Interactions of Monetary and Macroprudential Policies in a Model of Korean Economy

Very Preliminary and Incomplete

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Abstract

We use a microfounded dynamic stochastic general equilibrium (DSGE) model with banks to study interactions between monetary and macroprudential policies in a small open economy. The model is calibrated/estimated for Korea. Cooperation of monetary and macroprudential policies is optimal under a financial shock. Prolonged periods of monetary accommodation lead to inflationary pressures, lower the effectiveness of macroprudential instrument (loan-to-value ratio) and contribute to further credit growth, increasing vulnerabilities.

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1. Introduction

"We are all macroprudentialists now", but we still know relatively little about the effectiveness of macroprudential policy and its particular instruments as well as how macroprudential policies work together with standard macro stabilization policies, in particular, monetary policy. One of the reasons for limited knowledge in this area is limited country experience with these tools. Korea is a notable exception.

Korea is one of the few countries that have been at the forefront of macroprudential policy (MaPP) implementation, even before the global crisis put macroprudential tools at the center stage of macrofinancial policy discussions. The approach so far has been surgical, focusing on specific problems as they emerged, especially since the global crisis, and at times subjugated by secondary objectives. Although these policies succeeded in addressing the targeted vulnerabilities, their success should not distract from the task of addressing the underlying fragilities that give rise to these vulnerabilities. This would require adapting Korea's macrofinancial framework to address these challenges, while recognizing the role of MaPP as giving a helping hand to appropriately calibrated macroeconomic policies.

Korea's use of macroprudential tools began in 2002 to address the fast increase in housing prices through loan-to-value ratios (LTV). Since then Korean authorities made extensive use of these tools along with other measures that included debt-to-income (DTI) limits since 2005, and ranged from supply side measures, to tax incentives/disincentives and direct support to the construction sector, to address perceived excesses in the housing market.[2] This combination of policies appears to have succeeded in containing house price booms and busts. Nonetheless, the growth of mortgages continues at a healthy clip, despite the reinstatement (Figure 1a). Furthermore, household debt in Korea is quite high (Figure 1b) and remains exposed to interest rate and rollover risks given the still high share of floating rate and bullet structure of mortgage loans.

[insert Figure 1]

Since the Global Recession the Korean government has introduced a multitude of additional measures geared towards addressing the key concerns that came to the fore at the height of the crisis. These measures were closely linked to the volatility of capital flows that

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[2] See Lim et al. (2011).

Korea faced starting with a sudden stop at the height of the Great Recession, and the fast pace of inflows in 2009 following the rapid recovery in Korea. Currently, Korean banks rely on foreign funds less than before the crisis, but banks' liabilities still remain sizeable (Figures 2a and 2b) making the banking sector potentially vulnerable to negative external shocks (downside scenarios in Europe, fiscal cliff in the US, and slowdown in China etc.).

[insert Figure 2]

Finally, the case of Korea motivates to look at coordination of monetary and macroprudential policies and their potential substitutability. As Figure 3 illustrates, the real interest rates were negative in Korea in the period September 2008 – January 2012, reflecting an accommodative monetary policy stance. At the same time, Korean government tightened LTVs, e.g. in July 2009 - for banks - and in October 2009 - for non-bank financial institutions (see Igan and Kang 2011 for more details). The question is which consequences a combination of relatively lax monetary and tight macroprudential policy has for price and financial stability of the economy.

[insert Figure 3]

We use a dynamic stochastic general equilibrium (DSGE) model accounting for the outlined financial vulnerabilities relevant for Korea and estimate it to study policy interactions and tradeoffs between monetary and macroprudential policies in a small open economy.

Literature on modeling macroprudential policy is currently growing very fast. In the context of a closed economy, Gertler and Kiyotaki (2010) and Gerali et al. (2009) models account explicitly for bank balance sheet variables and therefore constitute a suitable framework for macroprudential policy analysis. Angelini et al. (2011) study interactions between monetary and macroprudential policies (capital requirements as well as loan-to-value ratios) using the closed economy setup of Gerali et al. (2009). In the open economy context, Unsal (2012) studies capital inflow measures and its interactions in a model with demand-sided financial friction in a spirit of Bernanke et al. (1999). Funke and Paetz (2012) study the effects of nonlinear loan-to-value policies in Hong Kong in a DSGE-model with collateral constraints a lá Iacoviello (2005). In many of the open economy studies, however, the banking sector is either absent or it is modeled in a rudimentary way. We analyze monetary and macroprudential policies in a model with banks.

As a first step, we build on the setup outlined in Brzoza-Brzezina and Makarski (2011). This small open economy model contains housing sector and collateral constraints a lá Iacoviello (2005) as well as banking sector of Gerali et al. (2010), whereas banks are allowed to borrow from abroad and are subject to external balance sheet shocks. Furthermore, the model incorporates a standard set of nominal and real rigidities (Christiano et al 2005, Smets and Wouters 2007), which are important to fit the data. Importantly, this setup allows for distinct roles for monetary and macroprudential policies (see Angelini et al. 2011). The model is estimated for Korea with Bayesian techniques (An and Schorfheide 2010)[3].

The rest of the paper is organized as follows. Section 2 outlines the model; section 3 discusses calibrated parameters and the results of Bayesian estimation. Section 4 deals with policy exercises under a financial (bank balance sheet) shock, whereas section 5 outlines robustness exercises. Section 5 concludes and discusses direction for future work.

2. The Model[4]

2.1. Households and entrepreneurs

The economy is populated by impatient households, patient households and entrepreneurs. The discount factor of patient households is higher than the discount factor of impatient households and entrepreneurs (for simplicity impatient households and entrepreneurs have the same discount factor). This assumption implies the simultaneous existence of borrowers and lenders in equilibrium.

2.1.1. Patient Households

The patient household chooses consumption, stock of housing and deposits. Labor supply decision is delegated to the labor union. The expected lifetime utility of a patient households is given by:

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[3] As a next step (currently in progress), we extend the analysis by incorporating capital inflow levy (actually implemented in Korea since 2010) as an additional macroprudential measure applying on banks' balance sheets directly.

[4] The model below is a version of Brzoza-Brzezina and Makarski (2011).

$$E_0\sum_{t=0}^{\infty}\beta_p^t\varepsilon_{u,t}\left[\frac{(c_t^p(i)-\xi c_{t-1}^p)^{1-\sigma_c}}{1-\sigma_c}+\varepsilon_{\chi,t}\frac{\chi_t^p(i)^{1-\sigma_\chi}}{1-\sigma_\chi}-\varepsilon_{n,t}\frac{n_t^p(i)^{1+\sigma_n}}{1+\sigma_n}\right], \text{ where}$$

ξ stands for the degree of external habit formation and $\varepsilon_{u,t}$, $\varepsilon_{\chi,t}$, $\varepsilon_{n,t}$ are intertemporal, housing and preference shocks respectively. Preference shocks are modeled as AR(1) processes. The patient household faces the following budget constraint:

$$P_t c_t^P(i)+P_{\chi,t}(\chi_t^P(i)-(1-\delta_\chi)\chi_{t-1}^P(i))+D_t^H(i)\le W_t n_t^p(i)+(1+r_{t-1}^d)D_{t-1}^H(i)-T(i)+\Pi_t^p$$

To finance consumption, housing expenditure and new deposits patient household uses his labor income $W_t n_t^p(i)$, interest earned on deposits $(1+r_{t-1}^d)D_{t-1}^H(i)$ and dividends less lump sum taxes $\Pi_t^p-T(i)$.

In real terms the budget constraint can be written as:

$$c_t^P(i)+q_t^h(\chi_t^P(i)-(1-\delta_\chi)\chi_{t-1}^P(i))+d_t(i)\le w_t n_t^p(i)+(1+r_{t-1}^d)d_{t-1}(i)/\pi_t-T(i)/P_t+\Pi_t^p/P_t$$

with $q_t^h=\dfrac{P_{\chi,t}}{P_t}$ being real housing price, $w_t=\dfrac{W_t}{P_t}$ being the real wage, $d_t(i)=\dfrac{D_t^H(i)}{P_t}$ the real deposit.

