption.

3.5 Conclusion

This paper revisits the conventional topic of the wedge between the interest rate implied by standard Euler equation and money market rate in small open economies but focuses on exploring the systemic relationship between the wedge and possible determinants, monetary policy and NFA position. To that end, first of all, we calculate the EER based on standard Euler equation, and compare it with money market rate in small open economies. We find that the negative correlation between the two rates, which implies that EERs are not consistent with the money market rates. The negative correlation is also observed between the EER and world interest rate.

Second, we find that the wedge is systematically related to the NFA position, but is not

strongly linked to the stance of MP. Our results from DLS regression and VAR analysis show that the wedge reacts positively to the positive NFA shock, and the responses are statistically significant, while they respond to the opposite direction or do not move with statistical significance.

To the extent that the households' intertemporal decision on consumption may play a key role in explaining the movement of aggregate demand and business cycles, understanding the EER wedge is very important in studying the dynamics of consumption and its role in the economy. The empirical results all suggest that systemic channel that NFA position influences EERs is missing in standard Euler equation. In addition, contrary to the literature (e.g. Canzoneri et al. (2007)[11]), MP may not be the main driving force for the significantly large EER wedge in small open economies. Our empirical results may provide the evidence that we need to consider the NFA position carefully in modeling Euler equation.

3.6 Tables and Figures

Table 3.1: List of Variables in the VAR Model

Variable	Category	Australia	Canada	Finland	Korea	U.K.
c_t	consumption	Real household expenditure per capita				
y_t	output	Real GDP per capita				
π_t	inflation	CPI inflation				
i_t	money market rate	Overnight cash rate	Money market financing rate	1-month Helibor	Overnight call rate	Bank rate
b_t	NFA position	Foreign asset / Foreign liability				
Control Variable		Commodity price index, Crisis dummy variable with 1 for the period between 2008.Q3 ~ 2009.Q2, US dollar index				

Notes: Sample periods: Australia (88.2Q~13.4Q), Canada (89.4Q~13.4Q), Finland (92.4Q~13.4Q), Korea (94.3Q~13.4Q), U.K. (88.1Q~13.4Q).

Source: Bloomberg, IFS, CEIC database, King and Low (2014)

Table 3.2: Summary Statistics for Real Interest Rates

	Australia		Canada		Finland	
	r	\tilde{r}	r	\tilde{r}	r	\tilde{r}
mean	3.59	3.69	2.17	2.65	1.50	-0.81
std	3.39	2.03	3.20	3.00	2.77	5.59
min	-9.18	-0.98	-4.49	-9.09	-4.42	-14.27
max	13.77	7.41	9.39	8.27	9.64	11.10
corr(r, \tilde{r})	-	-0.19	-	-0.05	-	-0.13
corr(r^W, \tilde{r})	-	-0.43	-	-0.14	-	-0.38
	Korea		U.K			
	r	\tilde{r}	r	\tilde{r}		
mean	2.67	-10.56	3.00	9.44		
std	4.66	13.43	3.95	3.83		
min	-5.08	-56.11	-5.58	1.61		
max	22.51	11.39	12.45	16.19		
corr(r, \tilde{r})	-	-0.06	-	0.43		
corr(r^W, \tilde{r})	-	-0.29	-	0.65		

Table 3.3: DLS Regression Results

	Australia	Canada	Finland	Korea	U.K
$\hat{\theta}_0$	10.21 ^{***} (1.05)	6.73 ^{***} (0.50)	3.51 ^{***} (1.13)	7.15 [*] (4.30)	6.17 ^{***} (0.47)
$\hat{\theta}_b$	14.16 ^{***} (1.55)	-2.19 (1.91)	9.43 ^{***} (3.19)	36.79 ^{**} (16.01)	-26.32 ^{**} (12.83)
$\hat{\theta}_r$	-1.38 ^{***} (0.18)	-0.88 ^{***} (0.11)	-0.40 (0.42)	-1.75 ^{***} (0.52)	-0.64 ^{***} (0.13)
$H_0 : \hat{\theta}_r = -1$	Rejected	Not rejected	Not rejected	Not rejected	Not rejected
$H_a : \hat{\theta}_r < -1$					
<i>Notes:</i>	Numbers in parenthesis are standard error. *** : $p < 0.01$, ** : $p < 0.05$, * : $p < 0.10$				

Table 3.4: Correlation between the EER wedge and NFA position

	Australia	Canada	Finland	Korea	U.K
$corr(\lambda_t, b_t)$	0.66	0.45	0.49	0.34	-0.11

Table 3.5: Comparison of $corr(\tilde{r}_t, r_t)$ and $corr(\tilde{r}_t^{adj}, r_t)$

	Australia	Canada	Finland	Korea	U.K
$corr(\tilde{r}_t, r_t)$	-0.19	-0.05	-0.13	-0.06	0.43
$corr(\tilde{r}_t^{adj}, r_t)$	0.39	0.29	0.14	0.11	0.45

