# Monetary and Exchange Rate Policy in the Aftermath of the Asian Financial Crisis: The Case of Korea

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*This paper extends the structural VAR model of Bernanke and Mihov (1998) to one under a small-open economy in order to explore how the operating procedures of the monetary and foreign exchange policy in Korea changed in the aftermath of the 1997 Asian financial crisis. It finds strong evidence of apparent regime changes in the monetary and exchange rate policy after the financial crisis. The implications for monetary policy in Korea are that the operating procedure switched to a call rate target in the post-crisis period, but that its stance on monetary policy may remain in transition under an inflation targeting framework and a freely floating exchange rate regime. Moreover, the exchange rate presumably plays an important role in monetary policy or as an intermediate monetary policy target in order to stabilize prices.*

## I. Introduction

Many studies have shown that emerging countries change their monetary policy frameworks and foreign exchange policy regimes in the aftermath of a financial crisis.[1] The monetary policy frameworks of the crisis-hit countries tend to switch from monetary aggregate targeting (e.g., M2, M1, or the monetary base) to inflation targeting, whereas their foreign exchange policy regimes move from a "pegged" or

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[1] See Carstens and Werner (1999) for Mexico, Jansen (2001) and Ito and Hayashi (2004) for Thailand, and Hoffmaister (1999), Kim (2000), Oh (2000), Ito and Hayashi (2004), and Kim and Park (2006) for Korea.

"fixed" exchange rate to a "floating" one. For example, Mexico, Thailand, and Korea previously reacted to a financial crisis by switching their exchange rate policy regimes from fixed to floating, and by adopting inflation targeting as their new monetary policy frameworks.

Specifically, after the 1994 financial crisis, Mexico changed its foreign exchange policy regime from a predetermined to a freely floating exchange rate. In 1995, it then adopted both monetary base and interest rate targets to stabilize inflation. By 2008, it completely switched its operating target for monetary policy from a monetary base to the overnight interbank rate.

Similarly, Thailand (where the Asian financial crisis originated in July 1997) switched from a fixed to a managed/freely floating exchange rate after the crisis. In May 2000, it adopted inflation targeting, together with a short-term interest rate as a policy instrument, instead of monetary aggregates.

Korea also changed its foreign exchange policy regime from a managed-floating exchange rate to a freely floating exchange rate in December 1997.[2] In September 1998, it further adopted the call rate as a new operating target for monetary policy in order to keep inflation under control. Korea is now classified as having an inflation targeting framework and independently floating exchange rate system according to the IMF's classification of exchange rate arrangements and monetary policy frameworks.[3]

In general, the transition to a floating exchange rate regime tends to accompany a change in the monetary policy framework. For example, the crisis-hit countries described above experienced a sharp and large depreciation in their exchange rates. As a result, inflationary expectations increased and the need for a new anchor for monetary policy (e.g., inflation targeting) emerged in order to stabilize prices (Ito and Hayashi, 2004). Moreover, a number of inflation targeting countries have adopted floating exchange rate regimes and inflation targeting frameworks during financial crises when the rate of inflation is at a high level due to rapid depreciation in their exchange rates (Oh, 2000).[4]

Many previous studies have implicitly assumed that monetary and foreign

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[2] Based on the IMF's *de jure* exchange rate regime classification, Hernández and Montiel (2003) show that a managed-floating exchange rate was an official exchange rate regime from March 1980 to October 1997 in Korea. However, Kim et al. (2009) present the period of the regime as running from March 1980 to December 15, 1997. The exchange rate was pegged within a certain daily band of 2.25% during 1990~1997, and this band was widened to 10% in November 1997 (Kim, 2000; Chung et al., 2000).

[3] The IMF (2008) broadly categorizes a monetary policy framework as an exchange rate anchor, monetary aggregates target, or inflation targeting framework, while it defines an exchange rate arrangement as a currency board, fixed peg (band), crawling peg (band), or managed floating/independently floating rate.

[4] In contrast, in its post-crisis period, Malaysia, for example, moved to a less flexible exchange rate regime (fixed arrangement) compared before the crisis, while Philippines remained in the same exchange rate regime (independently floating).

exchange policy regimes change in the post-crisis period by accepting the corresponding changes in the economic structure and environment. Consequently, there has been no rigorous analysis of these regime changes, particularly the differences in their dates. Thus, focusing on Korea, the current paper sheds light on these issues by means of a regime switching and targeting hypothesis analysis, thereby contributing to the body of knowledge on this topic.

