Estimation and Evaluation of Monetary Policy in Korea Before and After the Global Financial Crisis

Jeonghun Choi
Department of Economics
Seoul National University

Abstract

This study estimates a simple small open dynamic stochastic general equilibrium model through the Bayesian approach using Korean data. It mainly analyzes the monetary policy conducted by the central bank of Korea in relation to the 2008–2009 global financial crisis. Specifically, it aims to answer three questions. (1) Is there any change in the Korean monetary policy before and after the global financial crisis? (2) If so, what is the difference between them? (3) What are the subsequent change in the role and effect of the monetary policy alteration? To answer these questions, we first implement a rolling estimation, which enables us to control the influence of the crisis and to find the time-varying characteristics of the Korean economy. Based on the results from the first stage, we re-estimate the model by dividing the whole sample period into two sub-periods, namely, pre-crisis and post-crisis. According to our estimation results, exchange rate movements become an additional interest in deciding the policy rate of Korea after the peak of the crisis. In addition, the behavior of the Korean monetary authority becomes relatively more aggressive. When models including the data of the peak of the crisis are estimated, model fits become worse and the posterior estimates are distorted. Finally, we conduct simulations to gauge the altered role and effect of the change. As measures of performance, volatilities of inflation, output, and exchange rate of the simulated series obtained by stochastic simulation show that the central bank of Korea can achieve more stabilized inflation and exchange rates under the post-crisis policy rule. Our results are robust for various specifications of the monetary policy rule, alternative prior distribution, and data that can be used as proxies for the exchange rate and inflation of Korea.

Keywords: Korean monetary policy, global financial crisis, exchange rate, small open economy DSGE model, Bayesian estimation

1 Introduction

This study examines the actual behavior of a central bank associated with the recent global financial crisis. As a case study, it aims to answer three questions. (1) Is there any change in the Korean monetary policy before and after the global financial crisis? (2) If so, what is the difference between them? (3) What are the subsequent change in the role and effect of the monetary policy alteration?

We use the Korean data to address how the central bank of Korea, the Bank of Korea (BOK) has implemented its interest rate policy after it adopted inflation targeting. Methodologically, we estimate a simple dynamic stochastic general equilibrium (DSGE) model for small open economies developed by Lubik and Schorfheide (2007) using the Bayesian approach proposed by Schorfheide (2000). Finally, we perform simulations to assess the role and the performance of the estimated policy behavior.

In fact, the issue of the actual behavior of a central bank has been discussed for various countries using the same methodology as described above.[1] An important interest in their analyses is whether or not a central bank considers the exchange rate when adjusting its policy instrument because exchange rate plays a crucial role in small open economies that are susceptible to foreign environments. However, there has been relatively less attention paid to East Asian countries.[2] One contribution of this paper is that it fills this void by investigating the manner in which the monetary policy has been conducted by the central bank of Korea, one of the East Asian countries.

The other important difference between this research and the earlier studies is that we consider the effect of the recent crisis on the monetary policy. In the middle of 2008, abnormal fluctuations were observed in the important macro variables of the Korean economy, such as inflation, output growth, nominal interest rate, and terms of trade. They were mainly due to almost purely exogenous effects associated with the recent crisis rather than economic agents' rational behaviors assumed in most DSGE models. In this respect, estimating DSGE models with data that include observations near the crisis may cause serious bias in their accuracy.

According to our estimation results, calculated log marginal data densities obtained from a five-year rolling window show that the model fits of the data significantly decline as a window starts to include the observation of 2008-Q3 and then worsen with the data of 2008-Q4. However, from the window starting from 2009-Q1, the corresponding log marginal data densities largely increase until the end of the windows.[3] Therefore, we decided to exclude these crisis-related data based on the

[1] See Lubik and Schorfheide (2007) for Australia, Canada, New Zealand, and the United Kingdom; Del Negro and Schorfheide (2008) for Chile; Adolfson et al. (2008) for Sweden; Teo (2009) for Taiwan; Caraiani (2011) for Romania; Caraiani (2013) for Czech Republic, Hungary and Poland;Garcia and Gonzalez (2013) for Australia, Chile, Columbia, New Zealand and Peru; and Zheng and Guo (2013) for China

[2] Although Eichengreen (2004), Shin (2007) and Kwark and Kim (2016) estimated the monetary policy of Korea, they used a single equation approach proposed by Clarida et al. (1998). On the other hand, Bae (2013) estimated a small open economy DSGE model to analyse the transmission of monetary policy in relation to financial frictions and argued that the Korean monetary policy did not systemically react to the variation of the exchange rate.

[3] Marginal data density is a Bayesian statistic implying the extent to which the model is explained by the data.

marginal data densities and divide the whole sample period into two sub-periods, namely, pre-crisis and post-crisis.

Results from separately estimating different models for two subperiods show that there is a clear difference in the Korean monetary policy. The criteria for model comparison, such as posterior odds and Kass and Raftery (1995) ratio against the model with the simple Taylor rule, show that the model with the augmented Taylor rule, including the response to exchange rate depreciation, is strongly more supported by the data in post-crisis than the baseline model. This finding implies that the exchange rate becomes an additional consideration in deciding the policy instrument in post-crisis, which is robust for various kinds of specifications of the monetary policy rule.

In addition, the estimated posterior densities of the monetary policy parameters in the pre-crisis and post-crisis periods indicate that the behavior of the BOK becomes more aggressive after the peak of the crisis. In particular, the estimated response of the policy rate to the CPI inflation is much larger in comparison to that of pre-crisis. This result is also robust for alternative data and with more loose prior densities of the policy parameters. It is worthwhile mentioning that to some extent, this finding is consistent with the official statement of the BOK about its reaction to the crisis.

Finally, we perform various simulations of the model to evaluate the change in the Korean monetary policy. Specifically, we compute impulse response functions and implement stochastic simulation depending on the estimated policy rules in the pre- and post-crisis periods. In doing so, the parameters except for those in the policy reaction function are fixed as the estimated posterior mean for the data of post-crisis to represent.

More importantly, the calculated standard deviations of the simulated data for important macro variables show that the performance of the monetary policy is better in terms of inflation and exchange rate changes under the dominant policy rule in the post-crisis period than in the pre-crisis period. However, the standrad deviation of output growth is worse under the former. Moreover, the additional attention to the exchange rate in post-crisis does not lead to a more fluctuating inflation. The standard deviation of CPI inflation under the augmented Taylor rule in the post-crisis period with a positive response to exchange rate is smaller than the same rule with zero response. Therefore, we assess that the BOK has been reacted to the recent crisis in a desirable way in that its policy behavior can be effective in stabilizing exchange rate in the face of increased foreign uncertainties caused by the crisis without aggravating the domestic inflation.

This paper is organized as follows. Sections 2 and 3 briefly review the small open DSGE model and the Bayesian approach, respectively. In Section 4, the data and choice of priors are described. Section 5 documents the estimation results, and Section 6 discusses the simulation results. Section 7 concludes.

2 Simple Small Open Economy Model

This section briefly describes the key equations of the model, which was originally developed Gali and Monacelli (2005) in the context of the New Keynesian DSGE framework for a small open economy. Lubik and Schorfheide (2007) simplified the model to estimate the monetary policies of Australia, Canada, New Zealand, and the United Kingdom; since then, the model has been widely used in analyzing monetary policies in other countries.[4] Detailed derivations are described in the appendix of Del Negro and Schorfheide (2008).

In the fully structured model (Gali and Monacelli, 2005), the terms of trade (Q_t), defined as the relative price of imported goods in terms of exported goods, is an endogenous variable. However, according to Lubik and Schorfheide (2007), the condition of international goods market clearing, by which Q_t is determined, is an excessively tight restriction for estimation. For the same reason, the authors simplified the world inflation (π_t^*) as independently determined. Therefore, these two variables, together with world output (Y_t^*) and the growth rate of unit root technology (Z_t), evolve according to the autoregressive process of order one as follows:

$$\triangle\hat{q}_t = \rho_q \triangle\hat{q}_{t-1} + \epsilon_t^q \tag{1}$$

$$\pi_t^* = \rho_{\pi*}\pi_{t-1}^* + \epsilon_t^{\pi*} \tag{2}$$

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \epsilon_t^z \tag{3}$$

$$\hat{y}_t^* = \rho_{y*}\hat{y}_{t-1}^* + \epsilon_t^{y*} \tag{4}$$

where ρ_q, $\rho_{\pi*}$, ,ρ_z and ρ_{y*} are the persistences of four shocks, ϵ_t^q, $\epsilon_t^{\pi*}$ ϵ_t^z and ϵ_t^{y*}. These shocks are independent and follow a normal distribution with zero means and variances, $\sigma^2_{\triangle q}$, $\sigma^2_{\pi*}$, σ^2_z and σ^2_{y*} respectively. $\hat{x}_t$ is a log deviation from the steady state of a certain variable X_t.

The demand side of the model is expressed as the New Keynesian open economy IS curve:

$$\hat{y}_t - \hat{\bar{y}}_t = E_t[\hat{y}_{t+1} - \hat{\bar{y}}_{t+1}] - (\tau + \lambda)(\hat{R}_t - E_t[\pi_{H,t+1} + \hat{z}_{t+1}]) \tag{5}$$

where $\hat{y}_t$ is the domestic output and $\hat{\bar{y}}_t$ is the natural level of output.[5] $\hat{R}_t$ is the nominal interest rate and $\pi_{H,t}$ is the producer price index (PPI) inflation. In addition, $\lambda = \alpha(2-\alpha)(1-\tau)$, and τ and α denote the elasticity of intertemporal substitution and the openness, respectively.[6] In (5), the effects

[4]In a similar vein, Del Negro and Schorfheide (2008), Caraiani (2011), Caraiani (2013) and Zheng and Guo (2013) analyzed the actual behavior of the central banks of Chile, Romnina, CEE (Czech Republic, Hungary and Poland) and China through the same model.

[5]The natural level of output means the output satisfied in the absence of nominal price rigidities.

[6]We assume that $0 < \alpha < 1$ and $0 < \tau < 1$. When $\tau = 1$, the model solution is not determinated.

of foreign economies are captured by $\hat{\bar{y}}_t$, which satisfies

$$\hat{\bar{y}}_t = -\frac{\lambda}{\tau}\hat{y}_t^*. \tag{6}$$

On the supply side, domestic firms' optimal price setting leads to the following New Keynesian Philips curve:

$$\pi_{H,t} = \beta E_t[\pi_{H,t+1}] + \kappa \hat{mc}_t \tag{7}$$

where β is the discount factor, κ is the slope of the Phillips curve ($\kappa > 0$) and $\hat{mc}_t$ is the firms' marginal cost, which satisfies

$$\hat{mc}_t = \frac{1}{\tau+\lambda}(\hat{y}_t - \hat{\bar{y}}_t) \tag{8}$$

When the relative purchasing power parity holds, the nominal exchange rate depreciation can be expressed as

$$\hat{e}_t = \pi_t - \pi_t^* - (1-\alpha)\hat{q}_t. \tag{9}$$

(9)is satisfied through the definition of CPI inflation (π_t):

$$\pi_t = \pi_{H,t} - \alpha\hat{q}_t. \tag{10}$$

Finally, the monetary policy conducted by an open economy central bank is described by the Taylor rule. Under inflation targeting, a central bank determines the nominal interest rate as its policy instrument in response to the CPI inflation, the output gap and the exchange rate depreciation, which is expressed in (11).[7]

$$\hat{r}_t = \rho_r\hat{r}_{t-1} + (1-\rho_r)[\psi_1\pi_t + \psi_2\hat{y}_t + \psi_3\triangle e_t] + \epsilon_t^r \tag{11}$$

where ρ_r is the smoothing parameter, and ψ_1, ψ_2 and ψ_3 are the reactions to the variables of interest.