Figure 3.1: Real EERs and Actual Rates

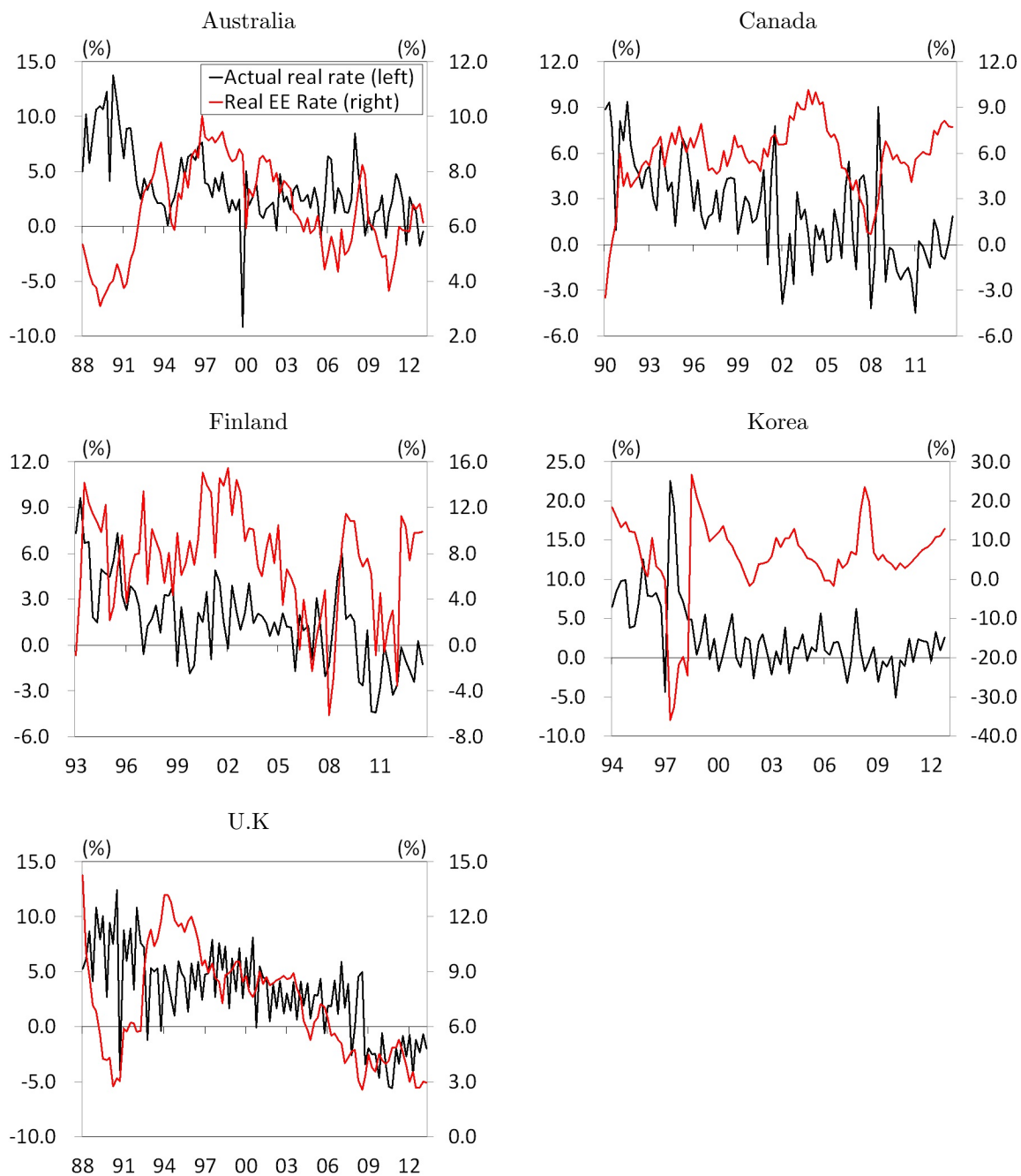