Euler equation is standard and reads as:

$$U'(c_t^P(i))=\beta^P E_t\left[\frac{U'(c_{t+1}^P(i))(1+r_t^d(i))}{\pi_{t+1}}\right].$$

From the Euler equation we see that consumption and saving decisions of patient households depend on the deposit rate that is set as a mark-up over monetary policy rate (see Section 2.2. below).

2.1.2. Impatient Households

An impatient household chooses consumption, the stock of housing and loans when maximizing its lifetime utility:

$$E_0\sum_{t=0}^{\infty}\beta_i^t\varepsilon_{u,t}\left[\frac{(c_t^i(i)-\xi c_{t-1}^i)^{1-\sigma_c}}{1-\sigma_c}+\varepsilon_{\chi,t}\frac{\chi_t^i(i)^{1-\sigma_\chi}}{1-\sigma_\chi}-\varepsilon_{n,t}\frac{n_t^i(i)^{1+\sigma_n}}{1+\sigma_n}\right].$$

Impatient households face the following budget constraint:

$$P_t c_t^i(i) + P_{\chi,t}(\chi_t^i(i) - (1-\delta_\chi)\chi_{t-1}^i(i)) + (1+r_t^{bH})L_{t-1}^H(i) \le W_t n_t^i(i) + L_t^J(i) - T(i)\ .$$

In real terms the constraint reads:

$$c_t^i(i) + q_t^h(\chi_t^i(i) - (1-\delta_\chi)\chi_{t-1}^i(i)) + (1+r_t^{bH})b_{t-1}^I(i)/\pi_t \le w_t n_t^i(i) + b_t^I(i) - T(i)/P_t$$

Borrowing constraint is given by:

$(1+r_t^{bH})L_t^H(i) \le m_t^H E_t(P_{\chi,t+1}(1-\delta_\chi)\chi_t^i(i))$, where

m_t^H is loan-to-value ratio and is evolving according to the MaPP rule (see below).

Borrowing constraint in real terms (λ_t is the Lagrange multiplier on this constraint):

$(1+r_t^{bH})b_t(i) \le m_t^H E_t(q_{t+1}^h \pi_{t+1}(1-\delta_\chi)\chi_t^i(i))$, where *b(i)* is real loan to impatient household.

Euler equation for impatient household is:

$$U'(c_t^I(i)) = \beta^I E_t\left[\frac{U'(c_{t+1}^I(i))(1+r_t^{bH}(i))}{\pi_{t+1}}\right] + \lambda_t(1+r_t^{bH})$$

The consumption and saving decision of impatient household depends not just on the lending rate (and therefore the monetary policy stance); macroprudential policy influences this decision separately via the borrowing limit constraint. Lowering the LTV ratio tightens the borrowing limit for given monetary policy stance.

2.1.3. Entrepreneurs

Entrepreneurs draw their utility from consumption only, therefore their expected lifetime utility can be written as:

$$E_0 \sum_{t=0}^{\infty} \beta_E^t \left[\varepsilon_{u,t}\, \frac{(c_t^E(i) - \xi c_{t-1}^E)^{1-\sigma_c}}{1-\sigma_c}\right].$$

Entrepreneurs produce homogenous intermediate goods according to the production technology:

$y_{W,t}(i) = A_t\left[u_t(i)k_{t-1}(i)\right]^{\alpha} n_t(i)^{1-\alpha}$, where

A_t is an exogenous total factor productivity (modeled with an AR(1) process), u_t is capital utilization rate, k_t is capital stock and n_t is labor input. Following standard assumptions in the literature (see Christiano et al. (2005)), we impose capital adjustment costs $\psi(u_t)k_{t-1}$ with $\psi(1)=0$, $\psi'(1)>0$ and $\psi''(1)>0$. In order to finance their expenditure on consumption, labor services, capital accumulation, capital adjustment costs, repayment of debt, and lump sum taxes entrepreneurs use their revenues and new loans, which is reflected in the following budget constraint:

$$P_t c_t^E(i) + W_t n_t(i) + P_{k,t}(k_t(i) - (1-\delta_k)k_{t-1}(i)) + P_t\psi(u_t(i))k_{t-1}(i) +$$
$$+(1+r_{t-1}^{bE})L_{t-1}^F(i) \le P_{W,t}y_{W,t}(i) + L_t^F(i) - T_t(i)$$

or in real terms:

$$c_t^E(i) + w_t n_t(i) + q_{k,t}(k_t(i) - (1-\delta_k)k_{t-1}(i)) + \psi(u_t(i))k_{t-1}(i) +$$
$$+(1+r_{t-1}^{bE})b_{t-1}^E(i) \le \frac{P_{W,t}}{P_t}y_{W,t}(i) + b_t^E(i) - T_t(i)/P_t$$

Similar to impatient households, entrepreneurs face a borrowing constraint:

$$(1+r_t^{bE})L_t^F(i) \le m_t^F E_t(P_{k,t+1}(1-\delta_k)k_t(i)),$$

where m_t^F is entrepreneurs' loan-to-value ratio and is specifies as a MaPP policy rule (see below).

Borrowing constraint in real terms:

$$(1+r_t^{bE})b_t^E(i) \le m_t^F E_t(q_{k,t+1}\pi_{t+1}(1-\delta_k)k_t(i))$$

The model calibration is designed such that borrowing constraint of the entrepreneurs and impatient households will bind in steady state. Following the argument of Iacoviello (2005), we will assume that under uncertainty the shocks will be small enough and both constraints will still be binding in the small neighborhood around the steady state.

2.1.4. Labor Supply and Wages

We assume that each household has a continuum of labor types of measure one and for each type there exists a labor union that sets the wages. Both types of households (patient and impatient) belong to the labor unions. Labor services are sold to perfectly competitive aggregators who pool all the labor types into undifferentiated labor service as follows:

$$n_t = \left((\gamma^I + \gamma^P) \int_0^1 n_t(h)^{\frac{1}{1+\mu_W}} dh \right)^{1+\mu_W}, \text{ where}$$

γ^I and γ^P denote the share of impatient and patient households in the population respectively.

This yields a standard condition for the labor demand of type *h*:

$$n_t(h) = \frac{1}{\gamma^I + \gamma^P} \left[\frac{W_t(h)}{W_t} \right]^{\frac{-(1+\mu_W)}{\mu_W}} n_t \text{ with } W_t = \left(\int_0^1 W_t(h)^{\frac{-1}{\mu_W}} dh \right)^{-\mu_W}.$$

The unions discount factor is the weighted average of the discount factors of patient and impatient households. The union sets the wage according to the Calvo scheme: with probability $(1-\theta_W)$ it receives a signal to reoptimize and sets the wage by maximizing the utility of its average member subject to the demand for its labor services. With probability θ_W it sets the wage according to:

$$W_{t+1}(h) = ((1-\zeta_W)\overline{\pi} + \zeta_W \pi_{t-1}) W_t(h), \text{ where}$$

$\overline{\pi}$ is steady state inflation and $\zeta_W \in [0,1]$.

2.2. Financial sector

As in Gerali et al. 2009, banking activity is divided into several steps. Saving banks purchase deposit accounts in the interbank market, brand them and sell to a financial saving intermediary, which then sells them as undifferentiated product to households. Lending banks take undifferentiated loans in the interbank markets (both domestic and international), brand them and sell to financial lending intermediary, which aggregates it into a single loan and offers it to households or firms.