When $\psi_3 = 0$, (11) becomes the simple Taylor rule. Del Negro and Schorfheide (2008) also considered the reaction to the terms of trade by replacing $\triangle e_t$ with $\triangle\hat{q}_t$ and both of them simultaneously. Table 1 summarizes these four monetary policy rules.

This study aims to analyse whether or not a change occurred in the Korean monetary policy before and after the crisis. To do so, we find the dominant policy rule in the pre- and post-crisis periods among the four candidiates. Although the BOK officially aims to stabilize inflation, as mentioned in Eo (2003) and Shin (2007), it effectively focuses on output or employement stability. In addition, as emphasized in Eichengreen (2004), movements in the exchange rate are cricial for future inflation, evolution of the output gap, finanacial stability and economic development in open economies. Therefore, the four reaction functions above can be considered appropriate rules in analysing the Korean monetary

[7] In (11), the ourput gap is defined as the output deviation from the stochastic trend

Model	Taylor-rule	Specification
(A)	Simple Taylor rule	$R_t = \rho_r R_{t-1} + (1-\rho_r)[\psi_1 \pi_t + \psi_2 \hat{y}_t] + \epsilon_t^r$
(B)	Augmented Taylor rule with $\triangle e_t$	$R_t = \rho_r R_{t-1} + (1-\rho_r)[\psi_1 \pi_t + \psi_2 \hat{y}_t + \psi_3 \triangle e_t] + \epsilon_t^r$
(C)	Augmented Taylor rule with $\triangle q_t$	$R_t = \rho_r R_{t-1} + (1-\rho_r)[\psi_1 \pi_t + \psi_2 \hat{y}_t + \psi_3 \triangle q_t] + \epsilon_t^r$
(D)	Augmented Taylor rule with both $\triangle e_t$ and $\triangle q_t$	$R_t = \rho_r R_{t-1} + (1-\rho_r)[\psi_1 \pi_t + \psi_2 \hat{y}_t + \psi_3 \triangle e_t + \psi_4 \triangle q_t] + \epsilon_t^r$

Table 1: Four Monetary Policy Rules

policy. We secure dominance through a Bayesian statistic that provides a guideline for the model best explained by the data. The details are discussed in the next section.

3 Bayesian Approach

This section briefly describes the Bayesian method proposed by Schorfheide (2000) used in estimating and comparing the four models. The Bayesian technique finds the posterior distributions of all parameters to be estimated in the following three steps. First, we find the posterior modes and the Hessian matrix using standard numerical optimizations. Second, based on these two findings, a joint posterior is evaluated by the product of given priors and likelihood. The Kalman filter is used to compute the log likelihood of the data for the given set of parameters. Finally, the Metropolis-Hastings algorithm generates samples from the posterior distribution. We generated 250,000 samples, and an initial 0.5 fraction of parameter vectors are dropped as a burn-in before running the posterior simulations. We use the software platform Dynare to solve and estimate the model.[8]

In addition, we compare the four models described in Table 1 based on their posterior odds ratios. Suppose that we want to compare two models, model (A) and a particular model (i), with two associated sets of deep parameters Θ_{M_A} and Θ_{M_i}. They are only different from each other in their monetary policy parameters. We denote Y_T as a dataset which consists of data variables and has a sample size of T. The Bayes theorem leads to the posterior densities of Θ_{M_A} and Θ_{M_i} as $P(\Theta_{M_A}|Y_T, M_A)$ and $P(\Theta_{M_i}|Y_T, M_i)$, respectively.

$$P(\Theta_{M_A}|Y_T, M_A) = \frac{P(Y_T|\Theta_{M_A}, M_A) \cdot P(\Theta_{M_A}|M_A)}{P(Y_T|M_A)} \quad \text{and} \quad P(\Theta_{M_i}|Y_T, M_i) = \frac{P(Y_T|\Theta_{M_i}, M_i) \cdot P(\Theta_{M_i}|M_i)}{P(Y_T|M_i)} \tag{12}$$

where $P(Y_T|\Theta_{M_A}, M_A)$ and $P(Y_T|\Theta_{M_i}, M_i)$ are the likelihoods of the data (Y_t) conditional on the sets

[8]We specify the scale parameter of 0.45 to maintain an acceptance rate of25% - 33% and use csminwel as an optimizer for the mode computation.

of parameters in the model (A) and (i). $P(\Theta_{M_A}|M_A)$ and $P(\Theta_{M_i}|M_i)$ are the prior densities of each model, and $P(Y_T|M_A)$ and $P(Y_T|M_i)$ are the marginal data densities conditional on those models computed by

$$P(Y_T|M_A) = \int_{\Theta_{M_A}} P(\Theta_{M_A}|M_A) \cdot P(Y_T|\Theta_{M_A}, M_A) d\Theta_{M_A} \quad \text{and} \quad P(Y_T|M_i) = \int_{\Theta_{M_i}} P(\Theta_{M_i}|M_i) \cdot P(Y_T|\Theta_{M_i}, M_i) d\Theta_{M_i}. \tag{13}$$

Both functions in (13) measure the fit of the corresponding model with the data.

Assuming model (A) as a null, we can compare it with model (i) by calculating the posterior odds ratio, $P(M_A|Y_T)/P(M_i|Y_T)$ which can be expressed as

$$\frac{P(M_A|Y_T)}{P(M_i|Y_T)} = \frac{P(M_A) \cdot P(Y_T|M_A)}{P(M_i) \cdot P(Y_T|M_i)} \tag{14}$$

where $P(M_A)$ and $P(M_2)$ are the prior distributions of models (A) and (i), respectively.

We assume that each model has equal probability as $P(M_A) = P(M_2)$. Therefore, a comparison of the two models' marginal data densities shows that a particular model fits the data more than model (A). In other words, the monetary policy that is better explained by the data is determined.

The marginal data density is computed as a log value, and thus the posterior odds ratio between the model (A) and (i) is calculated as $\exp(P(Y_T|M_A) - P(Y_T|M_i))$. We use the modified harmonic mean suggested by Geweke (1999) as an estimator of the marginal densities of data.

On the other hand, the data set used in our estimation, Y_t, consists of five individual time series similar to those in Del Negro and Schorfheide (2008). A more concrete explanation is given in the next subsection.

4 Data and Prior Distributions

This section concretly describes the data and the prior distributions used in our estimation. In order to avoid the stochastic singularity, the vector of observables Y_t consists of five variables as follows.[9]

$$Y_t = \{4\pi_t,\ \triangle\hat{y}_t + \hat{z}_t,\ 4\hat{r}_t,\ \triangle\hat{e}_t,\ \triangle q_t\} \tag{15}$$

Each component in Y_t corresponds to quartely Korean data starting from 2001 Q1 to 2015 Q4[10]

[9] The model includes five exogenous shocks.

[10] After the 1997 Asian financial crisis, the Korean monetary policy was characterized as inflation targeting, and the free-floating regime was adopted as the exchange rate policy in December 1997. There are two different views as to when the BOK started to implement inflation targeting. One argues 1997 based on Article 1 of the Bank of Korea Act, and the other contends 2001. Although the BOK adopted inflation targeting in January 1998, M3 was still used as one of its policy objectives until 2000 to avoid confusion in the transition of the monetary policy regime. In 2001, M3 was converted to a monitoring indicator. In this study, we follow the latter view.

: CPI inflation ($4\pi_t$), real GDP per capita ($\triangle\hat{y}_t + \hat{z}_t$), nominal interest rate ($4\hat{r}_t$), nominal effective exchange rate depreciation ($\triangle\hat{e}_t$) and terms of trade change ($\triangle q_t$).[11] Most of the data are obtained from Economic Statistical System provided by the BOK. For the estimated Korean population used to calculate the GDP per capita, we acquired its time series from Korean Statistical Information Service. Finally, the nominal effective exchange rate index is taken from the Bank for International Settlements. All data are expressed as percentage change and demeaned before estimation.

There are two more possible candidates for $\triangle e_t$. One is a nominal effective exchange rate index provided by the International Monetary Fund (IMF). The other is simply the bilateral exchange rate between the Korean won and US Dollar. On the other hand, the Core CPI inflation series of Korea can be used as π_t instead of the CPI inflation because the former has its own importance, as price changes in agricultural and oil products can distort the latter.[12] Therefore, we estimate the four models in Table 1 with these alternative data for robustness. The results are described in Appendix C.3

Now, we document how to set the prior distributions for the parameters to be estimated. It is important to ensure underlying rationale for prior distributions because it affects the estimation results in finding the joint posterior distributions. The model has three types of parameters: i) monetary policy parameters, ii) other structural parameters and iii) parameters for exogenous shocks. Table 2 summarizes the choice of priors used in our estimation.

Parameters		**Distribution**	**Mean**	**Std.dev**
Monetary Policy Rule				
Response to inflation	ψ_1	Gamma	1.5	0.5
Response to output	ψ_2	Gamma	0.25	0.13
Response to nominal exchange rate depreciation	ψ_3	Gamma	0.25	0.13
Reponsee to terms of trade changes	ψ_4	Normal	0	0.5
Interest rate smoothing	ρ_r	Beta	0.5	0.2
Other Model Parameters				
Fraction of imported goods	α	Beta	0.3	0.05
Steady state real interest rate	r_{ss}	Gamma	2.5	1.0
Degree of stickiness	κ	Gamma	0.29	0.14
Intertemporal substitution between imported goods	τ	Beta	0.5	0.2
Exogenous shocks				
Persistence of terms-of-trade changes	ρ_q	Beta	0.31	0.13
Persistence of foreign output	ρ_{y*}	Beta	0.93	0.03
Persistence of foreign inflation	$\rho_{\pi*}$	Beta	0.47	0.11
persistence of domestic technology	ρ_z	Beta	0.26	0.12
Terms-of-trade changes shock	σ_q	Beta	1.88	0.99
Foreign output shock	σ_{y*}	Beta	1.88	0.99
Foreign inflation shock	$\sigma_{\pi*}$	Beta	1.88	0.99
Unit root technology shock	σ_z	Beta	1.88	0.99
Monetary policy shock	σ_r	Beta	0.68	0.36

Table 2: Prior distributions

[11]The nominal interest rate and the CPI inflation are expressed as annual rates. Therefore, we multiply 4 by $\hat{r}_t$ and π_t. As $\hat{y}_t$ is a log deiviation from the unit root technology ($\hat{a}_t$) we restore the implicit trend by adding $\hat{z}_t = \hat{a}_t - \hat{a}_{t-1}$ to express the implicit trend in the Korean GDP.