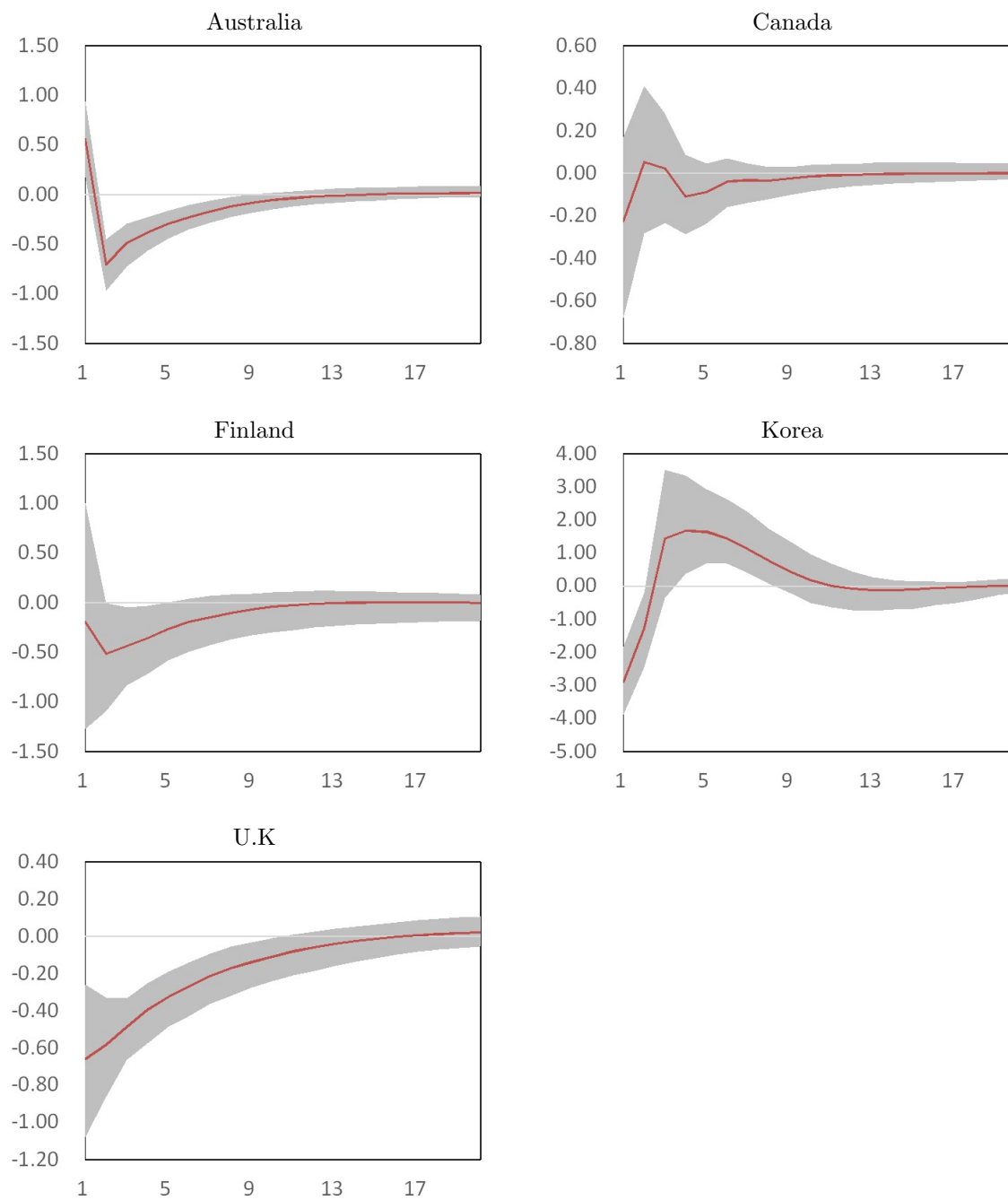
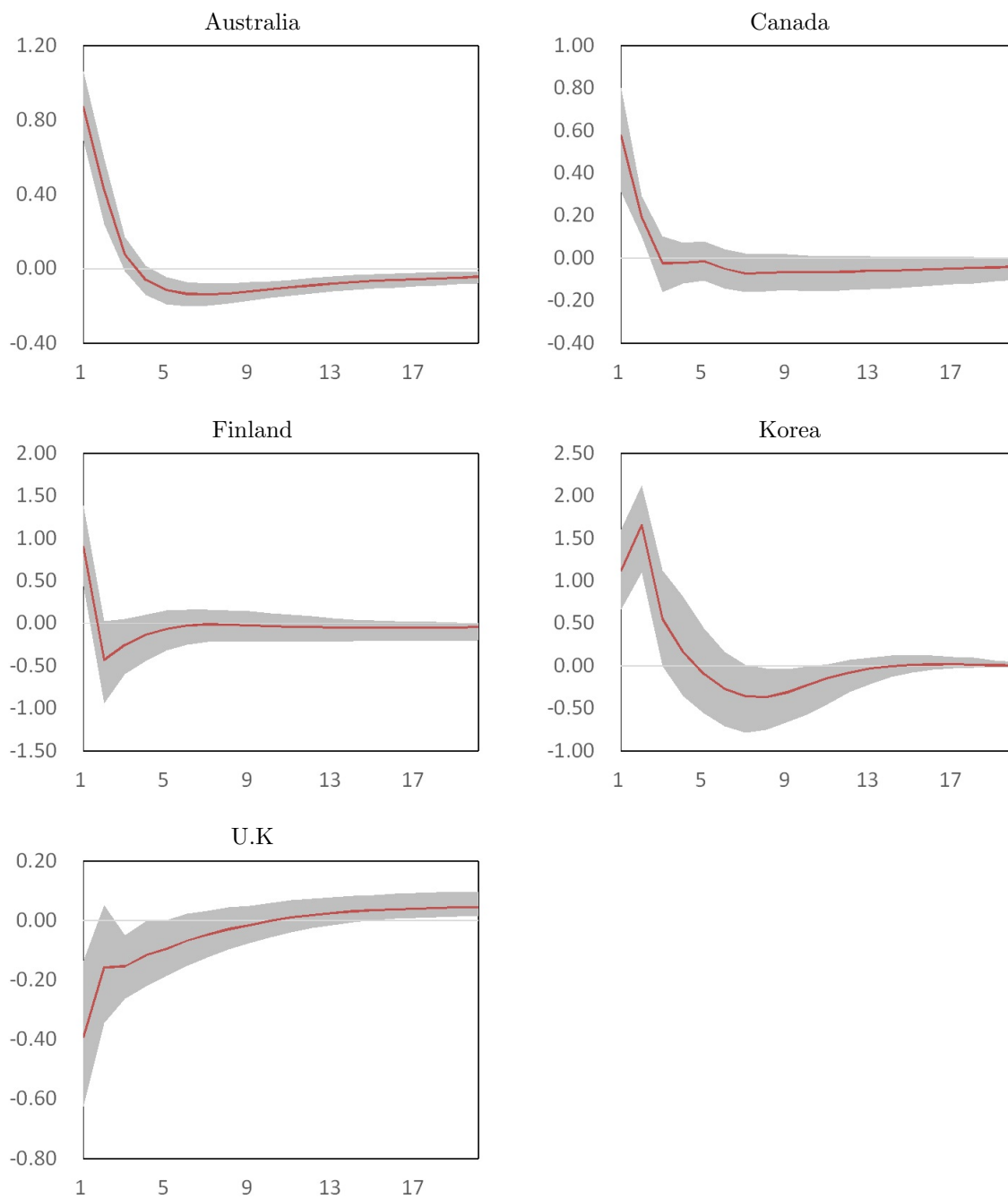