2.2.1. Financial Intermediaries

Financial intermediaries operate under perfect competition and act as Dixit-Stiglitz aggregators. The optimization problems of financial intermediaries give rise to standard demand for banks' products (deposits and loans to households and entrepreneurs):

$$D_t^H(i) = \left(\frac{R_{D,t}^H(i)}{R_{D,t}^H} \right)^{\frac{1+\mu_{HD}}{\mu_{HD}}} D_t^H$$

$$L_t^H(i) = \left(\frac{R_{L,t}^H(i)}{R_{L,t}^H} \right)^{\frac{-(1+\mu_{HL})}{\mu_{HL}}} L_t^H$$

$$L_t^E(i) = \left(\frac{R_{L,t}^E(i)}{R_{L,t}^E} \right)^{\frac{-(1+\mu_{EL})}{\mu_{EL}}} L_t^E$$ [5]

2.2.2. Saving Banks

Saving Banks collect deposits from saving intermediaries and deposit them in the interbank market. Following Brzoza-Brzezina and Makarski (2011), we assume that for each unit of deposits collected the bank can deposit $z_{D,t}^H$ units on the interbank market ($z_{D,t}^H$ follows an AR(1) process with mean one):

$$D_{IB,t}^H(i) = z_{D,t}^H D_t^H(i)$$

Savings banks operate under monopolistic competition and set interest rates according to a standard Calvo scheme. Once the banks receive a signal to reoptimize the interest rate (which occurs with probability $(1-\theta_D)$), they maximize:

$$E_t \sum_{j=0}^{\infty} \theta_D^j \beta_p^{j+1} \Lambda_{t,t+j+1}^p \left(R_{t+j} D_{IB,t+j}^H(i) - X_{D,t}^H(i) D_{t+j}^H(i) \right)$$

subject to deposit demand and the condition on the interbank market above. X denotes the optimal interest rate chosen by the bank.

2.2.3. Lending Banks

Here we describe lending to households, as lending to entrepreneurs is symmetric. Lending banks takes loans in the domestic interbank market at the policy rate and in the foreign interbank market at the foreign interest rate subject to the risk premium:

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[5] Notation here: $R_{D,t}^H = 1 + r_t^d$ and so on.

$$\rho_t = \exp\left(-\varphi \frac{e_t L_t^*}{P_t \tilde{y}_t}\right)\varepsilon_t ,$$

where e is nominal exchange rate and L* stands for foreign borrowing. Again, as in Brzoza-Brzezina and Makarski (2011), we introduce time-varying spreads by assuming:

$$L_t^H(i) = z_{L,t}^H (L_{IB,t}^H(i) + e_t L_{IB,t}^{H,*}(i)) .$$

Lending banks operate under monopolistic competition and set their interest rates according to Calvo scheme. With probability $(1-\theta_L)$ they receive a signal to reoptimize the interest rate. The banks maximize profits

$$E_t \sum_{j=0}^{\infty} \theta_L^j \beta_p^{j+1} \Lambda_{t,t+j+1}^p \left(X_{L,t}(i) L_{t+j}^H(i) - R_{t+j} L_{IB,t+j}^H(i) - e_{t+j+1} R_{t+j}^* \rho_{t+j} L_{IB,t+j}^{H,*}(i) \right)$$

subject to loan demand and the condition on the interbank market above.

The optimization of wholesale branch gives rise to the standard UIP condition.

2.3. Producers

The model has the following production sectors in the economy: capital goods sector, housing goods sector and consumption goods sector. The first two operate under perfect competition. In the consumption goods sector we have the entrepreneurs (see above), which sell their undifferentiated goods to retailers. Retailers differentiate the goods and sell them to domestic and foreign aggregators. Aggregators combine differentiated domestic intermediate goods and differentiated foreign intermediate goods into a single final good.

2.3.1. Capital Goods Producers

Each period capital goods producer buys $i_{k,t}$ of final consumption goods and old undepreciated capital from entrepreneurs. Next capital goods producer transforms it into new capital. The technology to produce new capital is given by:

$$k_t = (1-\delta)k_{t-1} + \left(1 - S_k\left(\frac{i_{k,t}}{i_{k,t-1}}\right)\right) i_{k,t} .$$

The setup is adopted from Christiano et al. (2005). Capital adjustment costs satisfy: $S_k(1) = S_k'(1) = 0$ and $S_k''(1) > 0$.

2.3.2. Housing Producers

Housing producers operate similarly to capital goods producers. The stock of housing follows:

$$\chi_t = (1-\delta_\chi)\chi_{t-1} + \left(1 - S_\chi\left(\frac{i_{\chi,t}}{i_{\chi,t-1}}\right)\right) i_{\chi,t}\,,$$

where the adjustment cost function also satisfies: $S_\chi(1) = S_\chi{}'(1) = 0$ and $S_\chi{}''(1) > 0$.

2.3.3. Final Good Producers

Final good producers buy differentiated goods from domestic retailers $y_{H,t}(j_H)$ and importing retailers $y_{F,t}(j_F)$ to aggregate them into a single final good and sell on a perfectly competitive market. Final good is aggregated according to:

$$y_t = \left[\eta^{\frac{\mu}{1+\mu}} y_{H,t}{}^{1+\mu} + (1-\eta)^{\frac{\mu}{1+\mu}} y_{F,t}{}^{1+\mu}\right]^{1+\mu}, \text{ where}$$

$$y_{H,t} = \left[\int_0^1 y_{H,t}(j_H)^{\frac{1}{1+\mu_H}} dj_H\right]^{1+\mu_H}$$

$$y_{F,t} = \left[\int_0^1 y_{F,t}(j_F)^{\frac{1}{1+\mu_F}} dj_F\right]^{1+\mu_F}.$$

The problem of the CES-aggregator gives rise to standard demand functions for differentiated goods:

$$y_{H,t}(j_H) = \left(\frac{P_{H,t}(j_H)}{P_{H,t}}\right)^{\frac{-(1+\mu_H)}{\mu_H}} y_{H,t} \text{ and } y_{F,t}(j_F) = \left(\frac{P_{F,t}(j_F)}{P_{F,t}}\right)^{\frac{-(1+\mu_F)}{\mu_F}} y_{F,t} \text{ with}$$

$$y_{F,t} = (1-\eta)\left(\frac{P_{F,t}}{P_t}\right)^{\frac{-(1+\mu)}{\mu}} y_t \text{ and } y_{H,t} = \eta\left(\frac{P_{H,t}}{P_t}\right)^{\frac{-(1+\mu)}{\mu}} y_t, \text{ where}$$

η is the home bias parameter. Price aggregates are given by:

$$P_{H,t} = \left[\int P_{H,t}(j_H)^{\frac{-1}{\mu_H}} dj_h\right]^{-\mu_H} \text{ and } P_{F,t} = \left[\int P_{F,t}(j_F)^{\frac{-1}{\mu_F}} dj_F\right]^{-\mu_F}$$

2.3.4. Retailers

There are three groups of retailers: domestic, importing and exporting retailers, which are all subject to nominal rigidities a lá Calvo.

Domestic retailers purchase undifferentiated intermediate goods from entrepreneurs, transform them into differentiated goods and sell them to aggregators. Each period with probability $(1-\theta_H)$ they receive a signal to reoptimize and then set the price to maximize expected profits. Alternatively they index the price according to:

$$P_{H,t+1}(j_h) = ((1-\zeta_H)\overline{\pi} + \zeta_H \pi_{t-1}) P_{H,t}(j_H) \text{ with } \zeta_H \in [0,1].$$

Importing retailers are symmetric to domestic retailers. We assume prices are sticky in domestic currency, i.e. pass-through is incomplete. Prices are reoptimized with probability $(1-\theta_F)$ and indexed otherwise according to:

$$P_{F,t+1}(j_h) = ((1-\zeta_F)\overline{\pi} + \zeta_F \pi_{t-1}) P_{F,t}(j_F)$$

Exporting retailers purchase domestic undifferentiated goods to sell them abroad at price $P^*_{H,t}(j^*_H)$, which is expressed in foreign currency. Prices are sticky in the foreign currency too. The demand for exported goods is given by:

$$y^*_{H,t}(j^*_H) = \left(\frac{P^*_{H,t}(j^*_H)}{P^*_{H,t}}\right)^{\frac{-(1+\mu_{H^*})}{\mu_{H^*}}} y^*_{H,t},$$

where $y^*_H(j^*_H)$ is the output of the retailer and the following definitions apply:

$$y^*_{H,t} = \left[\int_0^1 y^*_{H,t}(j^*_H)^{\frac{1}{1+\mu^*_H}} dj^*_H\right]^{1+\mu^*_H} \quad \text{and} \quad P^*_{H,t} = \left[\int P^*_{H,t}(j^*_H)^{\frac{-1}{\mu^*_H}} dj^*_h\right]^{-\mu^*_H}.$$