[12]Core CPI inflation is the growth rate of the CPI index excluding the prices of agricultural and oil products which are highly volatile because of their inherent susceptibility.

Priors for the monetary policy parameters are set to be similar to those in Lubik and Schorfheide (2007). The prior mean for ψ_1 is chosen as 1.5, which is also used in studies analyzing the Korean economy using DSGE models, such as Lall and Alp (2012) and Park (2012). However, compared with the standard deviations set in these two papers, a larger standard deviation of 0.5 is imposed for ψ_1.[13] The priors for ψ_2 and ψ_3 are centered at 0.25 with a standard deviation of 0.13. Since discrepancies are found in setting the prior for ψ_2 in studies on the Korean economy, we follow the prior in Lubik and Schorfheide (2007) as a benchmark and consider the disagreement in appendix C.2.[14] In addition, the underlying assumption in setting the priors for ψ_2 and ψ_3 is that inflation is the key factor of the BOK in adjusting the policy rate, and the rest of the variables in (11) are equally important. For ψ_4, the response to the terms of trade change, we set a zero mean with a large standard deviation of 0.5 following the study of Del Negro and Schorfheide (2008), whichy implies that no a priori knowledge exists about the response to the terms of trade change. Finally, the prior mean for the interest rate smoothing parameter, ρ_r is set to follow the benchmark prior in Lubik and Schorfheide (2007): mean of 0.5 and standard deviation of 0.2. Again, we describe the estimation result with a looser prior on ρ_r in appendix C.2.[15]

Among the other model parameters, the openness parameter α is set to 0.3 because the rate of dependence on import to the nominal GDP of Korea from 2001 to 2008 ranges from 25% to 30%.[16]with a standard deviation of 0.05. Similar to Lubik and Schorfheide (2007) and Del Negro and Schorfheide (2008), we estimate the steady state real interest rate, r_{ss}, instead of the discount factor, β, and impose the same prior used in these studies. In other words, the mean is set to 2.5 with a standard deviation of 1.0. The corresponding value of β to the prior mean of 2.5 for r_{ss} is 0.993, which is also reasonable for Korea. We impose the prior mean of κ as 0.29 with a standard deviation of 0.14 based on the estimate of the slope of the Phillips curve for Korea in Piao and Joo (2011).[17] For τ, the intertemporal substitution between imported goods, we set 0.5 as its mean with a standard deviation of 0.2 according to Lubik and Schorfheide (2007) and Del Negro and Schorfheide (2008). These values are reasonable because those used in studies examining the Korean economy in the context of the New Keynesian DSGE model, such as Park (2012) and Kim and Yie (2015), are almost similar (0.47 and 0.53, respectively).

Similar to Lubik and Schorfheide (2007) in which authors implemented pre-sample analysis to

[13]Lall and Alp (2012) estimated a small open DSGE model to assess the BOK's action of allowing exchange rate change freely during the peak of the crisis. Park (2012) estimated the potential GDP and GDP gap of Korea. In both analyses, the prior standard deviation for ψ_1 is set to 0.1 and 0.15.

[14]whereas Lall and Alp (2012) and Bae (2013) impose 0.2 as its mean, Park (2012) and Yoo and Cho (2015) chose 0.5.

[15]In Park (2012), the mean is set to 0.5. However, Lall and Alp (2012) and Bae (2013) assumed a large dependency of the current nominal interest rate of Korea on its lag by choosing 0.7 as its mean.

[16]These values are provided by the Korea International Trade Association. Suh (2011) also used 0.3 in calibrating the openness to study the transmission mechanism of the change in Korean monetary policy.

[17]Authors estimated the New Keynesian Phillips curve after the currency crisis in Korea using data from 2001 Q1 to 2009 Q4.

characterize the specific features of the four countries, we choose the priors for the persistence and the underlying uncertainty of exogenous shocks by fitting an autoregressive of order one using data from 1985-Q1 to 2000-Q4, except that the data of the terms of trade starts in 1988-Q1.[18] We use the output growth rate of Korea, US CPI inflation, and ratio of US GDP to Korean GDP as proxies for z_t, π_t^*, y_t^*, respectively. The obtained estimates are statistically significant as described below. Finally, the priors of the magnitude of the shocks are chosen according to those in Lubik and Schorfheide (2007) and Del Negro and Schorfheide (2008).

$$\triangle q_t = \underset{(0.13)}{0.31^{***}} \triangle q_{t-1} + \epsilon_t^q, \quad z_t = \underset{(0.12)}{0.26^{**}} z_{t-1} + \epsilon_t^z$$

$$\pi_t^* = \underset{(0.11)}{0.47^{***}} \pi_{t-1}^* + \epsilon_t^{\pi *}, \quad y_t^* = \underset{(0.03)}{0.93^{***}} y_{t-1}^* + \epsilon_t^{y*}$$

*** and ** indicate the significance level at 1%, 5% respectively.

5 Estimation of the Korean Monetary Policy

This section reports the estimation results. We estimate and compare the four models described in Table 1 in two steps: (1) rolling estimation and (2) estimation for two sub-periods. As documneted in Section 1, controlling the effect of the global financial crisis is handled in the first step. In addition, it reveals time-varying characteristics of the Korean monetary policy. The second step complements the lack of statistical reliability inherent in the first step for the small number of observations. We implemente the rolling estimation with a fixed size of a window containing 20 samples, and one period of the data is added as increment.

5.1 Models best supported by the data in pre- and post-crisis

Figure 1 illustrates the estimated log data densities obtained from 41 windows. A feature appearing in the figure is that the log data densities significantly decrease regardless of the model when a rolling window starts to include samples of 2008-Q3 (12th window). Thereafter, when the 2009-Q1 data become a starting point of a window, the log data densities almost recover to their original levels and gradually increases until the end. The shaded area represents the windows including the data for 2008-Q3and 2008-Q4, which corresponds to the peak of the crisis.

[18]The data of the terms of trade provided by the BOK is only available from 1998-Q1.

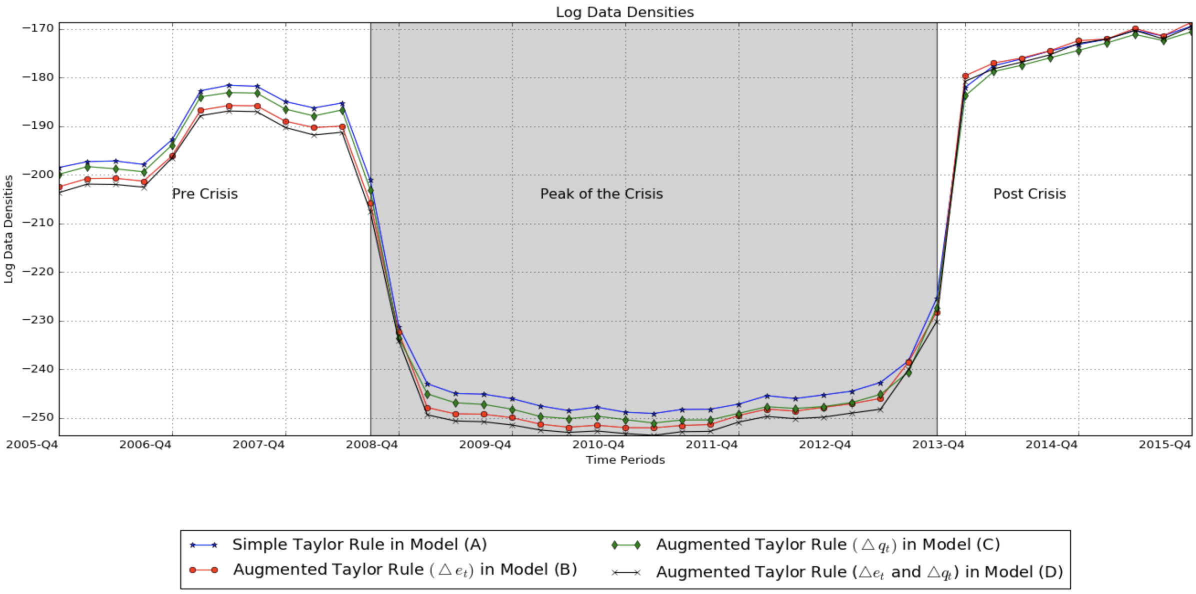

Figure 1: Rolling Estimation Result : Log data densities

This figure provides a basis for excluding the data on the peak of the crisis. Since the size of a window is fixed, the sharp movements in the log data densities are strange in themselves. Further, they are headed to the worse direction. It is implausible that the data of 2008-Q3 and 2008-Q4 are come from agents' optimized behaviors in the rational expectation model. Rather, they are more likely to represent the effect of the sudden crisis, which cannot be captured by the model. In this respect, estimating the model including these two problematic samples can distort the posterior distributions of model parameters. Therefore, we proceed with our analysis controlling the effectof the recent crisis by estimating the model without the two periods and dividing the whole period into two sub-periods: pre-crisis (2001-Q1 - 2008-Q2) and post-crisis (2001-Q1 - 2015-Q4).

More importantly, the other feature in Figure 1 is an apparent change in the Korean monetary policy before and after the recent crisis. Although the log marginal data densities obtained from estimating the model with the simple rule are the largest in the pre-crisis period, they become almost similar and even worse than others in the post-crisis period. The gaps between model (A) and others are evident in the pre-crisis period, but they are small in the post-crisis period.

As mentioned earlier, rolling estimation inherently lacks statistical reliability because one window contains only a small number of samples. In addition, the contained information in a window is slightly different from one another. In this respect, we re-estimated the four models for the two subperiods. The resulting log data densities are described in Table 3. We also document the posterior odds and Kass and Raftery (1995) ratio (KR ratio) against the marginal data density of model (A) for interpretation.[19]

[19]DeJong and Dave (2011) provided guidance for interpreting the posteior odds ratio. If the posterior odds ratio of model B against that of model A ranges from 1 to 3, then it is "very slight evidence", if it ranges from 3 to 10, then it is "slight evidence", if it ranges from 10 to 100, it is "very strong evidence" in favor of model B.; and if it exceeds 100, then it is "decisive evidence" for model B. In addition, the KR ratio is the difference of the log marginal data density of the two models multiplied by 2. If the ratio is above 10, then it can be considered "very strong evidence", if it is between

Pre-crisis (2001Q1-2008Q2)

Number of Obs. : 30	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-271.850**	-277.201	-278.607	-276.192
Posterior odds	**(1.000)**	(0.005)	(0.001)	(0.013)
KR Ratio	**(-)**	(-10.702)	(-13.514)	(-8.684

Post-crisis (2009Q1-2015Q4) : Excluding the peak of the crisis

Number of Obs. : 28	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	-218.357	**-215.144**	-220.194	-216.557
Posterior odds	(1.000)	**(24.854)**	(0.159)	(6.050)
KR Ratio	(-)	**(6.426)**	(-3.674)	(3.600)

Post-crisis (2008Q3-2015Q2) : Including the peak of the crisis

Number of Obs. : 30	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-299.102**	-301.829	-301.428	-303.877
Posterior odds	(**1.000)**	(0.065)	(0.098)	(0.008)
KR Ratio	**(-)**	(-5.454)	(-4.652)	(-9.550

Table 3: Log data densities and Posterior Odds before and after global crisis

As shown in Table 3, the dominant monetary policy rule before the crisis is different from that after the crisis. In the pre-crisis period, model (A), in which the simple reaction function is the decision rule of a central bank, is best explained by the data compared with the other three models because their posterior odds against model (A) are between 0 and 1 and the KR ratios are negative. By contrast, it is strong evidence in the post-crisis that model (B), in which a central bank follows the augemented Taylor rule with additional reaction to exchange rate depreciation, is the dominant monetary policy rule. Its posterior odds ratio and the KR ratios against those of model (A) are more than 10 and 6, respectively. Therefore, the monetary authority of Korea, the BOK, considers the exchange rate in deciding the policy rate after the crisis.