Figure 3.2: Impulse Response of the EER wedge to the MP shock (+1 std)



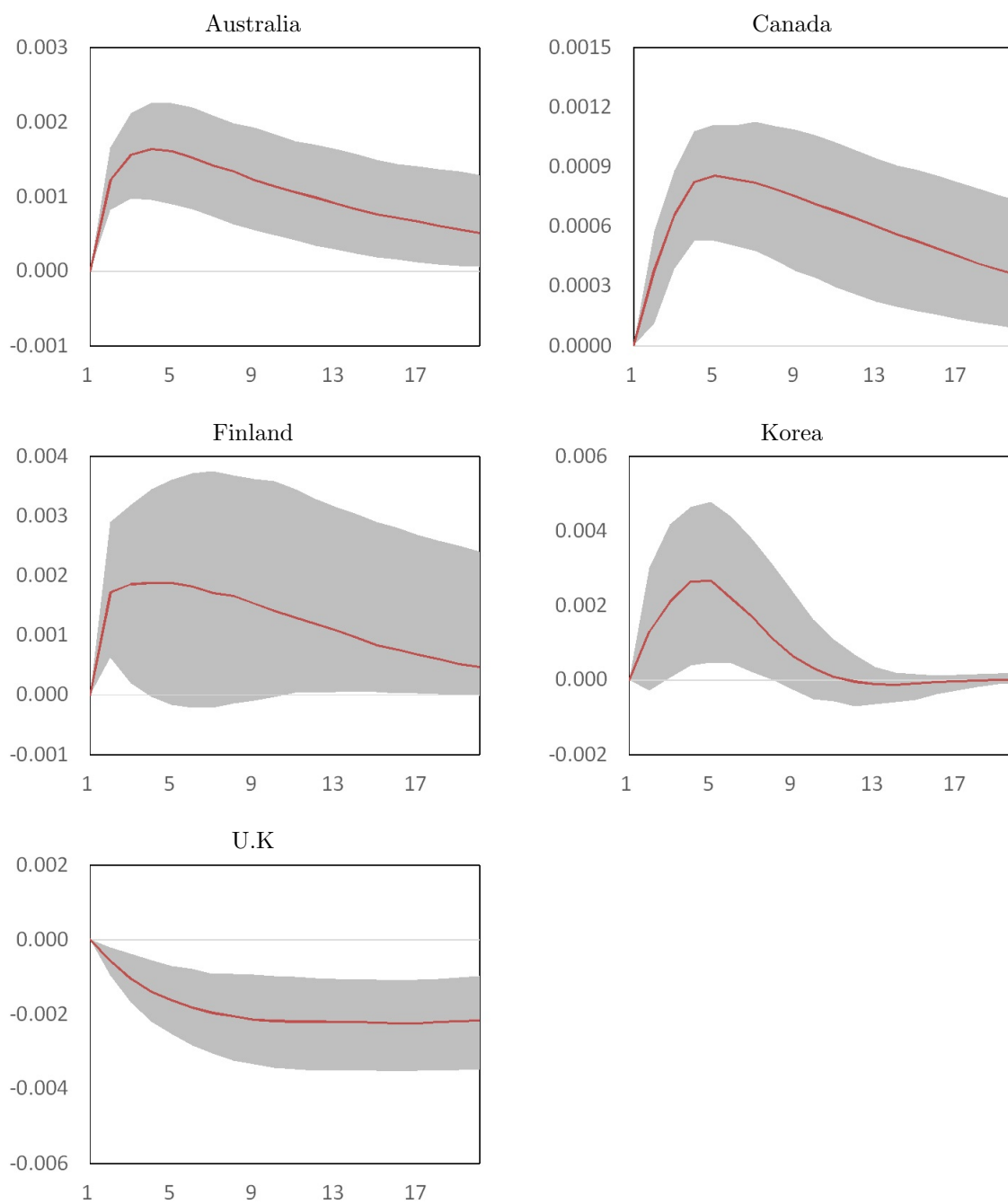
Notes: Shaded area is 90% bootstrap interval.

Figure 3.3: Impulse Response of the EER wedge to the NFA shock (+1 std)



Notes: Shaded area is 90% bootstrap interval.

Figure 3.4: Impulse Response of Consumption to the NFA shock (+1 std)



Notes: Shaded area is 90% bootstrap interval.

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Appendix A

APPENDIX TO CHAPTER 1

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

The structural shocks of a recursive VAR model of three variables ($\hat{\pi}_t^*$, \hat{y}_t^* , \hat{R}_t^{*IB} ; ordered as listed) are identified by using a standard Cholesky decomposition, as in Eq (A.1). I place the federal funds rate (FFR) last in the ordering as in Ghironi (2000)[41], so that the output and inflation gap are restricted from simultaneously reacting to the interest rate shock, while FFR is allowed to react simultaneously to them.

$$AX_t = \sum_{i=1}^p B_i X_{t-i} + \varepsilon_t \quad (\text{A.1})$$

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.