We assume that the demand abroad is given by:

$$y^*_{H,t} = (1-\eta^*)\left(\frac{P^*_{H,t}}{P^*_t}\right)^{\frac{-(1+\mu^*_H)}{\mu^*_H}} y^*_t.$$

We further assume that foreign demand, the interest rate and inflation follow exogenous AR(1) processes allowing for contemporaneous correlation between shocks. With probability θ^*_H exporting retailers cannot reoptimize their price and follow the pricing rule:

$$P^{*}_{H,t+1}(j^{*}_{h}) = ((1-\zeta^{*}_{H})\overline{\pi}^{*} + \zeta^{*}_{H}\pi_{t-1})P^{*}_{H,t}(j^{*}_{H})$$

2.4. Monetary Policy

We assume a Taylor rule of the form:

$$R_t = \left(\frac{R_{t-1}}{\overline{\overline{R}}}\right)^{\gamma_R} \left(\left(\frac{\pi_t}{\overline{\overline{\pi}}}\right)^{\gamma_\pi} \left(\frac{\tilde{y}_t}{\overline{\overline{\tilde{y}}}}\right)^{\gamma_y}\right)^{1-\gamma_R} e^{\varphi_t},$$

where monetary policy systematically reacts to deviations of inflation and output from its equilibrium levels.

2.5. Macroprudential Policy

Macroprudential policy is represented by a countercyclical rule for LTV ratios on household loans:

$$\hat{m}^{H}_{t} = \rho_{mH}\hat{m}^{H}_{t-1} - \rho_2\hat{x}_t + \varepsilon^{m^H}_{t}$$, where

variables with hats denote deviations from steady state and x is the variable, to which macroprudential policy is systematically reacting. In the case of Korea it would be realistic to assume x to be growth of housing prices (Igan and Kang 2011). We will, however, also examine other alternatives, such as output growth (following Angelini et al. 2011) and household credit growth.

LTV ratios of firms are evolving according to an AR(1) process in our baseline simulations:

$$\hat{m}^{F}_{t} = \rho_{mH}\hat{m}^{F}_{t-1} + \varepsilon^{m^F}_{t}.$$

2.6. Fiscal Policy

The government uses lump sum taxes to finance its expenditures. Fiscal policy is Ricardian, governments budget constraint is given by:

$$G_t = T_t,$$

Where we assume that government expenditure follows an AR(1) process.

2.7. Market Clearing, Balance of Payments, GDP

In the final goods market we have:

$$c_t + i_{k,t} + i_{\chi,t} + g_t + \psi(u_t)k_{t-1} = y_t \text{, where}$$

$$c_t = \gamma^I c_t^I + \gamma^P c_t^P + \gamma^E c_t^E$$

Market clearing in the intermediate homogenous goods market is:

$$\int_0^1 y_{H,t}(j)dj + \int_0^1 y^*{}_{H,t}(j)dj = y_{W,t}$$

Clearing condition for the housing market is given by:

$$\gamma^P \chi_t^P + \gamma^I \chi_t^I = \chi_{t-1}$$

Balance of payments (expressed in home currency) has the form:

$$\int_0^1 P_{F,t}(j_F)y_{F,t}(j_F)dj_F + e_t R_{t-1}^* \rho_{t-1} L_{t-1}^* =$$

$$= \int_0^1 e_t P^*{}_{H,t}(j^*{}_H)y^*{}_{H,t}(j^*{}_H)dj^*{}_H + e_t L_t^*$$

GDP is defined by:

$$P_t \tilde{y}_t = P_t y_t + \int_0^1 e_t P_{H,t}^*(j_H^*)y_{H,t}^*(j_H^*)dj_H^* - \int_0^1 P_{F,t}(j_F)y_{F,t}(j_F)dj_F$$

With $\tilde{y}_y$ denoting GDP.

3. Calibration and Estimation

Most calibrated values are set in line with the literature or based on the long-run averages from Korean and U.S. data (see Table 1). Share of the constrained households is set to 0.4, which is consistent with Leif (2009), who set the share for Korea to 0.39 in “normal times” and to 0.5 in a “crisis scenario”. LTV ratios in steady state correspond to historical averages for Korea (Igan and Kang (2011)), home bias (share of home goods in final goods) parameter calibration is in line with Gertler et al. (2007).

Parameter	Value (Steady State)	Parameter	Value (Steady State)
New Household Loans to GDP (flow)	0.05	Housing Investment to GDP	0.05
New Firm Loans to GDP (flow)	0.04	Exports to GDP	0.32
Labor Income Share in GDP	0.66	Import to GDP	0.30
Domestic Money Market Rate	1.04^0.25	Share of Entrepreneurs in the Economy	0.25
Domestic Rate on Household Loans	1.07^0.25	Share of Impatient Households in the Economy	0.4
Domestic Rate on Firm Loans	1.08^0.25	Share of Patient Households in the Economy	0.35
LTV Households	0.5	Foreign Inflation Target	1.02^0.25
LTV Firms	0.2	Home Bias	0.6
Domestic Inflation Target	1.03^0.25	Foreign Money Market Rate	1.035^0.25
Absorption to GDP	0.98	External Debt to GDP	0.35
Consumption to GDP	0.6	Investment to GDP	0.15

Table 1. Calibrated Model Parameters and Steady State Ratios.

Note: interest rates are reported on quarterly basis.

Bayesian Estimation

The model is estimated using twelve macroeconomic quarterly time series for the period 1999/Q1 to 2008/Q4. Time series covering the Korean economy are: real GDP, real government expenditure, real consumption, the real exchange rate, consumer price inflation, the money market interest rate, spreads between the money market rate and the household deposit rate, household loan rate and corporation loan rate. The data sources are Bank of Korea and OECD. For the foreign economy we use the following U.S. variables extracted from the FRED database: real GDP, consumer price index and effective Federal Funds rate. All variables are seasonally adjusted. National account variables are taken in logs. We transform the data into a form suitable for computing the likelihood function. We apply standard HP filtering procedure to detrend all time series. Following Adolfson et al. (2008), we estimate a structural foreign VAR separately and then keep these estimated values fixed during Bayesian estimation[6]. The VAR has the form:

$$F_0 X_t = F(L) X_{t-1} + \varepsilon_t \text{, where } \varepsilon_t \sim N(0, \Sigma_x)$$

The identification scheme follows Adolfson et al. (2008), i.e.:

$$F_0 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -\gamma_1 & -\gamma_2 & 1 \end{bmatrix}$$

We choose not to exclude foreign variables as observables in Bayesian estimation as these data series might be useful to identify some of the parameters governing cross-country linkages[7].

Priors are chosen in accordance with existing literature (see Smets and Wouters (2007), Adolsfson et al. (2007, 2008)), all values are listed in Table 2. Dogmatic priors are imposed on parameters, which are weakly identified from the data. These values are in line with the estimated for small open economies (e.g. Brzoza-Brzezina and Makarski (2011)). In particular, intertemporal elasticity of substitution for housing is set to 4 and for consumption to 2. Adjustment cost parameters for capital and housing are also set to values typically reported in the literature (Christiano et al. 2005). The rest of parameters are estimated with Bayesian techniques (estimates relating to the shock processes are given in the Appendix).

[6] Foreign VAR has lag order 2 (chosen according to the Schwartz criterion).

[7] The model incorporates 10 structural shocks, 9 of them follow AR(1) processes, whereas monetary policy shock is assumed to be iid. To avoid stochastic singularity, we introduce two measurement errors: for GDP and real exchange rate series. We apply 4 Metropolis Hastings chains with one million draws in each of them discarding the first 30% of them as burn-in. Mode is computed with csminwel1 routine. Average acceptance rate is between 25% and 30%. Brooks and Gelman (1998) diagnostics indicate good convergence of chains. All diagnostics as well as plots of posterior distributions are available upon request.