The sub-table at the end of Table 3 shows that the resultant model fits are distorted if the crisis effect is not controlled. Despite the similar number of observations in the pre-crisis period, the log marginal data densities for 2008-Q3 to 2015-Q4 are smaller than those for 2001-Q1 to 2008 Q2, thus implying that including the data of the peak of the crisis worsens the model fits. Moreover, without excluding these samples, the monetary policy change in Korea cannot be captured through the model comparison technique.

We can now provide the answer for the first question: (1) Is there any change in the Korean monetary policy framework before and after the global financial crisis? Our answer is yes, and the exchange rate movement becomes an additional consideration of the BOK after the recent crisis according to the model comparison result. The next subsection documents the specific differences in

6 and 10, then it is "strong evidence", if it is between 2 and 6, then it is "positive evidence", and if it below 2, then it is "not worth more than a bare mention".

the monetary policies in Korea before and after the crisis.

5.2 Different features of the two periods' policy rules

Specifically, we describe the posterior distributions of the monetary policy parameters that represent the responses of the nominal interet rate in the reaction function (11). Similar to the previous section, we estimate the models in two steps. The rolling estimation results are plotted in Figure 2, and the posterior estimates for the two sub-periods are documented in Table 4.

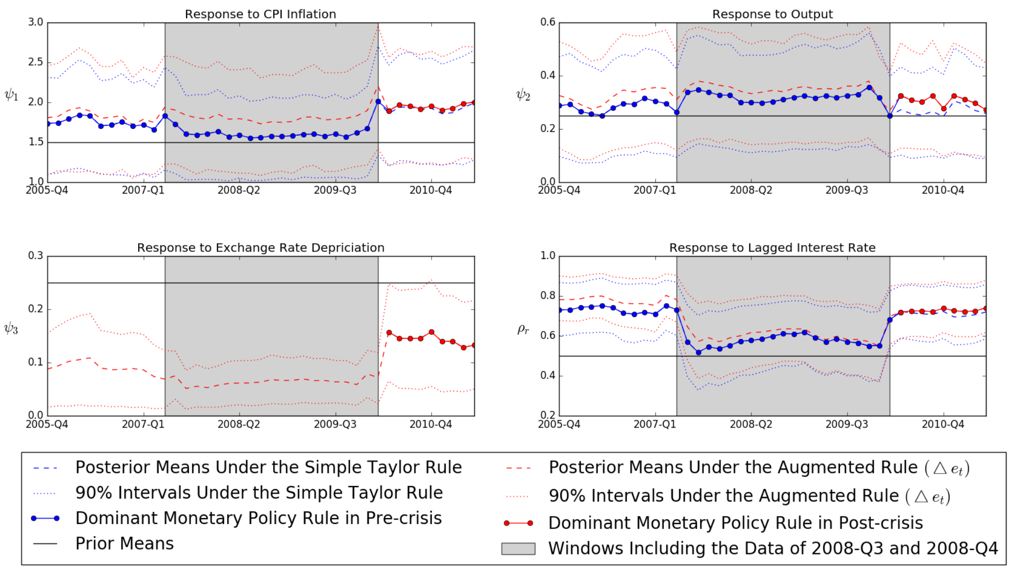

Figure 2: Rolling Estimation Result : Monetary Policy Parameters

Time Period		Pre-Crisis : 2001-Q1 - 2008-Q2				Post-Crisis : 2009-Q1 - 2015-Q4			
Dominant Rule		Simple Rule in Model (A)				Augmented Rule in Model (B)			
	Priors	Posteriors		90% Interval		Posteriors		90% Interval	
ψ_1	1.5 (0.5)	1.751	(0.39)	[1.119	2.339]	2.049	(0.430)	[1.348	2.738]
ψ_2	0.25 (0.13)	0.305	(0.12)	[0.108	0.493]	0.333	(0.125)	[0.139	0.529]
ψ_3	0.25 (0.13)	-	(-)	[-	-]	0.131	(0.046)	[0.056	0.203]
ρ_r	0.5 (0.2)	0.770	(0.06)	[0.673'	0.873]	0.739	(0.071)	[0.629	0.853]

Table 4: Posterior mean and std.dev of monetary policy parameters before and after global crisis

Figure 2 and Table 4 show clear differences in the response of the nominal interest rate to the CPI inflation and the nominal exchange rate depreciation. The policy rate decided by the BOK responds more actively to them after the recent crisis. As depicted in Figure 2, the posterior means of ψ_1 and ψ_3 obtained from the rolling estimation are clearly larger in the post-crisis period (red thick line with round markers) than in the pre-crisis period (blue thick line with round markers).[20] As described in Table 4, on the other hand, the posterior mean of ψ_1 increases by about 20% when we estimate the

[20]The dominant monetary policy rule in the pre-crisis period is the simple Taylor rule. Therefore, no thick blue line with round markers is observed for the pre-crisis period.

model using all of the observations in each sub-period. For ψ_3, the posterior means obtained from the rolling estimation in the pre-crisis period are smaller than 0.1, which is less explained by the data than model (A) with zero response to the exchange rate. Therefore, its magnitude of 0.131 in the post-crisis period can be considered a striking increase. In all sub-periods, the posterior standard deviations of these two parameters are more concentrated than their priors, thus implying that the data used in our estimation are informative.

On the other hand, no significant differences are observed in the posterior means of the remaining monetary policy parameters ψ_2 and ρ_r. Nevertheless, the posterior means of ψ_2 are slightly larger in the post-crisis period than in the pre-crisis period, as shown in Figure 2 and Table 4. A notable feature is that the nominal interest rate responds more to the output-gap than to the exchange rate depreciation. For ρ_r, the lagged interest rate seems to have a weaker effect on determining the current interest rate in the post-crisis period than in the pre-crisis period. Similarly, the posterior standard deviations of ψ_2 and ρ_r are smaller than their priors, thus implying the improvements of the uncertainties of these parameters because of the data.

In the previous section, the samples at the peak of the crisis affect the marginal data densitieis. Similarly, as shown by the shaded area in Figure 2, a sharp change is observed in each panel when the samples of 2008-Q3 and 2008-Q4 are included in a window. Specifically, the nominal interest rate starts to respond less to the CPI inflation, nominal exchange rate depreciation and lagged interest rate and more to the output-gap. Later, from the window starting from the data of 2009-Q1, the results turn around again. Therefore, the posterior distributions of the monetary policy parameters can also be over- or underestimated if we do not control the influence of the crisis, as shown in Table 5.

Time Period		2008-Q3 - 2015-Q4				Post-Crisis : 2009-Q1 - 2015-Q4			
Dominant Rule		Simple Rule in Model (A)				Augmented Rule in Model (B)			
	Priors	Posteriors		90% Interval		Posteriors		90% Interval	
ψ_1	1.5 (0.5)	1.728	(0.35)	[1.137	2.275]	**2.049**	(**0.430**)	[**1.348**	**2.738**]
ψ_2	0.25 (0.13)	0.357	(0.12)	[0.156	0.549]	**0.333**	(**0.125**)	[**0.139**	**0.529**]
ψ_3	0.25 (0.13)	-	(-)	[-	-]	**0.131**	(**0.046**)	[**0.056**	**0.203**]
ρ_r	0.5 (0.2)	0.575	(0.57)	[0.425	0.723]	**0.739**	(**0.071**)	[**0.629**	**0.853**]

Table 5: Posterior mean and std.dev of policy parameters in post-crisis

We obtained the posterior distributions of the remaining parameters of the model. Since our focus is the monetary policy parameters, we describe in this paper some of their notable features and the details are presented in the Appendix A. In the windows with the 2008-Q3 and 2008-Q4 data, the posterior means of all of the parameters except for r_{ss}, ρ_{y*}, $\rho_{\pi*}$ and $\sigma_{\pi*}$ are strikingly distorted. After these two data are excluded, the posterior means generally recover those in the pre-crisis period. However, the slope of the Phillips curve, κ, decrerases by about 30% compared with its mean in the pre-crisis period. Recently, many studies have argued that the relationship between inflation and output-gap or marginal cost tends to be attenuated.[21] More importantly, Roberts (2006) argued that the decline of the slope is associated with a more aggressive monetary policy with the 1960 to 2002 data, consistent with our result for Korea.

Therefore, the monetary policy in Korea after the peak of the crisis is different from that before the crisis. According to the estimated Bayesian posterior distribution of the monetary policy parameters, the BOK seems to adjust the policy rate in response to the CPI inflation and output-gap to a greater extent in the post-crisis period than in the pre-crisis period. In particular, the former is outstanding. In addition, according to the evidence in section 5, the exchange rate depreciation seems to be an additional factor in deciding the nominal interest rate. However, our results show that the magnitude of the reaction to exchange rate is smaller than that to the output-gap.

Our estimation results are robust for various specifications of reaction functions. Table 9 in Appendix C.1 documents the log data densitieis and the two statistics for model comparison under expected inflation targeting and alternative measures of the output gaps. The expected inflation targeting rule is expressed by replacing the current CPI inflation (π_t) in (11) by its expected value conditional on the current information ($E_t[\pi_{t+1}]$). In addition, we estimate the model by substituting the output deviation from the stochastic trend ($\hat{y}_t$) with the output growth rate ($\triangle\hat{y}_t + \hat{z}_t$) and the output deviation from the potential output ($\hat{y}_t - \hat{\bar{y}}_t$). As indicated in Table 9, computed log data densities are the largest under the benchmark policy rule, and the dominant policy rule in the post-crisis period is always the augmented rule with the exchange rate regardless of specifications.

Moreover, our results are still robust for alternative priors and other data. First, we test the robustness using more diffuse priors on ψ_1 and distributions with larger mean (0.75) and standard deviation (0.3) for ψ_2 and ψ_3. We impose the uniform distribution forρ_r. As indicated in Table 10 and 11, the results are not significantly different from those under the benchmark prior. The tables in Appendix C.3 describe the estimation results using other data mentioned in section 4: the birateral exchange rate (Korean won / U.S Dollar), the nominal effective exchange rate provided by the IMF and the core CPI inflation rate. Again, our main results are robust.