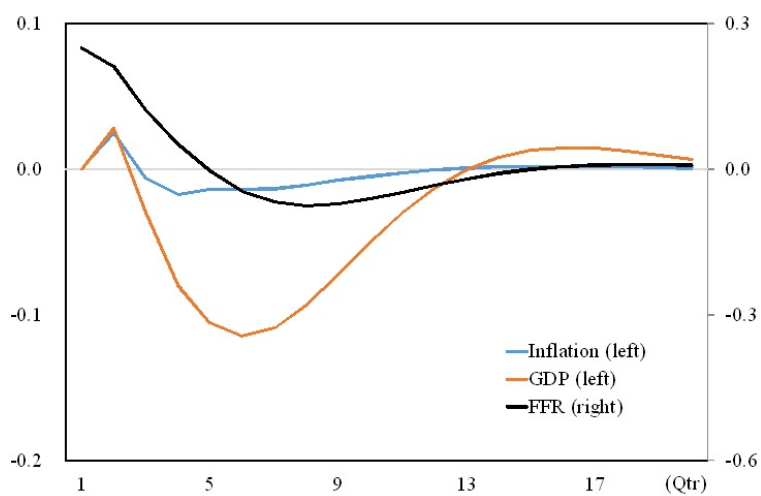
Figure A.1 illustrates the responses of U.S GDP, inflation, and FFR to a 25bp increase in FFR. The output and inflation gap (deviation from the steady state) react with a lag of two or three quarters, and these results are in line with the literature. We can find that all variables return to their steady states over time.

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

	$\hat{\pi}_t^*$	\hat{y}_t^*	\hat{R}_t^{IB*}
\hat{y}_t^*			0.470 (0.221)
$\hat{\pi}_t^*$		0.183 (0.143)	0.387 (0.145)
$\hat{\pi}_{t-1}^*$	-0.088 (0.094)	-0.165 (0.143)	-0.426 (0.233)
\hat{y}_{t-1}^*	0.097 (0.058)	0.970 (0.088)	-0.109 (0.143)
\hat{R}_{t-1}^{IB*}	0.098 (0.041)	0.093 (0.062)	0.756 (0.101)
$\hat{\pi}_{t-2}^*$	-0.158 (0.096)	0.091 (0.146)	0.371 (0.237)
\hat{y}_{t-2}^*	0.017 (0.057)	-0.061 (0.087)	-0.090 (0.142)
\hat{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: Impulse Response to Contractionary U.S FFR (25bp)

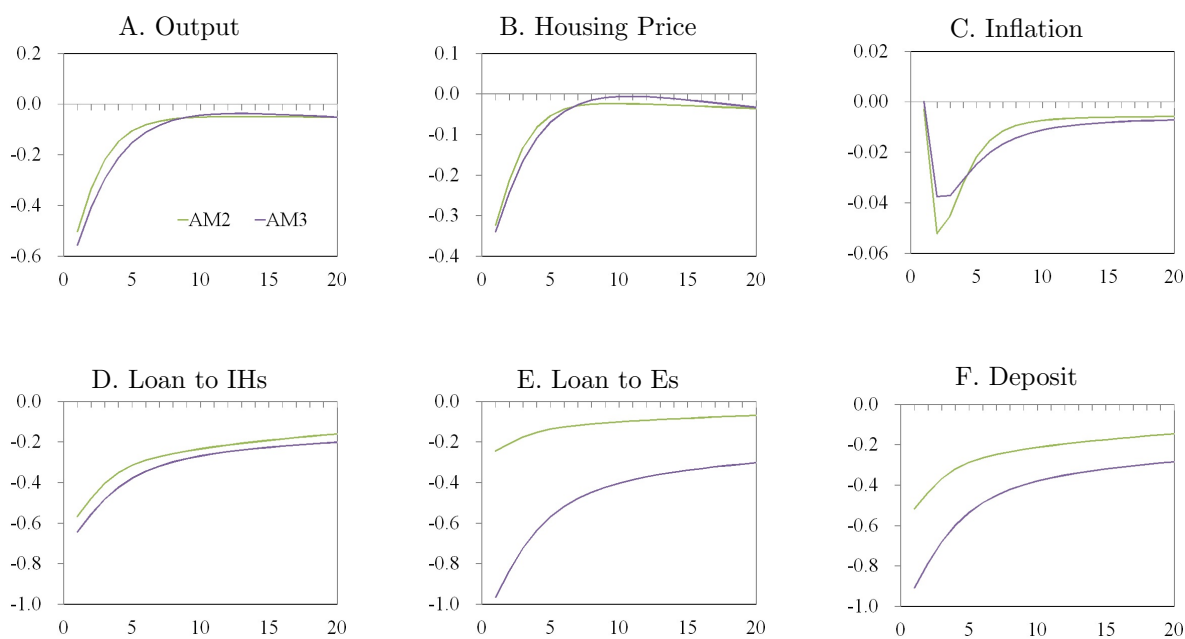


Notes: Horizontal axis : Quarters from the shock;
Vertical axis: Percentage deviation from steady state.

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)[36]). I set up an alternative model (AM3) that blocks the bank attenuator channel. A comparison between AM2 (green line) and AM3 (purple line) in Figure A.2 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.

Appendix B

APPENDIX TO CHAPTER 2

B.1 IV Candidates for MP Shocks

B.1.1 Daily Short-term Spot Rate Changes on MP Decision Dates: IV 1 through 4

Following Cochrane and Piazzesi (2002)[20] and others, we test daily movements of short-term interest rates around MP decision announcements, by defining an MP shock as the daily change in the spot rates on that day. Financial market participants anticipate MP decisions before actual policy announcements, and short-term rates may have already been adjusted beforehand. If on the contrary the MP announcement is a mere surprise, market rates will adjust only after the announcements. We test the following four short-term interest rates: overnight rates (IV1), market interest rates with maturity of 1 month (IV2), Treasury bill rates with maturity of 3 months (IV3), and daily exchange rates per US dollar (IV4).