Parameter	Prior			Posterior	
	Type	Mean	St. Dev.	Mode	Mean
σ_n	norm	4.00	0.50	3.85	3.87
θ_W	beta	0.50	0.10	0.53	0.53
θ_H	beta	0.50	0.10	0.33	0.34
θ_F	beta	0.50	0.10	0.53	0.51
θ_D	beta	0.50	0.10	0.66	0.66
θ_L	beta	0.50	0.10	0.55	0.57
θ_H^*	beta	0.50	0.10	0.48	0.49
ζ_W	beta	0.50	0.10	0.45	0.46
ζ_H	beta	0.50	0.10	0.45	0.45
ζ_F	beta	0.50	0.10	0.44	0.45
ζ_H^*	beta	0.50	0.10	0.52	0.51
ϕ_R	beta	0.70	0.10	0.93	0.92
ϕ_π	norm	1.50	0.10	1.48	1.48
ϕ_y	norm	0.50	0.05	0.51	0.50

Table 2. Prior and Posterior Distributions: Structural Parameters.

4. Policy Analysis Under a Financial Shock

The financial shock in this model $z_{L,t}^{H}$ applies to the balance sheet of the bank:

$$L_t^H(i) = z_{L,t}^H (L_{IB,t}^H(i) + e_t L_{IB,t}^{H,*}(i))$$

An expansionary financial shock implies a decrease in the spread for household loans (Figure 4). As borrowing costs of households decline, they increase their borrowing in absolute (l_h) and relative terms as a ratio to GDP (l_h_y). Consumption goes up, which eventually leads to a rise in GDP and inflation (pi). Real exchange rate (q) appreciates as capital is flowing into the home country.[8] This shock represents the vulnerability of Korean banks to exogenous shocks (such as a global liquidity shock): for an exogenous reason (not related to domestic monetary policy) balance sheets of the banks grow or shrink affecting borrowing costs in the home economy.

[insert Figure 4]

Noteworthy, expansionary financial shock in this model moves inflation, output as well as household loan-to-GDP ratio in the same direction, calling for tightening of both monetary and macroprudential policies. In the next section we study, what the optimal policy response to this shock should be: should one or both (monetary and macroprudential) policies respond, are there gains from cooperation between monetary and macroprudential authorities.

Optimal Simple Rules

In this section we examine optimal simple rules in response to financial shock. We start by looking at the scenario, where macroprudential policy is passive (LTV ratio is kept at its steady state level) and only monetary policy reacts to the shock. Monetary authority minimizes the objective function:

$$L^{MP} = Var(\hat{\pi}) + 0.5Var(\hat{y}) + 0.1Var(\Delta\hat{i})$$ [9]

subject to the constraints of the economy and the policy rule of the form:

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + \rho_\pi \hat{\pi} + \rho_y (\hat{y}_t - \hat{y}_{t-4}) + \rho_4 \hat{x}_t ,$$

where i is the annualized quarterly policy rate, π is the year-on-year inflation and y is quarterly output. We also study augmented Taylor rules, where the additional variable x stands for household credit growth, housing inflation or exchange rate. The results are presented in Table 3.

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[8] On Figure 4, GDP falls on impact slightly because net exports decline due to real exchange rate appreciation. Therefore the inflation also starts slightly below zero. These negative impact effects can be eliminated by introducing modified UIP condition as in Adolfson et al. (2008). The policy results (in particular, the ranking of policies) are not affected by the presence (absence) of modified UIP.

[9] The weights in the objective function are consistent with Angelini et al. (2011).

Rule	ρ_i	ρ_π	ρ_y	ρ_{lH}	$\rho_{\pi X}$	ρ_e	Loss	Loss increase to best (%)
standard	1,17	1,93	0,60	-	-	-	0,6313	0,01
Augmented rules								
HH credit growth	1,19	1,49	0,45	0,01	-	-	0,6340	0,42
housing inflation	1,13	1,41	0,50	-	0,21	-	0,6312	best
exchange rate	1,21	1,50	0,56	-	-	0,05	0,6334	0,33

Table 3. Optimal Simple Rules under Active Monetary and Passive MaPP Policies[10].

As we can see from Table 3, the 4-parameter rule reacting too housing inflation performs best, yielding the smallest loss. However, the improvement relative to the standard Taylor rule (which is second best) is only marginal. This result is similar to the one obtained by Iacoviello (2005) in a closed economy context. Credit growth rule performs slightly worse than the housing inflation rule, and it is also costly to react to nominal exchange rate. These results indicate that (apart from the housing rule) monetary policy has to somewhat sacrifice its standard objectives (output and inflation stabilization) when it aims at stabilizing nominal exchange rate or in addition reacts to financial indicator (credit growth). However, these loss increases appear rather small.

Second policy scenario assumes inactive monetary policy (nominal interest rate is kept at the steady state level) and active macroprudential policy as represented by the following countercyclical LTV rule:

$$\hat{m}^H_t = \rho_{mH}\hat{m}^H_{t-1} - \rho_2 \Delta\hat{b}_t ,$$

[10] As the objective function of the model is flat, we first did an extensive grid search over the parameter space and then applied the Matlab routine fmincon to find the optimal rule coefficients. In cases, where gradient-based methods were particularly inefficient, we also applied Nelder-Mead type algorithms (such as fminsearch).

where $\Delta\hat{b}_t$ is household credit growth. The macroprudential authority minimizes the following loss function:

$$L^{MaPP} = Var(\hat{b}_t - \hat{y}_t) + 0.1Var(\Delta\hat{m}_t^H)$$

subject to the above macroprudential rule and the constraints of the economy.

There is no consensus in the literature regarding the loss function of the macroprudential authority. We follow Angelini et al. (2011) and Kannan, Rabanal and Scott (2009) by assuming that macroprudential authority minimizes the variation in household loans-to-GDP ratio. Furthermore, we assume macroprudential authority minimizes the variation in changes of its instrument, as large changes of LTV ratios may be very costly in reality. It is debated whether the objective function of macroprudential authority should include real variables (output growth or unemployment). In contrast to Angelini et al. (2011), we do not include output stabilization term into the objective function, leaving this task to monetary policy exclusively. Optimization results are presented in Table 4.

Rule	ρ_{mH}	ρ_{lH}	**Loss**
HH credit growth	0.99	-9.99	83,94

Table 4. Optimal Simple Rules under Active Monetary and Passive MaPP Policy.

Noteworthy, in the absence of monetary policy stabilization, macroprudential policy is very persistent and aggressive. The reason is that now only macroprudential instrument alone has to ensure determinacy and stabilize the economy after the shock.[11] We also studied macroprudential rules reacting to GDP growth (as e.g. Angelini et al. 2012) and housing inflation. They, however, implied an even more aggressive response (and even higher loss) or led to indeterminacy. Clearly, macroprudential policy is too narrow to effectively substitute monetary policy in this scenario. Therefore large (and probably very distortive in reality) policy interventions on the macroprudential side are required in this case.

[11] In the abscence of monetary policy macroprudential policy turns procyclical for all rules we examined. Only procyclical macroprudential policy can ensure stable and unique equilibrium in this case.

So far, we assumed that each policy acted separately, taking into account that the other policy would stay inactive. This is an extreme non-cooperative scenario. As a next step we consider a non-cooperative scenario, where each authority will still take the action of the other as given, but both policies will be active. In particular, it implies that monetary authority maximizes its objective function and chooses the parameters of the standard Taylor rule (ρ_i, ρ_π and ρ_y) taking the parameters of the macroprudential authority (ρ_{mH} and ρ_{lH}) as given and vice versa for macroprudential authority[12]. The results are presented in Table 5.

Scenario	ρ_i	ρ_π	ρ_y	ρ_{mH}	ρ_{lH}	**Joint Loss**
Non-cooperative, taking the other as given, but active	0,52	1,55	0,05	0,99	9,99	**0,05 (MP) + 6,98 (MaPP) = <u>7,03</u>**

Table 5. Optimal Simle Rules Under Active Non-Cooperation.

Under this scenario, monetary policy reacts much less aggressively than under passive macroprudential policy (see first line of Table 3).This is, however, “compensated” by a very aggressive countercyclical macroprudential policy. The associated loss consisting of the sum of the two respective objective functions is displayed in the last column of Table 5.