6 Assessment of the Change

So far, our estimation results indicate that the BOK started to consider the exchange rate depreciations additionally and reacted more aggressively to inflation and output after the peak of the crisis

[21] Doyle and Beaudry (2000) found a flattening pattern of the slope of the Phillips curve in the 1980s and the 1990s for the United States and Canada, respectively. Benati (2007) examined the changes in the reduced form relationship between output and inflation for the United Kinddom, the Eurozone, Canada, Italy, Sweden, Japan, France and Australia using data after post-World War II. Kuttner and Robinson (2010) also argured the flattening κ for the United States and Australia using data from 1960 to 2007.

than in the pre-crisis period. Based on this result, this section provides an answer to the last research question: (3) What are the effects of the monetary policy change in Korea? To answer the question, we evaluate the estimated policy rule in the post-crisis period with that in the pre-crisis period using varous types of simulation techniques.

6.1 Impulse Response Functions

We first assess the role of the Korean monetary policy in the post crisis period in relation to that in the pre-crisis period by computing the impulse response functions of four important variables, namely, nominal interest rate, CPI inflation, output growth and nominal exchange rate depreciation for a unit shock on monetary policy, as depicted in Figure 3.[22]

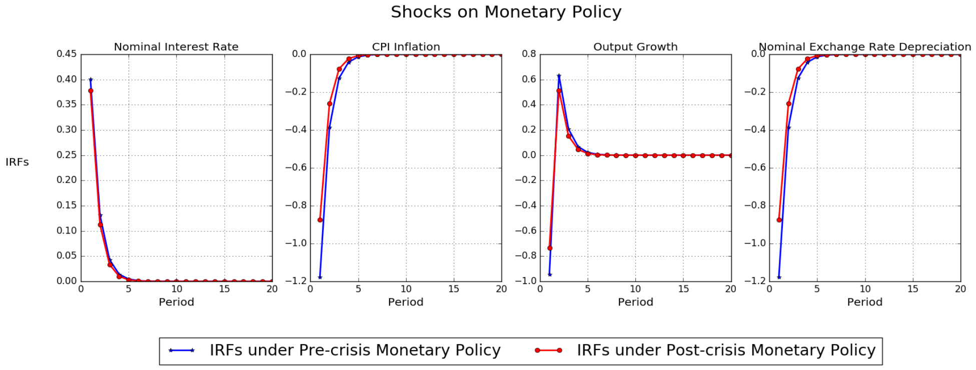

Figure 3: Responses of Five Important Macroeconomic Variables to Monetary Policy Shock

In both periods, contractionary monetary policy decreases CPI inlfation, output growth and appreciates the domestic currency. The decrease in CPI inflation and output growth and the appreciation of the domestic currency are more evident under the estimated monetary policy rule in the pre-crisis period than under the estimated dominant policy rule in the post-crisis period. As shown in Figures 8 in appendix B, the responses of output growth are almost similar, implying the effect of changes in the paramers except for those in (11).

We can also examine the reactions of the central bank to various shocks in the model. The four pannels in Figure 4 report the effects of one standard deviation of increase in five shocks, ϵ_t^z, ϵ_t^q, ϵ_t^{y*} and $\epsilon_t^{\pi*}$ on the nominal interest rate.

[22]In Appendix B, the Bayesian IRFs are reported for the nominal interest rate, CPI inflation, output growth, nominal exchange rate depreciation and terms of trade change given one standard deviation of five shocks in the model based on posterior estimates in the pre- and post-crisis period.

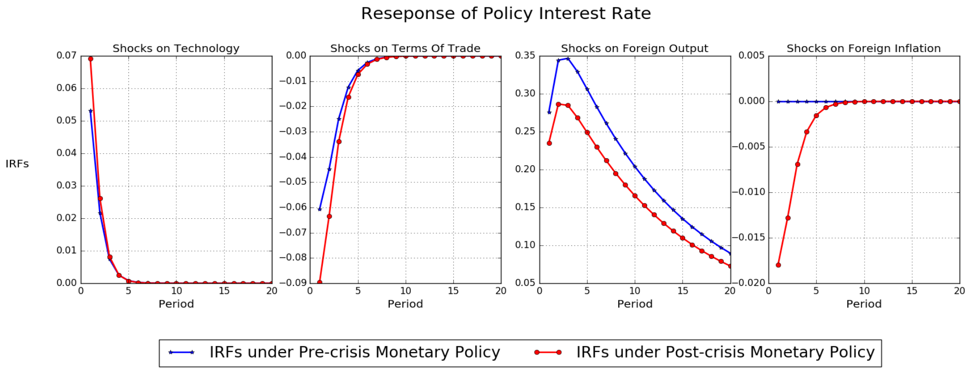

Figure 4: Response of Nominal Interest Rate to Five Exogenous Shocks

The innovation of technology creates an expansionalry effect on the economy, and it increases the nominal interest rate. The improvement in the terms of trade increases the CPI inflation through exchange rate appreciation but diminishes output. As the former dominates the latter, the central bank lowers the nominal interest rate. The positive shock on the foreign output increases the domestic output, appreciates the domestic currency, and lowers the CPI inflation. As indicated in Appendix B, the former two effects dominate the latter, thus increasing the nominal interest rate. Finally, the positive foreign inflation shock appreciates the domestic currency, which leads to the decrease in the nominal interest rate in the post-crisis period beacuse of the additional consideration of nominal exchange rate. Under the simple rule, the nominal interst rate does not react to the appreciation.

For the technology shock, the policy interest rate reponds more during the pre-crisis period than during the post-crisis period. For shocks on the terms of trade, the reactions of the BOK are simialr. The foreign output shock affects the nominal interest rate to a greater extent in the pre-crisis period relative to the post-crisis period. However, according to the Bayesian IRFs depicted in Figure 8 in Appendix B, the influence of technology and the terms of trade shocks are larger in the pre-crisis period than in the post-crisis becasue they are also based on different model parameters except for the coefficients in the Taylor rule.

6.2 Stochastic Simulation

This subsection examines the effect of the change in the Korean monetary policy on the volatilities of CPI inflation, output growth and exchange rate changes through stochastic simulation. We first solve the model to express all endogenous variables as a function of the exogenous variables as follows.[23]

$$X_t = F(\Theta)S_{t-1} + G(\Theta)U_t \tag{16}$$

Where X_t is the vector of all endogenous variables, and S_{t-1} is the vector of predetermined state

[23]Engogenous variables are shown as follows : $\hat{y}_t$, $\hat{r}_t$, π_t, $\hat{z}_t$, $\triangle q_t$, $\hat{\tilde{y}}_t$, $\triangle \hat{e}_t$, π^*_t, $\pi_{H,t}$ and $\hat{mc}_t$. Exogenous variables consist of five predetermined state variables : $\hat{r}_{t-1}$, $\triangle q_{t-1}$, $\hat{y}^*_{t-1}$, $\hat{z}_t$ and π^*_{t-1} and five corresponding exogenous shocks : ϵ^r_t, ϵ^q_t, ϵ^{y*}_t, ϵ^z_t and $\epsilon^{\pi*}_t$.

variables , and U_t consists of exogenous shocks. F and G are coefficient matrices composed of elements that are functions of the model parameters in Θ. As mentioned earlier, we use the posterior means as estimates of the model parameters to generate a series of the variables in X_t by imposing zero starting values on S_{t-1} and drawing shocks from U_t. Thereafter, we can calculate the volatilities of each series.

In practice, we generated 5,000 series of 80 quarters and then computed the average volatilities for the last 40 quarters to avoid the effect of an extreme value drawn for a certain shock and the influence of starting values. Moreover, a simulation is conducted in three ways depending on the dominant monetary policy rules and the estimates of the monetary policy parameters in the pre- and post-crisis periods. As discussed in the previous subsection, the remaining parameters are fixed similar to those estimated in the post-crisis period.

The calculated volatilities of CPI inflation and the growth rates of output and exchange rate are shown in Table 6 where θ_{MP} represents the set of parameters in the monetary policy reaction function. $\hat{\theta}_{MP}^{Pre}$ and $\hat{\theta}_{MP}^{Post}$ are corresponding sets of posterior means in the pre- and post-crisis periods, respectively. To determine the effect of the additional consideration of exchange rate, we also run a simulation under $\hat{\theta}_{MP}^{Post}$ and impose a restriction of $\psi_3 = 0$. The numbers in square brackets are the minimum and maximum volatilities in the 5,000 series.

θ_{MP}	$\theta_{MP} = \hat{\theta}_{MP}^{Pre}$			$\theta_{MP} = \hat{\theta}_{MP}^{Post}(\hat{\psi}_3 = 0.131)$			$\theta_{MP} = \hat{\theta}_{MP}^{Post}(\hat{\psi}_3 = 0)$		
σ_{π_t}	0.469	[0.307	0.833]	**0.376**	**[0.219**	**0.674]**	0.379	[0.245	0.690]
$\sigma_{(\hat{y}_t-\hat{y}_{t-1}+\hat{z}_t)}$	1.101	[0.796	1.445]	1.219	[0.893	1.550]	**1.067**	**[0.794**	**1.379]**
$\sigma_{\triangle e_t}$	3.632	[2.437	4.864]	**3.429**	**[2.306**	**4.577]**	3.618	[2.434	4.834]

Table 6: Volatilities Calculated from Stochastic Simulation

According to Table 6, the BOK can reduce volatilities of CPI inflation and exchange rate at the cost of the increase in output volatility. Comparing the first and second column, we can assess the macroeconomic performance of the monetary policy change in Korea before and after the crisis. The variations of CPI inflation and exchange rate decrease by about 20% and 10%, respectively, in the post-crisis period compared with those in the pre-crisis period. However, although the posterior mean of ψ_2 is larger in the post-crisis period, the output growth rate becomes more volatile in the post-crisis period, about 10% larger than that in the pre-crisis period. Therefore, the benefits of the monetary policy change in Korea are more stable inflation and exchange rates but the cost is a more volatile output.

The values in the third column represent calculated volatilities under the estimated dominant policy rule in the post-crisis period except that there is no reaction of the policy rate to the exchange rate ($\psi_3 = 0$). The volatilities of all variables in the third column are smaller than those in the first column. Therefore, if the BOK does not consider the exchange rate in deciding the nominal interest rate in the post-crisis period, then it can achieve better performance in all aspects. The difference in the fluctuations in the second and third column shows the effect of the additional response to the exchange rate on macroeconomic volatilities after the peak of the crisis. As expected, the standard deviation of output growth decreases from 1.219 to 1.067 and that of exchange rate increases from 3.429 to 3.618. However, even with $\psi_3 = 0$, the volatility of CPI inflation does not improve (0.376). Rather, it is even larger (0.379) than that under $\psi_3 = 0.131$. In this respect, we track the change in the fluctuations of the three variables for increasing the response of the nomoinal interest rate to the exchange rate (ψ_3) as depicted in Figure 5. We compute the standard deviations of the three variables for 50 values of ψ_3 from 0 to 0.5.