B.1.2 Daily Futures Prices of Financial Instruments on MP Decision Dates: IV 5 through 9

A variety of futures assets, even though the underlying instrument is not directly related to MP, exist in financially developed SOEs. Like spot rates, futures prices also retain meaningful information about market expectations regarding future paths of MP. We here test the following five futures contracts under financial assets: futures prices under short-term (IV5), medium-term (IV6), and long-term (IV7) fixed-income (bond) instruments,¹ currency futures

¹Although the relationship with the MP instrument is not as close as those with short-term instruments, there are also good reasons to regard movements of futures prices under long-term fixed-income instruments as embedding market expectations for MP announcements. If we follow the expectation hypothesis regarding the term structure, long-term rates can be explained by expectations for short-term rates and the liquidity premium, assuming there is no credit risk with the financial instruments.

rates per USD (IV8), and national stock price futures rates (IV9).^{2 3}

B.1.3 Beveridge-Nelson Decomposed Overnight Rates: IV10

If there is no other economic news except MP announcements on MP decision dates, we may define MP shocks as deviations of MP instruments on that day from the expected future paths. What is an ‘expected future path’? Here we use an econometric technique of Beveridge and Nelson (1981)[6] (‘BN’ hereafter) and seek to provide potential instruments for unexpected MP shocks.

BN propose a definition of the permanent component of an $I(1)$ time series with drift as the limiting forecast as the horizon goes to infinity, adjusted for the mean rate of growth over the forecast horizon, as shown in (B.1).

$$\begin{aligned} x_t = r_t - z_t &= r_t + \psi^*(L)e_t = r_t + \psi_0^*e_t + \psi_1^*e_{t-1} + \dots \\ &= r_t + \sum_{j=1}^{\infty} E(\Delta r_{t+j} - \mu | I_t) = \lim_{j \rightarrow \infty} r_{t+j|t} - \mu j \end{aligned} \quad (\text{B.1})$$

where x_t is the (adjusted) permanent component of r_t and z_t is the transitory component. According to Box-Jenkins’s method, we find that daily MP instruments in each country follow the ARIMA process, as reported in (B.2).

²Theoretical and empirical studies have suggested a relationship between currency or equity prices and MP surprises. For example, a representative theory of the relationship between MP and currency would be the uncovered interest rate parity (UIP) theory. According to UIP, risk-neutral investors are indifferent between the interest rates in two countries since the exchange rate between those countries is expected to be adjusted such that the return on deposits in each country equalizes, thereby eliminating the potential for uncovered interest arbitrage profits. However, as is well-known in international macroeconomics, many empirical studies report that high-interest-rate currencies tend to appreciate (the UIP puzzle). Therefore, we need to use these attentively.

³Following Gertler and Karadi (2015)[38], considering the fact that the day of an FOMC meeting varies from month to month, we take the following step in constructing daily MP instruments. First, for each day of the month, we cumulate the surprise on any FOMC days during the last 31 days; and second, we create cumulative daily surprise series by cumulating all MP decision-day surprises.

$$\begin{aligned}
\text{US [ARIMA(1,1,2)] : } \Delta r_t &= \underset{(25.41)}{0.58} \Delta r_{t-1} + e_t - \underset{(-32.00)}{0.77} e_{t-1} - \underset{(-4.30)}{0.06} e_{t-2} \\
\text{AU [ARIMA (2,1,2)] : } \Delta r_t &= \underset{(47.64)}{0.61} \Delta r_{t-1} - \underset{(-64.98)}{0.95} \Delta r_{t-2} + e_t - \underset{(-38.33)}{0.61} e_{t-1} + \underset{(49.48)}{0.92} e_{t-2} \\
\text{CA [ARIMA (1,1,0)] : } \Delta r_t &= - \underset{(-11.67)}{0.17} \Delta r_{t-1} + e_t \\
\text{KO [ARIMA(1,1,2)] : } \Delta r_t &= \underset{(25.41)}{0.58} \Delta r_{t-1} + e_t - \underset{(-32.00)}{0.77} e_{t-1} - \underset{(-4.30)}{0.06} e_{t-2} \\
\text{UK [ARIMA (1,1,0)] : } \Delta r_t &= \underset{(4.96)}{0.05} \Delta r_{t-1} + e_t
\end{aligned} \tag{B.2}$$

where Δr_t is the first difference of the overnight rate, e_t is the residual, and the numbers in parenthesis are t -values. Following Morley (2002)[69], we can transform this result into a state space representation, $R_t = FR_{t-1} + \varepsilon_t$, and implement BN decomposition. For example, for the US case, state space representation can be expressed as (B.3):

$$\begin{bmatrix} \Delta r_t \\ e_t \\ e_{t-1} \end{bmatrix} = \begin{bmatrix} \phi_1 & \theta_1 & \theta_2 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \Delta r_{t-1} \\ e_{t-1} \\ e_{t-2} \end{bmatrix} + \begin{bmatrix} e_t \\ e_t \\ 0 \end{bmatrix} \tag{B.3}$$

Then, the BN trend is $r_t + (1,1)$ element of $F(I(n) - F)^{-1}R_t$ where n denotes a dimension of the state space matrix, and the transitory component, an MP shock, is the $(1,1)$ element of $-F(I(n) - F)^{-1}R_t$. Assuming that there is no economic news on an MP decision day and that overnight financial markets behave consistently with the market efficiency hypothesis, the BN trend on an MP decision date is the market participants' long-run forecast conditional on information up to the date, and the transitory component on the day is the unexpected MP shock.⁴

⁴We assume market efficiency in the overnight interest rate market, so the market price may be determined based on the entire information set available up to time $t(I_t)$.