The work of Rudebusch and Svensson (1999) has distinguished between "target" and "targeting" as well as clarified the distinction between two meanings of targeting. The first meaning of targeting refers to setting a point target for a target variable with an acceptable band using all available information, while the second refers to restricting information on an instrument rule depending on the deviation of the target variable from the target level. In this paper, the meaning of targeting that I adopt is similar to the second meaning, but it is occasionally used as the first for context. Specifically, targeting is defined herein as restricted information for a target variable to respond only to a policy shock.[5]

Monetary authorities (e.g., a central bank) manage exchange rate movements in order to control the exchange rate path under a fixed or managed-floating exchange rate regime and use the short-term interest rate as its operating target for monetary policy under an inflation targeting framework. Therefore, this empirical study begins by looking specifically at the historical movements of the two policy rates, namely the call rate and the exchange rate. Subsequently, it tests for the presence of a structural break and a regime change in monetary and exchange rate policies using the Chow test (as well as the multiple structural break test of Bai and Perron (2003)) and using a simple Markov switching model, respectively. The results confirm hypothesis about their presence around the financial crisis period, in particular showing an apparent difference in the dates of the regime change.

To investigate how the operating procedures of the monetary and foreign exchange policies in Korea changed in the aftermath of the 1997 financial crisis, this paper extends the structural vector autoregressive (VAR) model of Bernanke and Mihov (1998) to one under a small-open economy. The modified version of the model is initially estimated using a Bayesian method. Then, from the extracted residual information, a covariance model of the market for bank reserves is estimated using the gradient-based Broyden, Fletcher, Goldfarb, and Shanno (BFGS) method, which is a non-linear parameter estimation technique. Finally, based on estimated likelihood information, the targeting hypothesis for the policy rates is tested using both the Bayes factor and the likelihood ratio.

The results imply that the operating procedure of monetary policy in Korea changed to a call rate target under an inflation targeting framework and a freely floating exchange rate regime (where the exchange rate and call rate show high and

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[5] For more details, refer to (15)-(16) in Section III.

low volatility, respectively) in the post-crisis period from monetary aggregate targeting under a managed-floating exchange rate regime (where the exchange rate and call rate show low and high volatility, respectively) in the pre-crisis period. Furthermore, they suggest that the exchange rate may play an important role in monetary policy or as an intermediate target to stabilize prices.[6] The empirical outcomes strongly support the existence of regime changes in the monetary and exchange rate policy in the aftermath of the financial crisis.

The remainder of this paper is organized as follows. Section II briefly describes the monetary policy of the Bank of Korea (BOK) before and after the 1997 financial crisis, and examines evidence of the changes in the monetary and foreign exchange policy regimes following the crisis. Section III presents a modified version of the model proposed by Bernanke and Mihov (1998). Section IV describes the data, variables, and estimation methodology and discusses the targeting hypothesis tests for assessing the changes in the operating procedures of the monetary and foreign exchange policies before and after the crisis. Section V concludes.

# II. Monetary Policy of the BOK

## 1. Objectives and Target

The BOK's ultimate objectives in the operation of monetary policy are price stability and financial stability, both of which are essential to sustaining economic growth and smoothing the transmission channels of monetary policy.[7] To this end, it uses indirect adjustment instruments such as its lending policy, reserve requirement policy, and open market operations in monetary policy.[8]

From the mid-1980s, the reserve requirement policy of the BOK was largely used as a means of adjusting market liquidity in order to control monetary expansion via the foreign sector. However, as financial markets liberalized and developed rapidly from the early 1990s, the role of the reserve requirement policy as a liquidity adjustment instrument declined. Even a small change in the reserve requirement ratio significantly affected the market liquidity level and banks' balance sheets. As a

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[6] The exchange rate and monetary aggregates such as reserve money, M1 or M2 serve as the intermediate target for monetary policy (IMF, 2008).

[7] The BOK has set the inflation target for 2010-2012 within the range of 3.0 ± 1% in terms of the annual CPI average (http://www.bok.or.kr/eng/index.jsp).

[8] Indirect adjustment instruments are market-friendly in that they correspond to the natural movements of the market. The central bank's loan system has been used as a major channel for the supply of money in the support of rapid economic growth and used by banks as a means to finance operational funds. However, it has rarely been used of late because borrowing from the central bank indicates shortcomings in their funding and management capabilities (Bank of Korea, 2001).

result, open market operations – where the BOK directly controls the call rate – emerged as a major monetary policy instrument. One of the main objectives of open market operations is to adjust banks' reserves and keep the call rate at the target level.

*Pre-crisis Period*

Korea's monetary policy started with a financial stabilization program in 1957. Under the program, a money supply ceiling (M1) was set on a quarterly or annual basis. As the balance of payments began to improve in 1976, the BOK targeted M1 growth. However, as M1 moved irregularly, the BOK elected to use M2 as its leading monetary indicator after 1979. After 1980, Korea's monetary policy was characterized by controlling the growth rate of monetary aggregates (M2 and MCT = M2 + certificate of deposit (CD) + money in trust). In 1996 when the money-in-trust account system was reorganized, M2 also became unstable.[9] Thus, MCT emerged as a new monetary indicator.[10] In 1997, the BOK started to use the double monetary targeting system of M2 and MCT as joint target indicators, placing more emphasis on the latter. However, even the usefulness of MCT had declined because of continuous financial system innovation.[11]

In addition, following the initial financial liberalization and deregulation of the Korean economy in the 1990s, government restrictions on short-term foreign borrowings were removed. This led to the free movement of foreign capital through the domestic financial market. In other words, foreign capital bearing low interest rates flowed into the domestic market in search of higher rates of return. As a result, money demand became unstable and the effectiveness of monetary aggregates in monetary policy declined, and the call rate emerged as a major instrument of monetary policy in 1998.