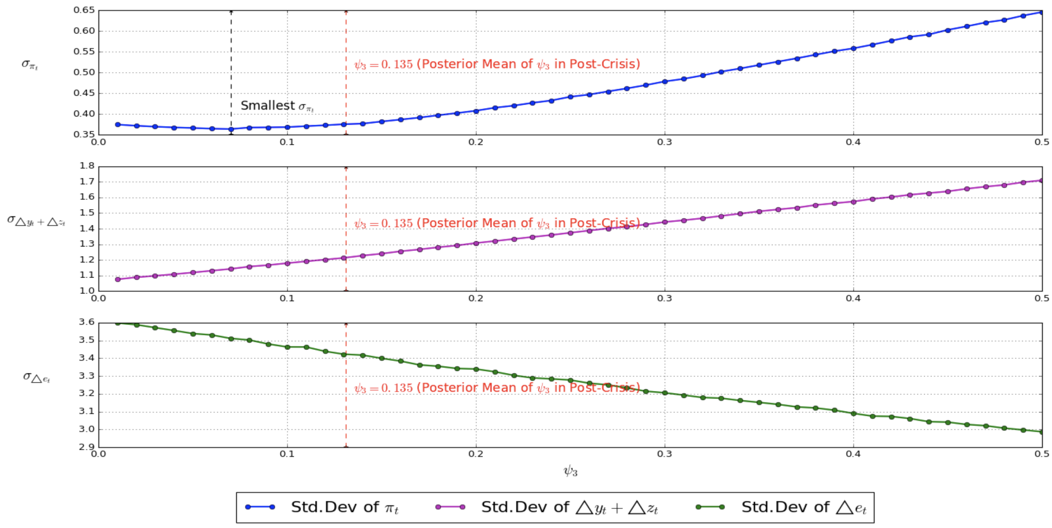

Figure 5: Performance of three variables for different $\psi_{3\text{s}}$

The uppermost panel in Figure 5 indicates the reason for the smaller variance of CPI inflation under the positive response to the exchange rate compared with that under no response. Although the volatilities of the output growth and the exchange rate depreciation linearly change with increasing ψ_3, the standard deviation of the CPI inflation varies in a U-shape for low values of ψ_3. As expressed in the figure, the value under which the standard deviation of CPI inflationi is the smallest is not zero but positive (the black dotted line). This finding implies that the BOK does not have to abandon variations of inflation to stabilize the exchange rate.

In light of the objective of the BOK, which is to stabilize inflation, the estimated policy rule in the post-crisis period can be assessed as appropriate and positive because it contributes to the stabilization of inflation together with exchange rate. In doing so, a more volatile output follows as the cost of the alteration of monetary policy. Further consideration of the exchange rate in the post-crisis period can be considered reasonable because Korea, which is a small open economies, is inherently susceptible to foreign environments. For the BOK, the effect of the crisis is almost purely exogenous, so that it may have faced more uncertainties about future foreign economic conditions. In this respect, adjusing the nominal interest rate in reaction to the movement of exchange rate can be regarded as a way of actively preparing for the crisis. Moreover, according to our estimates of the exchange rate coefficient in the reaction function, the extent of the response does not damage the BOK's foremost target, the stabililzation of inflation.

7 Conclusion

This study estimates and assesses the monetary policy conducted by the central bank of Korea, the BOK, in accordance with the recent global financial crisis. We conclude with this section by summing up the answers for the three research questions.

The estimation results show that the variation of exchange rate has become an additional factor of the BOK in deciding the nominal interest rate in the post-crisis period. The model, which includes the augmented Taylor rule with the reaction to the nominal exchange rate depreciation, is strongly supoprted by the data in terms of the widely used criteria for model comparison. Moreover, the posterior estimates of the coefficients in the monetary policy rule specified by the Taylor-type reaction function show that the BOK adjusts the policy rate more aggressively in the post-crisis period than in the pre-crisis period. In particular, the parameter representing the reponse to the CPI inflation is estimated to be clearly larger in the post-crisis period than in the pre-crisis period.

The alteration of the Korean monetary policy can be assessed as desirable in that the volatilities of inflation and exchange rate depreciation obtained from the simulated series based on the model solution and the posteiror estimtes are smaller under the estimated monetary policy rule in the post-crisis period. While the standard deviation of output growth is calculated to be larger, the behavior of the BOK can be justified because its most important object is the stabilization of inflation. In addition, the reaction to exchange rate can be cosidered reasonable because it was highly likely that the BOK had to prepare for unprecedented uncertainties followed by the crisis.

According to the BOK, it actively reacted to the crisis by using various policy instruments because of the increasing uncertainty in international financial markets and the deepening of the global depression. Our results are consistent with the official behavior of the BOK except that we only addresses one policy instrument, the nominal interest rate. Moreover, our results can be model dependent. The model used in our analysis is excessively simple in expressing the complexity of the real economic dynamics of small open economies. Further studies are required to bridge this gap.

References

Adolfson, M., Laséen, S., Lindé, J., and Villani, M. (2008). Evaluating an estimated new Keynesian small open economy model. *Journal of Economic Dynamics and Control*, 32(8):2690–2721.

Bae, B. H. (2013). The Role of Financial Factors in the Business Cycle and the Transmission of Monetary Policy in Korea. *Bank of Korea WP*, 30.

Benati, L. (2007). The Time-Varying Phillips Correlation. *Journal of Money, Credit and Banking*, 39(5):1275–1283.

Caraiani, P. (2011). Comparing monetary policy rules in the Romanian economy: a New Keynesian approach. *Romanian Journal of Economic Forecasting*.

Caraiani, P. (2013). Comparing monetary policy rules in CEE economies: A Bayesian approach. *Economic Modelling*, 32:233–246.

Clarida, R., Galı, J., and Gertler, M. (1998). Monetary policy rules in practice: some international evidence. *european economic review*, 42(6):1033–1067.

DeJong, D. N. and Dave, C. (2011). *Structural Macroeconometrics.* (Second Edition). Princeton University Press.

Del Negro, M. and Schorfheide, F. (2008). Inflation dynamics in a small open-economy model under inflation targeting: some evidence from Chile. *FRB of New York Staff Report*, (329).

Doyle, M. and Beaudry, P. (2000). What Happened to the Phillips Curve in the 1990s in Canada. *Staff General Research Papers.*

Eichengreen, B. (2004). Monetary and exchange rate policy in Korea: assessments and policy issues. *CEPR discussion paper.*

Eo, Y. (2003). Estimation of Monetary Policy Reaction Function after Adopting Inflation Targeting of Korea. *Korean Journal of Money and Finance*, 8.

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

Garcia, C. J. and Gonzalez, W. D. (2013). Exchange rate intervention in small open economies: The role of risk premium and commodity price shocks. *International Review of Economics and Finance*, 25:424–447.

Geweke, J. (1999). Using simulation methods for Bayesian econometric models: inference, development, and communication. *Econometric Reviews*, 18(1):1–73.

Kass, R. E. and Raftery, A. E. (1995). Bayes factors. *Journal of the American Statistical Association*, 90(430):773–795.

Kim, I. and Yie, M.-s. (2015). Unemployment and Optimal Monetary Policy. *Korean Journal of Money and Finance*, 29:1–41.

Kuttner, K. and Robinson, T. (2010). Understanding the flattening Phillips curve. *The North American Journal of Economics and Finance*, 21(2):110–125.

Kwark, N.-S. and Kim, W.-H. (2016). Estimation of the Monetary Policy Reaction Function in Korea Before and After the Global Financial Crisis. *Menuscript.*

Lall, Subir, E. S. and Alp, H. (2012). Did Korean Monetary Policy Help Soften the Impact of the Global Financial Crisis of 2008-2009? *IMF Working Papers*, 12(5):1.

Lubik, T. A. and Schorfheide, F. (2007). Do central banks respond to exchange rate movements? A structural investigation. *Journal of Monetary Economics*, 54(4):1069–1087.

Park, M. H. (2012). A Study on Estimating and Forecasting the Korea's Potential GDP using a Bayesian DSGE Approach. *Korea Review of Applied Economics*, 14:1–36.

Piao, J. S. and Joo, S. (2011). New Keynesian Phillips Curve after the Currency Crisis in Korea. *Korea Review of Applied Economics*, 13(1):83–106.

Roberts, J. M. (2006). Monetary Policy and Inflation Dynamics. *International Journal of Central Banking.*

Schorfheide, F. (2000). Loss function-based evaluation of DSGE models. *Journal of Applied Econometrics*, 15(6):645–670.

Shin, K. (2007). Evaluation of Monetary and Exchange Rate Policy in Korea After the Financial Crisis. *The Korean Economic Review.*

Suh, J.-D. (2011). A New Keynesian Model of the Small Open Economy : Korea. *Daejeon University Social Science Review*, 29:1–44.

Teo, W. L. (2009). Estimated Dynamic Stochastic General Equilibrium Model of the Taiwanese Economy. *Pacific Economic Review*, 14(2):194–231.

Yoo, B. H. and Cho, S. (2015). Markov-switching Open-economy DSGE Model : the Case of Korea. *Journal of Korean Economic Analysis*, 21:1–56.

Zheng, T. and Guo, H. (2013). Estimating a small open economy DSGE model with indeterminacy: Evidence from China. *Economic Modelling*, 31(1):642–652.

Appendix

A Korean Monetary Policy Before and After the Crisis

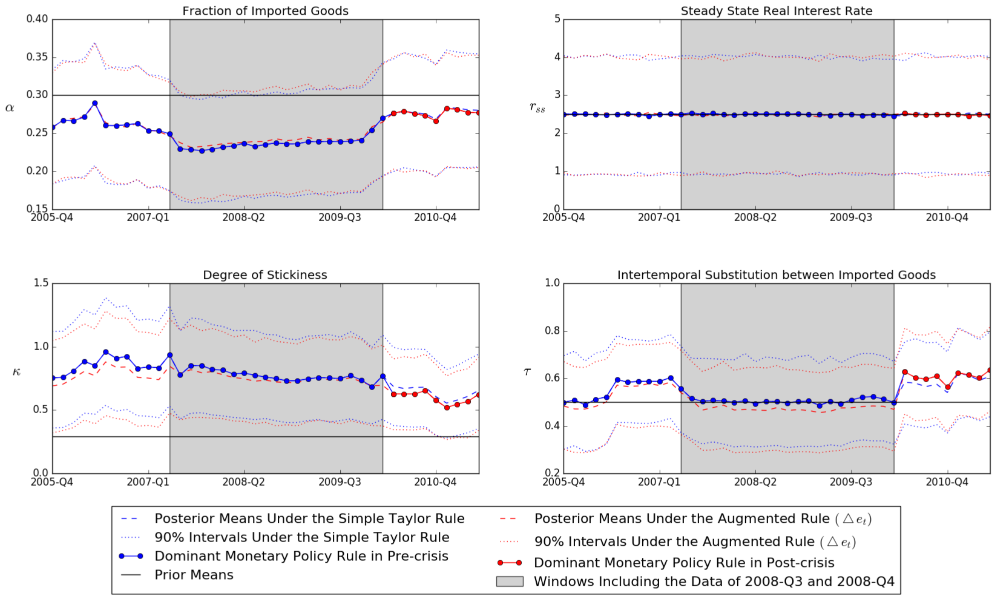

Figure 6: Rolling Estimation Result : Model Parameters

Time Period		Pre-Crisis : 2001-Q1 - 2008-Q2				Post-Crisis : 2009-Q1 - 2015-Q4			
Dominant Rule		Simple Rule in Model (A)				Augmented Rule in Model (B)			
	Priors	Posteriors		90% Interval		Posteriors		90% Interval	
α	0.3 (0.05)	0.251	(0.04)	[0.180	0.322]	0.277	(0.04)	[0.203	0.349]
r_{ss}	2.5 (1.0)	2.472	(0.98)	[0.933	4.002]	2.495	(1.01)	[0.919	4.057]
κ	0.29 (0.14)	0.943	(0.25)	[0.531	1.347]	0.678	(0.18)	[0.377	0.960]
τ	0.5 (0.2)	0.556	(0.11)	[0.368	0.739]	0.629	(0.10)	[0.464	0.801]