B.1.4 Residuals from Forward-looking Taylor Rule Estimation: IV11

Following Clarida, Gali, and Gertler (2000)[19] and many others, we estimate the forward-looking Taylor rule as equation (B.4) assuming that the policy rate adjusts to gaps between expected inflation and output and their respective target levels. Residuals from the policy rule estimation can be interpreted as the difference between actual policy rates and the rates implied by the rule had monetary authorities followed it. Roughly speaking, the residuals indicate the unintended policy shocks caused by a central bank that strictly obeys the rule.

$$r_t = \rho r_{t-1} + (1 - \rho) [rr^* + (\beta - 1) \pi^* + \beta \pi_{t,k} + \gamma x_{t,q}] + v_t \quad (\text{B.4})$$

where r^* , $\pi_{t,k}$, $x_{t,q}$, ρ are the target interest rate, the inflation rate at time $t + k$, the output gap in period $t + q$,⁵ and the degree of smoothing of interest rate changes, respectively. The real rate and its long-run equilibrium are $rr_t^* \equiv r_t^* - E[\pi_{t,k} | \Omega_t]$ and $rr^* \equiv r^* - \pi^*$, where Ω_t is the information set at the time that the interest rate is set. Note that the residual from the rule is the form $v_t = -(1 - \rho) [\beta [\pi_{t,k} - E(\pi_{t,k} | \Omega_t)] + \gamma [x_{t,q} - E(x_{t,q} | \Omega_t)]]$.

Unless $\pi_{t,k} = E[\pi_{t,k} | \Omega_t]$ and $x_{t,q} = E[x_{t,q} | \Omega_t]$, the explanatory variables and the error term become correlated. In order to solve this orthogonality problem, we estimate with the Generalized Method of Moments, which utilizes an optimal weight matrix that accounts for the possible serial correlation in v_t .⁶ The estimation results are summarized in Table B.1.

⁵The output gap is measured by the difference between industrial production and its HP filtered series.

⁶We use instrument sets, which include four lags of policy rates, inflation, the output gap, and the spread between long-term and TB (3-month) rates.

Table B.1: Estimation Results for Forward-looking Policy Rule

	β	γ	ρ	π^*
US [1980~2013]	3.46 (0.55)	0.44 (0.56)	0.90 (0.03)	4.08 (0.27)
CA [1982~2013]	3.63 (0.40)	-0.64 (0.64)	0.57 (0.13)	2.58 (0.16)
AU [1991~2013]	3.24 (0.56)	-2.68 (0.71)	0.83 (0.03)	2.60 (0.17)
KO [1996~2013]	1.77 (0.51)	-0.21 (0.17)	0.85 (0.02)	4.60 (1.12)
UK [1989~2013]	1.84 (0.17)	1.13 (0.27)	0.44 (0.14)	0.68 (0.48)

Note: Numbers in parentheses are standard errors.

B.2 IV Test Results

B.2.1 IVs for U.S. MP Shocks

Table B.2 summarizes the results of the weak IV test, for each suggested IV for U.S. MP shocks. Each row displays the t -value and R^2 for the first-stage least square. We find that almost all the IV candidates have strong relationships with the residual series of the MP instrument. Spot short-term rates (IV1~3) have significant explanatory power at the 95% significance level through all sample periods tested. As already shown clearly in other studies, intraday movements of Federal Fund futures rates and Eurodollar futures rates (IV5a~5e) are significantly relevant to the MP instruments, reporting the highest t -values and R^2 . The BN decomposed rate (IV10) also shows high relevancy while the residual from the Taylor rule estimation (IV11) shows mixed results, which are significant for the full sample but not for the sub-samples.

Table B.3 exhibits over-identification test results for the proposed U.S. IVs. The IV set consisting of intraday FFFR (IV5 series) shows very low Sargan statistics, indicating that they are sufficiently orthogonal to residual series of other endogenous variables in the VAR system. Spot short-term rates (IV1~4) show mixed results; through the 1980~2008 sample, the IVs cannot reject the null hypothesis that the IVs are endogenous with other residual series of other financial instruments (3-month, 3-year, and 10-year TBs) at the 5% significance level, but through other sub-samples the null hypothesis is not rejected.

B.2.2 IVs for SOE MP Shocks

We summarize the relevancy of IVs for each of the focal SOEs in Table B.4. Above all, spot overnight rates (IV1) turn out to be the most highly relevant to the residual of the MP instruments, in line with Cochrane and Piazzesi (2002)[20]. In all analyzed SOEs, IV1 is significant at the 5% significance level and the explanatory power of the IV (R^2) ranges from 0.07 to 0.23. Short-term rates (with 3-month maturity, IV2) have a close relationship with the MP instruments that is significant at the 10% significance level in all SOEs. Daily

innovation of overnight rates through BN decomposition (IV10) produces almost the same results as were obtained for IV1. However, the results for the remaining IVs are mixed by country: residuals from Taylor rule estimation (IV11) show significant relevancy except in the UK. Spot market rates (3-month maturity, IV3) and futures rates for fixed-income or bond instruments (IV5~7) are significantly relevant to MP shocks in Canada and the UK. Spot FX rates per US dollar (IV4) and futures rates under FX rates (IV8) or under a sovereign stock price index (IV9) offer little explanation of the portions of the MP instruments.