Finally, we turn to the cooperative scenario, in which both monetary and macroprudential policies are active and are minimizing joint loss function:

$$L^{coop} = Var(\hat{\pi}_t) + 0.5Var(\hat{y}_t) + 0.1Var(\Delta\hat{i}_t) + Var(\hat{b}_t - \hat{y}_t) + 0.1Var(\Delta\hat{m}_t^H)$$

subject to policy rules:

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + \rho_\pi \hat{\pi} + \rho_y (\hat{y}_t - \hat{y}_{t-4})$$

$$\hat{m}^H_t = \rho_{mH} \hat{m}^H_{t-1} - \rho_{lH} \Delta\hat{b}_t .$$

As shown in Table 6 (first row), under cooperation, macroprudential policy is no longer that aggressive as it was in the previous non-cooperative scenarios. Remarkably, this leads to the best outcomes in terms of losses. Under non-cooperative scenario (row 2 in Table 6), the balance

[12] Technically, this scenario is implemented as iterative optimization between the two authorities. Starting values are set at standard Taylor rule with smoothing of 0.5 for monetary authority and as a countercyclical rule with smoothing 0.7 and $\rho_{lH} = 1.5$ for macroprudential authority. The convergence criterion is set for optimal parameter values.

between monetary and macroprudential policies is suboptimal: whereas both policies try to counteract the shock in a countercyclical manner, macroprudential policy does too much, while monetary policy – too little. Under passive non-cooperation (row 3 in Table 6) the losses are very big due to the fact that macroprudential policy is too narrow to completely substitute monetary policy. Hence, there are substantial gains from cooperative actions of monetary and macroprudential policies. This result is intuitive: as all objectives move into the same direction and call for tightening of both policies under expansionary financial shock, it is optimal for the policies to react simultaneously and less aggressively (which also leads to lower costs). This optimal balance is achieved in a cooperative scenario.

Active MaPP and MP Under Different Cooperation Scenarios

Scenario	ρ_i	ρ_π	ρ_y	ρ_{mH}	ρ_{lH}	**Joint Loss**
Cooperative, both active	0,45	0,64	0,10	0,98	4,19	**<u>5,15</u>**
Non-cooperative, taking the other as given and active	0,52	1,55	0,05	0,99	9,99	**0,05 (MP) + 6,98 (MaPP) = <u>7,03</u>**
Non-cooperative, taking the other as given and inactive	1,17	1,93	0,60	0,99	-9,99	**0,63 (MP) + 83,94 (MaPP) = <u>84,57</u>**

Table 6. Optimal Simple Rules under Cooperation and No-Cooperation Scenarios.

Deterministic Simulations

In our previous (stochastic) simulations in one of the non-cooperative scenarios we had to assume that one of the policies stayed inactive *forever*. However, it is not a realistic assumption. In reality (e.g. around 2009 in Korea), monetary policy was accommodative *for a few quarters*, whereas macroprudential policy (LTV policy) was tightened. We now turn to simulations of such a scenario. In particular, we assume:

$$\hat{i}_t = \begin{cases} 0 & 1-6 \quad quarter \\ \hat{i}_t = \rho_i \hat{i}_{t-1} + \rho_\pi \hat{\pi} + \rho_y (\hat{y}_t - \hat{y}_{t-4}) & afterwards \end{cases}$$

Under this scenario monetary policy is accommodative (interest rate set at steady state level) in the first 6 quarters, and then monetary policy operates according to the Taylor rule. Technically, this scenario implies a non-linearity in the monetary policy rule, therefore we use deterministic algorithm of Fair and Taylor (1983) and simulate the model under anticipated shock. Macroprudential policy is active throughout the simulation. The coefficients in both policy rules are set according to the cooperative scenario. The Figures 5-6 below plot key variables under two scenarios. The first scenario (labeled "6Q") is accommodative on the monetary side as described above, whereas under the alternative scenario (labeled "active MP") both policies are active and set according to respective policy rules.

[insert Figure 5]

The main implication form the absence of active monetary policy in the first quarters of simulation is the surge in inflation. Output expands by more under accommodation scenario too. Surge in inflation has further implications for financial stability and macroprudential policy effectiveness. Figure 6 shows the dynamics of household and firm loans as well as macroprudential policy response (LTV ratio on household loans).

[insert Figure 6]

As loan contracts are set in nominal terms, the debt-deflation mechanism embedded in the collateral constraint is at work here. Under accommodative scenario, impatient households will be able to borrow more due to surge in inflation. Therefore macroprudential policy has to react stronger under this scenario: LTV ratio for households has to be lowered by more. Furthermore, as household LTV is applied only locally, it does not affect the costs of borrowing for the firms, which due to the debt-deflation argument are able to borrow more. Monetary accommodation therefore creates a credit boom in other sectors of the economy, which are not covered by the narrow macroprudential policy measures. This example illustrates that macroprudential policy should not be regarded as a substitute for monetary policy. Prolonged monetary accommodation under this scenario appears costly and suboptimal in terms of both price and financial stability.

5. Robustness (to be completed)

The robustness of the analysis has to be done along the following dimensions. First of all, the objective function for both authorities is ad hoc. Therefore it is necessary to use alternative weighting schemes and (if feasible) to perform Ramsey policy analysis. In the latter case, it would be of interest to consider welfare approximations of utility functions of heterogeneous agents (both types of consumers as well as entrepreneurs) and to aggregate them as in Bilbiie et al. (2012).

Second, the role of the share of impatient agents should be studied. In the previous simulations we set this parameter to 0.4. However, empirical estimates of this parameter usually differ substantially across studies or have large uncertainty bands; moreover, the share of liquidity constrained households is likely to change across time: in particular, it is expected to increase in crisis times.

Third, optimal policies to other shocks should be investigated. Of particular interest are shocks leading to the goal conflict between macroprudential and monetary authorities (e.g. technology shock). Such cases could give rise to the "push-me-pull-you" game between the authorities.

Finally, worth investigating are scenarios where monetary policy sets interest rate to minimize the joint objective, whereas macroprudential policy is passive. We are currently performing all these robustness exercises.

5. Summary and Further Work

We estimated model for Korean economy with distinct roles for monetary and macroprudential policy and studied optimal policy responses in the face of an expansionary financial shock, that improves the wholesale financing conditions of the banks and therefore lowers the spreads of the household loans. Our results show that cooperation between monetary and macroprudential policies are optimal in this case. Monetary accommodation in periods of macroprudential tightening leads to inflationary pressures, lowers MaPP effectiveness and contributes to potentially higher vulnerabilities in other sectors of the economy. Under financial shock, monetary and macroprudential policies should work hand in hand and should not be regarded as substitutes.

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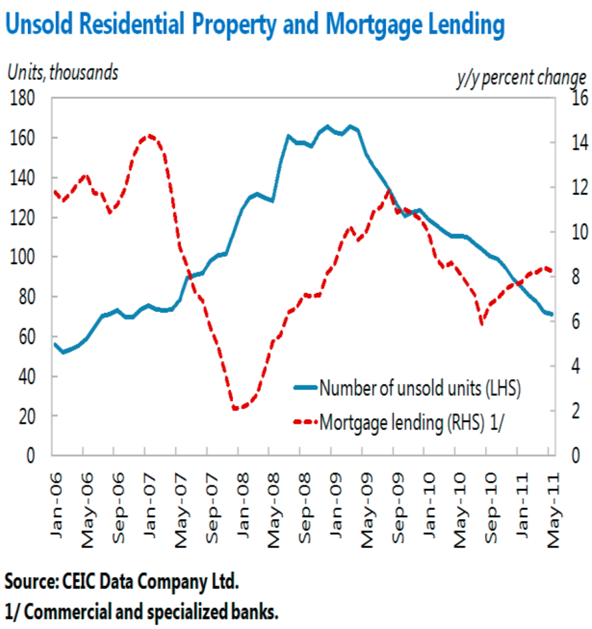
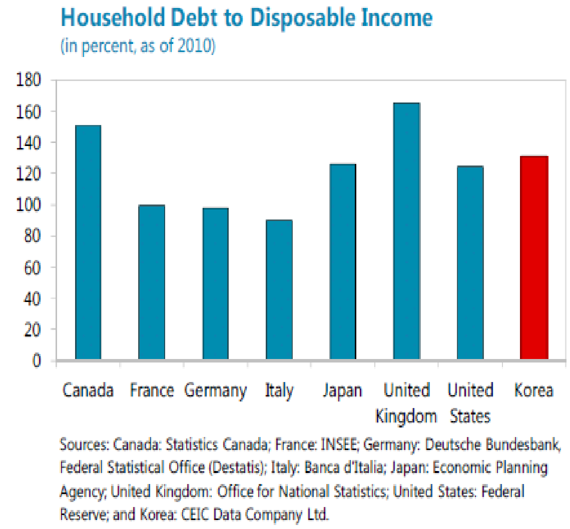
Figures