Table 7: Posterior mean and std.dev of other model parameters before and after global crisis

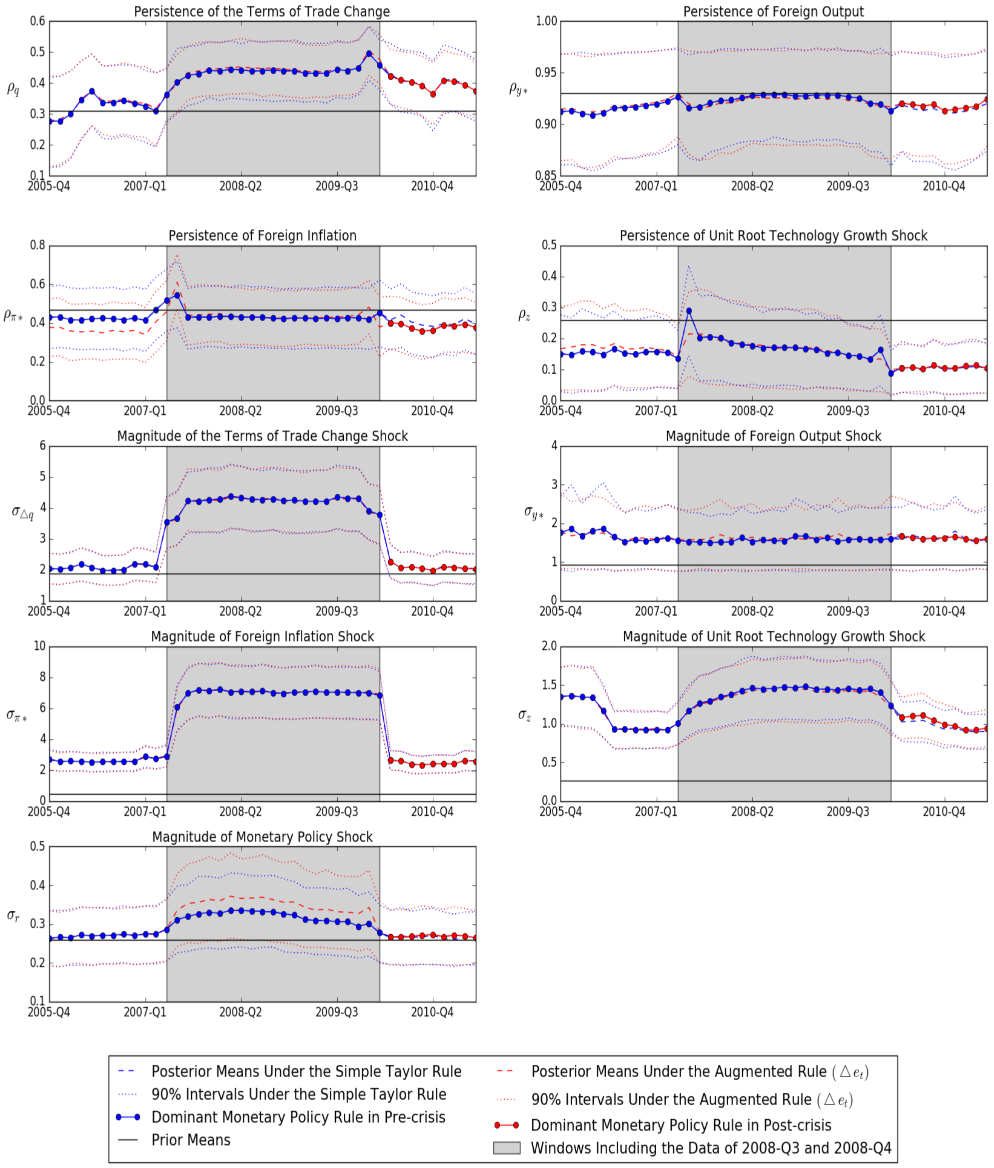

Figure 7: Rolling Estimation Result : Shock Parameters

Time Period		Pre-Crisis : 2001-Q1 - 2008-Q2				Post-Crisis : 2009-Q1 - 2015-Q4			
Dominant Rule		Simple Rule in Model (A)				Augmented Rule in Model (B)			
	Priors	Posteriors		90% Interval		Posteriors		90% Interval	
ρ_q	0.31 (0.13)	0.295	(0.07)	[0.177	0.405]	0.410	(0.05)	[0.328	0.491]
ρ_{y*}	0.93 (0.03)	0.914	(0.03)	[0.022	0.216]	0.921	(0.03)	[0.017	0.141]
$\rho_{\pi*}$	0.47 (0.11)	0.444	(0.10)	[0.287	0.606]	0.415	(0.08)	[0.288	0.545]
ρ_z	0.26 (0.12)	0.121	(0.06)	[0.864	0.967]	0.081	(0.04)	[0.874	0.969]
σ_q	1.88 (0.99)	2.058	(0.25)	[1.644	2.462]	2.312	(0.30)	[1.829	2.782]
σ_{y*}	1.88 (0.99)	1.637	(0.62)	[0.935	1.501]	1.549	(0.56)	[0.819	1.286]
$\sigma_{\pi*}$	1.88 (0.99)	2.817	(0.36)	[2.232	3.361]	2.811	(0.36)	[2.222	3.381]
σ_z	1.88 (0.99)	1.221	(0.18)	[0.781	2.511]	1.058	(0.15)	[0.787	2.315]
σ_r	0.68 (0.36)	0.234	(0.03)	[0.179	0.286]	0.235	(0.04)	[0.176	0.288]

Table 8: Posterior mean and std.dev of shock parameters before and after global crisis

B Impulse Response Functions in Pre- and Post Crisis]

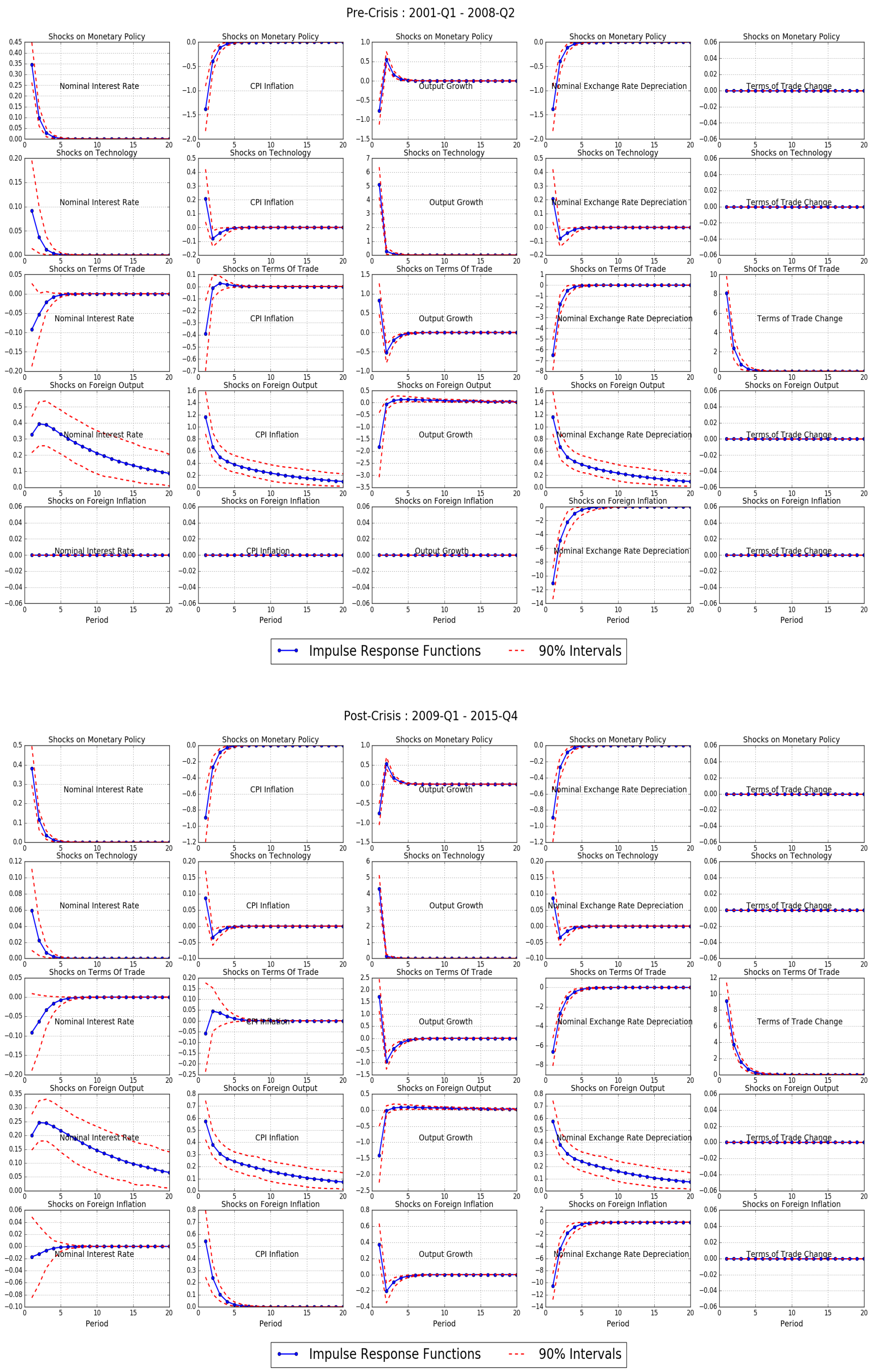

Figure 8: Impulse Response Functions under Dominant Policy Rules in Pre- Post- crisis