The evidence in Table B.4 leads us to select the best combination of multiple IVs in terms of relevancy. The selected IV sets for each country and their F -values in the first-stage least square are displayed at the bottom row of Table B.3. This allows us to establish a set of results for our analysis in a setting where there is unlikely to be a weak instruments problem.

Finally, in Table B.5, the over-identification test results are summarized for the selected IV combinations for both the focal SOEs and U.S. MP shocks. At the 5% significance level, almost none of the residual series rejects the null hypothesis. This indicates that the selected IV combinations for each country are exogenous to residual series of other variables.

Table B.2: Explanatory Power of Suggested IVs for U.S. MP Shocks

	1980~2008	1984~2008	1989~2008
IV1	1.82*[0.01]	2.84*** [0.03]	2.36** [0.03]
IV2	3.95*** [0.04]	2.65*** [0.02]	-0.97[0.00]
IV3	4.04*** [0.05]	5.00*** [0.08]	4.89*** [0.10]
IV5a	-		6.73*** [0.17]
IV5b	-	-	6.08*** [0.15]
IV5c		3.38*** [0.04]	4.00*** [0.07]
IV5d	-	3.79*** [0.05]	3.67*** [0.06]
IV5e	-	3.30*** [0.04]	3.29*** [0.05]
IV5f	-	2.59*** [0.02]	2.83*** [0.04]
IV10	7.58*** [0.14]	5.59*** [0.09]	2.75*** [0.03]
IV11	2.41** [0.02]	1.28[0.01]	1.34[0.01]

Notes: 1) t -values and R^2 (parentheses) of each IV in the first-stage regression of the VAR residual of MP and each IV.
2) ‘-’ indicates that selected IV is not available for a given sample period.
3) Bold parts are significant at the 95% confidence level.

Table B.3: Sargan's Statistics for Selected US IVs Following MP Shocks

Sample	1980~2008	1984~2008		1989~2008		
	[IV1~3,10]	[IV1~3,10]	[IV5c~5f]	[IV1~3,10]	[IV5c~5f]	[IV5a~5b]
Y	6.75	2.19	1.79	5.03	1.29	3.57
P	2.49	2.29	0.22	8.07	0.89	0.39
$R3m$	15.90	3.11	0.06	0.24	1.73	2.87
$R3y$	15.90	0.84	1.06	2.67	6.44	7.57
$R10y$	20.50	2.76	1.54	4.60	4.32	4.74
$Lend$	5.10	2.80	0.79	3.25	8.28	1.82
L	1	1	1	1	1	1
K	4	4	4	4	4	2
$\chi_{0.99(0.95)}^2 > K - L$		9.21(5.99)			6.64(3.84)	

Note: Reject H_0 at 1% (5%) significance level if $\chi_{0.99(0.95)}^2 > K - L$, where K and L are the number of IVs and endogenous variables.

Table B.4: Explanatory Power of Focal SOE IVs on the First-stage Residual of MP Shock

	Australia	Canada	Korea	U.K.
IV1	3.47^{***}	7.66^{***}	5.78^{***}	4.71^{***}
	[0.14]	[0.23]	[0.19]	[0.11]
2	1.90 [*]	5.39^{***}	3.59^{***}	5.85^{***}
	[0.05]	[0.13]	[0.08]	[0.17]
3	1.44	6.88^{***}	-2.25^{**}	4.56^{***}
	[0.03]	[0.20]	[0.03]	[0.11]
4	0.60	1.73 [*]	-	1.42
	[0.00]	[0.02]		[0.01]
5	-1.59	-10.70^{***}	-	-7.38^{***}
	[0.03]	[0.37]		[0.24]
6	-0.26	-	1.13	-
	[0.00]		[0.01]	
7	-0.12	-2.69^{***}	-	-0.62
	[0.00]	[0.04]		[0.00]
8	0.40	1.94 [*]	-1.47	1.86 [*]
	[0.00]	[0.02]	[0.01]	[0.02]
9	-	-1.53	-0.76	0.18
		[0.01]	[0.00]	[0.00]
10	4.12^{***}	7.66^{***}	5.71^{***}	-4.71^{***}
	[0.18]	[0.23]	[0.18]	[0.11]
11	2.09^{**}	2.50^{**}	2.73^{***}	0.21
	[0.06]	[0.03]	[0.05]	[0.00]
IV combinations	[IV1,5, 10,11] (<i>F</i> -value 7.4)	[IV 1,2,11] (<i>F</i> -value 34.6)	[IV1,8,10,11] (<i>F</i> -value 14.3)	[IV1,2,3,5] (<i>F</i> -value 23.7)

Notes: 1) *t*-values and R^2 (parentheses) of each IV in the first-stage regression of the VAR residual of MP and each IV.
2) ‘-’ indicates that selected IV is not available for a given sample period.
3) Bold parts are significant at the 95% confidence level.

Table B.5: Over-identification Test Results for Selected IVs

Residuals	Australia	Canada	Korea	UK
Y	6.70	9.68	9.70	2.19
P	4.83	7.95	5.77	5.40
$R3m$	1.49	4.41	4.13	8.77
$R3y$	3.83	11.66	6.99	5.90
$R10y$	3.37	10.89	7.98	3.86
$LEND$	2.71	1.05	14.33	0.13
FX	5.62	15.75	25.13	6.83
K	9	8	9	9
L	1	1	1	1
$\chi_{0.99(0.95)}^2 > K - L$	15.5	14.1	15.5	15.5

Note: Reject H_0 at 1% (5%) significance level if $\chi_{0.99(0.95)}^2 > K - L$, where K and L are the number of IVs and endogenous variables.