Figure 1





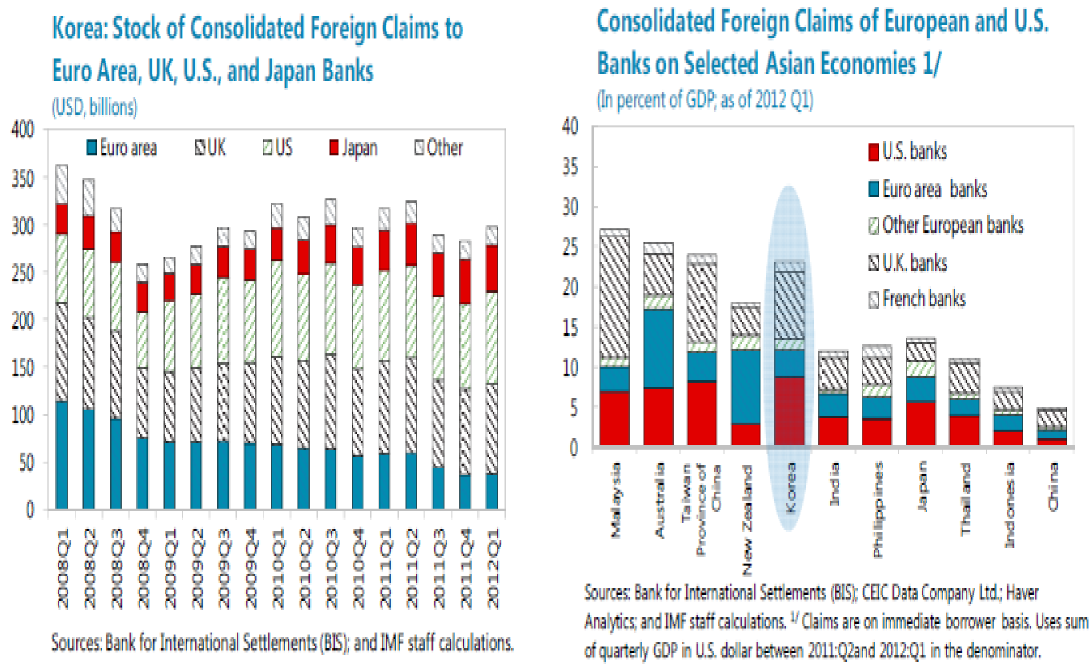
Figures 1a (left panel) and 1b (right panel).

1a: Unsold Residential Property and Mortgage Lending in Korea.

1b: Household Debt to Disposable Income.

Source: IMF Article IV on Korea (2012).

Figure 2



Figures 2a (left panel) and 2b (right panel).

2a: Stock of Consolidated Foreign Claims of Korean Banks to Foreign Banks.

2b: Consolidated Foreign Claims of European and U.S. Banks on Selected Asian Economies.

Source: IMF Article IV on Korea (2012).

Figure 3

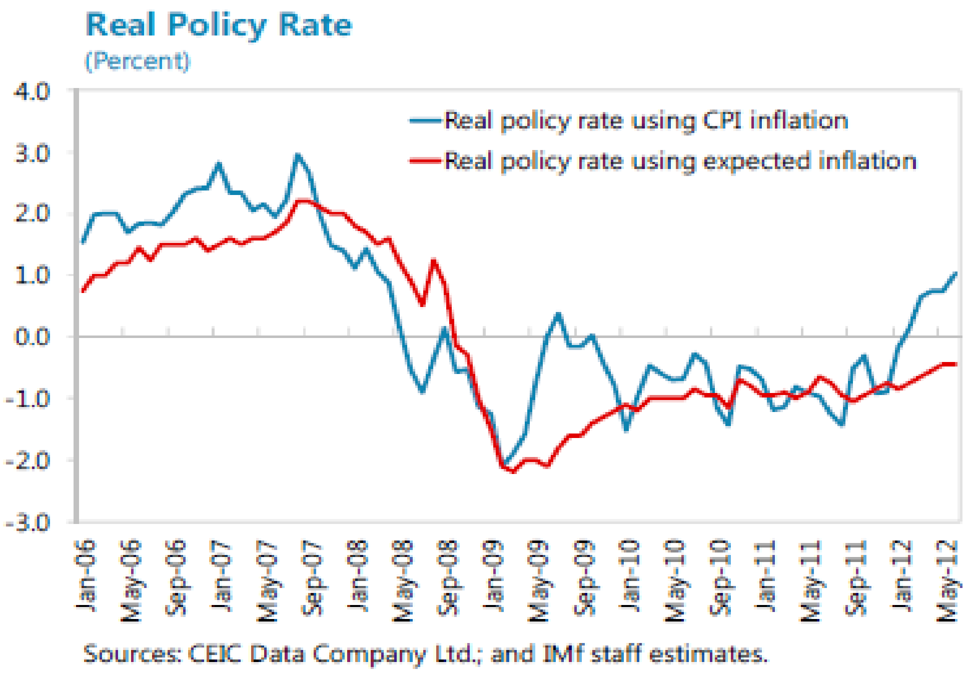


Figure 3. Real Policy Rate in Korea: January 2006 – May 2012.

Source: IMF Article IV on Korea (2012).

Figure 4

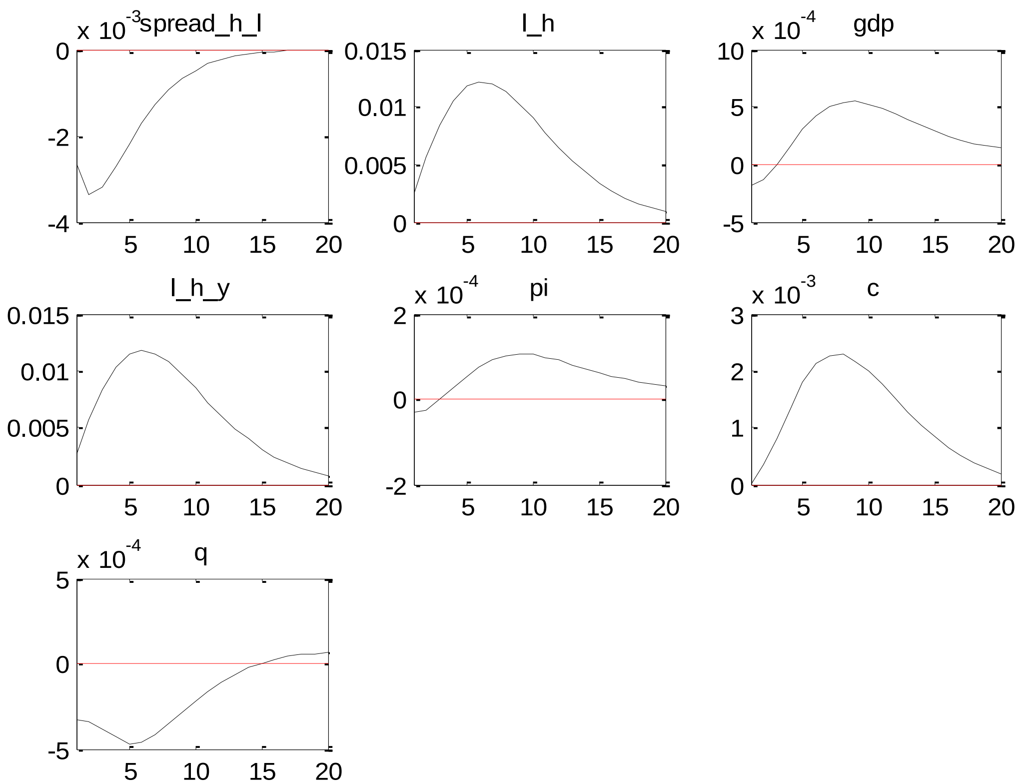


Figure 4. Effects of an Expansionary Financial Shock (decrease in spreads on household loans)