C Robustness

C.1 Other Specifications of Monetary Policy rule

	Pre-Crisis (2001Q1 - 2008Q1)				Post-Crisis (2009Q1-2015Q2)			
Model	(A)	(B)	(C)	(D)	(A)	(B)	(C)	(D)
				Benchmark : Ouput Rule (Current Inflation Targeting)				
LDD	**-271.849**	-277.036	-273.640	-278.46	-218.357	**-215.144**	-220.194	-216.557
PO ratio	**(1.000)**	(0.003)	(0.097)	(0.000)	(1.000)	**(24.854)**	(0.159)	(6.050)
KR ratio	**(-)**	(-5.454)	(-4.652)	(-9.550)	(-)	**(6.426)**	(-3.674)	(3.600)
				Ouput Rule (Expected Inflation Targeting)				
LDD	**-289.434**	-295.129	-290.487	-296.134	-250.558	**-248.144**	-252.408	-250.068
PO ratio	**(1.000)**	(0.003)	(0.349)	(0.001)	(1.000)	**(11.179)**	(0.157)	(0.146)
KR ratio	**(-)**	(-11.390)	(-2.106)	(-13.400)	(-)	**(4.828)**	(-3.700)	(0.980)
				Ouput Growth Rule (Current Inflation Targeting)				
LDD	**-295.865**	-302.929	-297.244	-304.071	-267.188	**-264.261**	-268.077	-265.128
PO ratio	**(1.000)**	(0.001)	(0.252)	(0.000)	(1.000)	**(18.672)**	(0.411)	(7.846)
KR ratio	**(-)**	(-14.128)	(-2.758)	(-16.412)	(-)	**(5.854)**	(-1.778)	(4.120)
				Ouput Growth Rule (Expected Inflation Targeting)				
LDD	**-296.863**	-303.594	-298.736	-305.400	-271.440	**-269.305**	-273.656	-271.043
PO ratio	**(1.000)**	(0.001)	(0.154)	(0.000)	(1.000)	**(8.457)**	(0.109)	(1.487)
KR ratio	**(-)**	(1021.472)	(8.020)	(9009.186)	(-)	**(4.270)**	(-4.432)	(0.794)
				Ouput Gap Rule (Current Inflation Targeting)				
LDD	**-294.881**	-301.214	-296.779	-303.855	-266.129	**-264.454**	-267.644	-265.300
PO ratio	**(1.000)**	(0.002)	(0.150)	(0.000)	(1.000)	**(5.339)**	(0.220)	(2.291)
KR ratio	**(-)**	(0.000)	(-3.796)	(-17.948)	(-)	**(3.350)**	(-3.030)	(1.658)
				Ouput Gap Rule (Expected Inflation Targeting)				
LDD	**-296.379**	-303.528	-298.075	-305.374	-268.127	**-266.222**	-270.280	-268.246
PO ratio	**(1.000)**	(0.001)	(0.183	0.000	1.000)	**(6.719)**	(0.116)	(0.888)
KR ratio	**(-)**	(-14.298)	(-3.392	0.000	-)	**(3.810)**	(-4.306)	(-0.238)

Table 9: Log data densities for various specifications of monetary policy rule

C.2 Alternative Prior

Whole period (2001Q1-2015Q4)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-613.158**	-620.744	-614.974	-620.354
Posterior odds	**(1.000)**	(0.001)	(0.163)	(0.001
KR Ratio	**(-)**	(-15.172)	(-3.632)	(-14.392

Pre-crisis (2001Q1-2008Q2)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-285.789**	-292.548	-286.643	-291.829
Posterior odds	**(1.000)**	(0.001)	(0.426)	(0.002
KR Ratio	**(-)**	(-13.518)	(-1.708)	(-12.080

Post-crisis (2008Q3-2015Q2)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-327.564**	-330.096	-329.001	-328.877
Posterior odds	(**1.000)**	(0.079)	(0.238)	(0.269)
KR Ratio	**(-)**	(-5.064)	(-2.874)	(-2.626

Post-crisis (2009Q1-2015Q4)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	-247.638	**-245.688**	-248.325	-245.283
Posterior odds	(1.000)	**(7.029)**	(0.503)	(10.538)
KR Ratio	(-)	**(3.900)**	(-1.374)	(4.710)

Table 10: Log data densities and Posterior Odds before and after global crisis

Time Period		Pre-Crisis : 2001-Q1 - 2008-Q2				Post-Crisis : 2009-Q1 - 2015-Q4			
Dominant Rule		Simple Rule in Model (A)				Augmented Rule in Model (B)			
	Priors	Posteriors		90% Interval		Posteriors		90% Interval	
ψ_1	1.5 (0.6)	2.101	(0.507)	[1.272	2.900]	2.575	(0.570)	[1.652	3.548]
ψ_2	0.75 (0.30)	0.518	(0.206)	[0.203	0.835]	0.594	(0.227)	[0.236	0.940]
ψ_3	0.75 (0.30)	-	(-)	[-	-]	0.191	(0.066)	[0.082	0.292]
ρ_r	0 (1.00)	0.815	(0.056)	[0.728	0.902]	0.789	(0.064)	[0.693	0.891]

Table 11: Posterior mean and std.dev of policy parameters before and after global crisis

C.3 Alternative Data

Nominal effective exchange rate index obtained from International Monetary Fund (IMF)

Whole period (2001Q1-2015Q4)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-611.149**	-616.997	-613.439	-619.080
Posterior odds	**(1.000)**	(0.003)	(0.101)	(0.000
KR Ratio	**(-)**	(-11.696)	(-4.580)	(-15.862

Pre-crisis (2001Q1-2008Q2)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-286.196**	-291.529	-287.430	-292.753
Posterior odds	**(1.000)**	(0.005)	(0.291)	(0.001
KR Ratio	**(-)**	(-10.666)	(-2.468)	(-13.114

Post-crisis (2008Q3-2015Q2)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-325.933**	-326.361	-327.944	-327.744
Posterior odds	(**1.000)**	(0.652)	(0.134)	(0.163)
KR Ratio	**(-)**	(-0.856)	(-4.022)	(-3.622

Post-crisis (2009Q1-2015Q4)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	-245.835	**-243.090**	-247.747	-244.410
Posterior odds	(1.000)	**(15.565)**	(0.148)	(4.158)
KR Ratio	(-)	**(5.490)**	(-3.824)	(2.850)

Table 12: Log data densities and Posterior Odds before and after global crisis

Time Period		Pre-Crisis : 2001-Q1 - 2008-Q2				Post-Crisis : 2009-Q1 - 2015-Q4			
Dominant Rule		Simple Rule in Model (A)				Augmented Rule in Model (B)			
	Priors	Posteriors		90% Interval		Posteriors		90% Interval	
ψ_1	1.5 (0.5)	1.748	(0.395)	[1.272	2.900]	2.032	(0.419)	[1.652	3.548]
ψ_2	0.25 (0.13)	0.304	(0.125)	[0.203	0.835]	0.331	(0.127)	[0.236	0.940]
ψ_3	0.25 (0.13)	-	(-)	[-	-]	0.134	(0.049)	[0.082	0.292]
ρ_r	0.5 (0.2)	0.769	(0.065)	[0.728	0.902]	0.739	(0.071)	[0.693	0.891]

Table 13: Posterior mean and std.dev of policy parameters before and after global crisis

Bilateral exchange rate (Korean Won/U.S. Dollar)

Whole period (2001Q1-2015Q4)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-622.413**	-627.220	-624.735	-628.728
Posterior odds	**(1.000)**	(0.008)	(0.098)	(0.002
KR Ratio	**(-)**	(-9.614)	(-4.644)	(-12.630

Pre-crisis (2001Q1-2008Q2)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-285.103**	-289.297	-286.727	-290.663
Posterior odds	**(1.000)**	(0.015)	(0.197)	(0.004
KR Ratio	**(-)**	(-8.388)	(-3.248)	(-11.120

Post-crisis (2008Q3-2015Q2)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-332.042**	-332.276	-334.624	-333.360
Posterior odds	(**1.000)**	(0.791)	(0.076)	(0.268)
KR Ratio	**(-)**	(-0.468)	(-5.164)	(-2.636

Post-crisis (2009Q1-2015Q4)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	-257.729	**-255.308**	-259.406	-257.183
Posterior odds	(1.000)	**(11.257)**	(0.187)	(1.726)
KR Ratio	(-)	**(4.842)**	(-3.354)	(1.092)

Table 14: Log data densities and Posterior Odds before and after global crisis

Time Period		Pre-Crisis : 2001-Q1 - 2008-Q2				Post-Crisis : 2009-Q1 - 2015-Q4			
Dominant Rule		Simple Rule in Model (A)				Augmented Rule in Model (B)			
	Priors	Posteriors		90% Interval		Posteriors		90% Interval	
ψ_1	1.5 (0.5)	1.748	(0.379)	[1.272	2.900]	2.196	(0.459)	[1.652	3.548]
ψ_2	0.25 (0.13)	0.300	(0.118)	[0.203	0.835]	0.315	(0.115)	[0.236	0.940]
ψ_3	0.25 (0.13)	-	(-)	[-	-]	0.102	(0.036)	[0.082	0.292]
ρ_r	0.5 (0.2)	0.774	(0.061)	[0.728	0.902]	0.728	(0.077)	[0.693	0.891]

Table 15: Posterior mean and std.dev of policy parameters before and after global crisis

Core CPI Index

Whole period (2001Q1-2015Q4)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-612.698**	-618.475	-614.974	-620.354
Posterior odds	**(1.000)**	(0.003)	(0.103)	(0.000
KR Ratio	**(-)**	(-11.554)	(-4.552)	(-15.312

Pre-crisis (2001Q1-2008Q2)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-284.959**	-290.548	-286.643	-291.829
Posterior odds	**(1.000)**	(0.004)	(0.186)	(0.001
KR Ratio	**(-)**	(-11.178)	(-3.368)	(-13.740

Post-crisis (2008Q3-2015Q2)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	**-326.523**	-326.920	-329.001	-328.877
Posterior odds	(**1.000)**	(0.672)	(0.084)	(0.095)
KR Ratio	**(-)**	(-0.794)	(-4.956)	(-4.708

Post-crisis (2009Q1-2015Q4)

	Model (A)	Model (B)	Model (C)	Model (D)
Lod data density	-246.423	**-243.943**	-248.325	-245.283
Posterior odds	(1.000)	**(11.941)**	(0.149)	(3.127)
KR Ratio	(-)	**(4.960)**	(-3.804)	(2.280)

Table 16: Log data densities and Posterior Odds before and after global crisis

Time Period		Pre-Crisis : 2001-Q1 - 2008-Q2				Post-Crisis : 2009-Q1 - 2015-Q4			
Dominant Rule		Simple Rule in Model (A)				Augmented Rule in Model (B)			
	Priors	Posteriors		90% Interval		Posteriors		90% Interval	
ψ_1	1.5 (0.5)	1.760	(0.392)	[1.272	2.900]	2.055	(0.420)	[1.652	3.548]
ψ_2	0.25 (0.13)	0.314	(0.141)	[0.203	0.835]	0.334	(0.129)	[0.236	0.940]
ψ_3	0.25 (0.13)	-	(-)	[-	-]	0.128	(0.046)	[0.082	0.292]
ρ_r	0.5 (0.2)	0.774	(0.063)	[0.728	0.902]	0.737	(0.072)	[0.693	0.891]

Table 17: Posterior mean and std.dev of policy parameters before and after global crisis