Figures 5 and 6

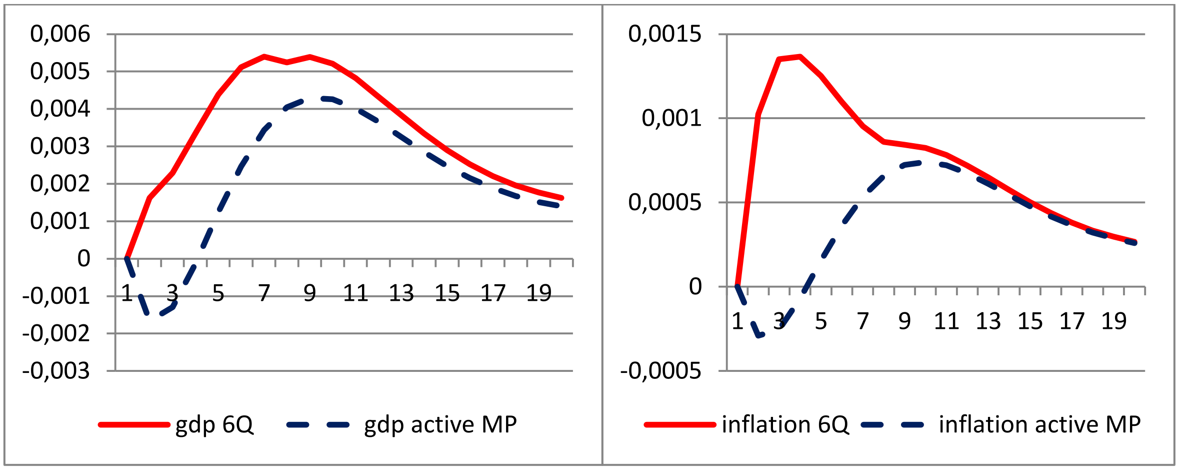


Figure 5. Inflation and GDP under Deterministic Scenarios.

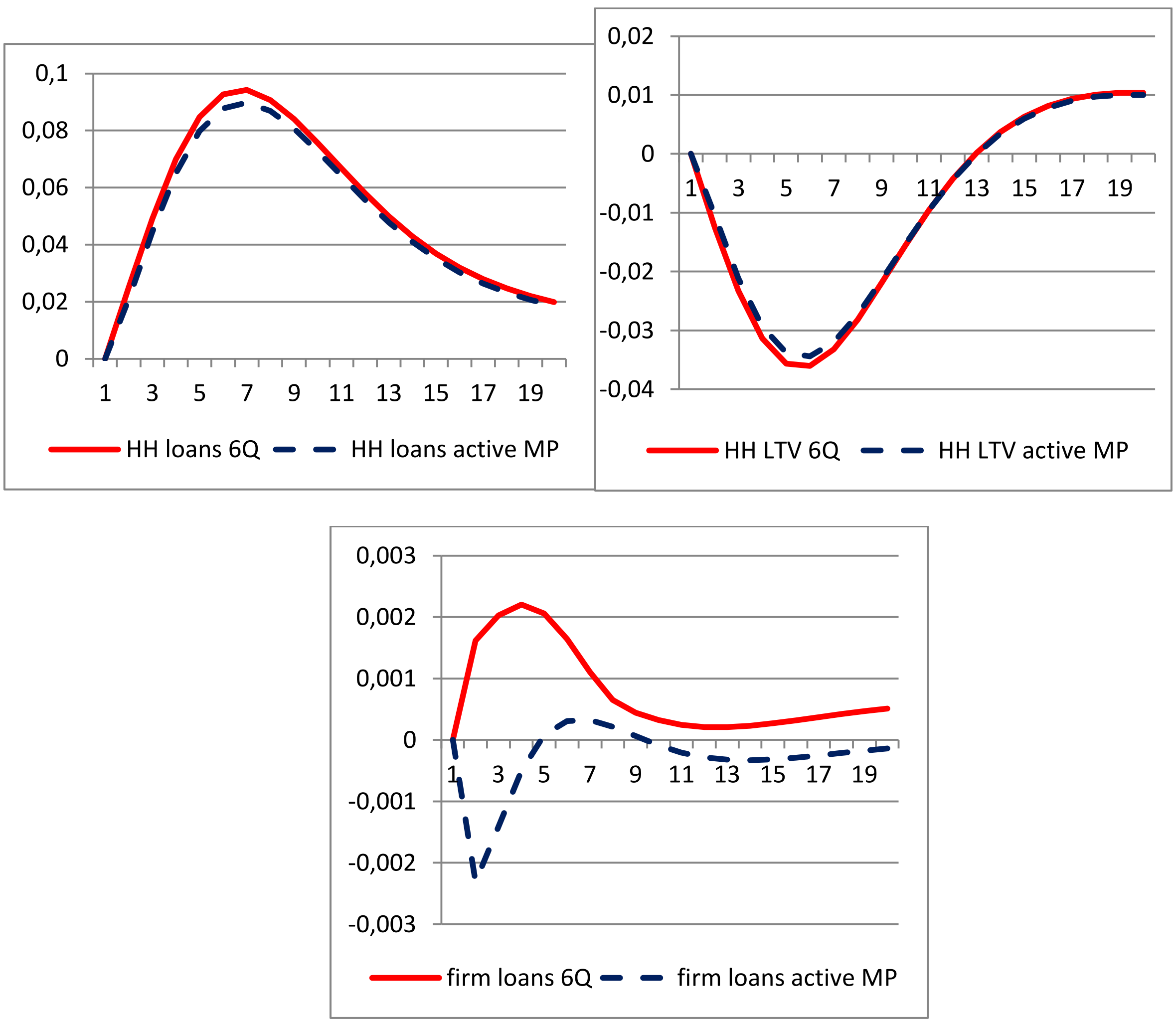


Figure 6. Household Loans, LTV on Household Loans, and Firm Loans Under Deterministic Scenarios.

Appendix: Prior and Posterior Distributions: Shocks

Parameter	**Prior**			**Posterior**	
	Type	Mean	St. Dev.	Mode	Mean
ρ_c	beta	0.70	0.10	0.61	0.66
ρ_A	beta	0.70	0.10	0.51	0.51
ρ_ρ	beta	0.70	0.10	0.48	0.47
ρ_g	beta	0.70	0.10	0.59	0.59
ρ_{m^h}	beta	0.70	0.05	0.70	0.70
ρ_{m^f}	beta	0.70	0.05	0.71	0.70
$\rho_{z_d^h}$	beta	0.70	0.10	0.64	0.63
$\rho_{z_l^h}$	beta	0.70	0.10	0.50	0.50
$\rho_{z_l^f}$	beta	0.70	0.10	0.49	0.49
σ_c	invg	0.05	Inf	0.075	0.049
σ_A	invg	0.05	Inf	0.014	0.014
σ_ρ	invg	0.05	Inf	0.011	0.012
σ_R	invg	0.01	Inf	0.001	0.002
σ_g	invg	0.01	Inf	0.012	0.012
σ_{m^h}	invg	0.10	Inf	0.042	0.064
σ_{m^f}	invg	0.10	Inf	0.047	0.308

$\sigma_{z_d^h}$	invg	0.01	Inf	0.004	0.004
$\sigma_{z_l^h}$	invg	0.01	Inf	0.003	0.003
$\sigma_{z_l^f}$	invg	0.01	Inf	0.005	0.006
$\sigma_{q^{obs}}$	invg	0.01	Inf	0.074	0.077
$\sigma_{gdp}{}^{obs}$	invg	0.01	Inf	0.004	0.004