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[9] Money-in-trust products were originally supposed to be long-term and performance-related. However, they had short maturities and low penalty charges for cancelation. Accordingly, the government authorities reorganized the trust account system in order to restore the original function of the money-in-trust. This caused funds from the money-in-trust to flow into banks' saving deposits. Consequently, it pushed up the growth rate of M2, although there was no change in the monetary policy stance.

[10] Although funds moved from the money-in-trust to time & savings deposits, MCT was not affected because the effects of the funds-flow had now been counteracted.

[11] The BOK imposed a 2% reserve requirement on CDs, so the interest rate declined and funds withdrawn from CDs flowed into cover bills that emerged as a new investment instrument. Although there was no change in the monetary policy stance, this situation made the BOK appear to be operating a contractionary monetary policy.

*Post-crisis Period*

The prevailing economic conditions in Korea changed considerably after the Asian financial crisis, which had originated in Thailand in 1997 and spread to the economies of surrounding countries (e.g., Korea, Indonesia, Taiwan, Malaysia, and the Philippines).[12] Korea was one of the most severely affected nations. In late November 1997, Korea's foreign reserves dropped to less than US$6 billion and the Korean won depreciated by approximately 25% against the US dollar (Koo and Kiser, 2001). Furthermore, because the domestic financial market had already been fully integrated into the international market, Korea's short-term external debt to total external debt ratio increased from approximately 44% in 1991 to 58% in 1996 and then decreased to approximately 42% in 1997 (Kim, 2000).[13] While Korea's foreign borrowings were mostly short-term, their domestic loans were mostly long-term.[14] This mismatch as well as the difficulties inherent in rolling over short-term debts crunched the Korean financial market (Koo and Kiser, 2001). As a consequence, the IMF demanded as part of a rescue plan that Korea tighten its monetary policy (i.e., raise its interest rates), adopt a flexible exchange rate policy, and restructure the financial sectors (Garcia-Blanch, 1998).[15] Following these recommendations, the Korean government reformed the country's monetary and foreign exchange policies.[16]

In April 1998, the BOK adopted inflation targeting as a new nominal anchor for monetary policy and set the inflation target to increase by $9 \pm 1\%$, based on the average annual consumer price index (CPI). As the effectiveness of monetary indicators declined and as financial markets became more liberalized and innovative, interest rates began to play increasingly important roles within monetary policy. Thus, in September 1998, the central bank made the call rate the official

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[12] There is no consensus on when exactly the financial crisis started in Korea. Park et al. (2001) define three subperiods: the pre-crisis period, crisis period, and post-crisis period. The crisis period in their study starts in October 1997 and ends in September 1998. The 1994 Mexican financial crisis also spread to surrounding countries (e.g., Argentina and Brazil) in what is known as the "Tequila effect".

[13] Sachs et al. (1996) note that a weak banking system is one of the determining factors of a financial crisis.

[14] The ratio of short-term foreign borrowing to foreign reserves reached 285% in 1997 (Koo and Kiser, 2001).

[15] Borensztein and Lee (2000) argue that the credit crunch at the firm level in the aftermath of the financial crisis occurred because of the restructuring of the financial sectors, not because of contractionary monetary policy.

[16] A tight monetary policy appreciates the local currency (Gould and Kamin, 2000); in other words, it prevents depreciation during a financial crisis (Baig and Goldfajn, 2002). Contrary to the IMF's expectations, the exchange rate in Korea actually depreciated. Critics argue that the IMF's tight monetary policy worsened the Korean economy by increasing the number of bankruptcies and the volume of capital flight (Demetriades and Fattouh, 1999).

operating target for monetary policy in order to pursue inflation targeting.[17]

Further, the BOK used monetary operation, which is a form of monetary target where the broadest monetary indictor (M3) serves as a monitoring variable. In 1999, the BOK set an average growth target for M3 of 13-14% (7-10% in 2000), along with an inflation target. Both targets were used during the transition period until the inflation targeting system became fully fledged. In 2000, the central bank adopted core inflation as its target indicator.[18] In 2001, M3 was used only as a monitoring variable, rather than as an intermediate target, and the range of monitoring was 6-10%. In 2003, the central bank completed the transition of its monetary policy framework to inflation targeting. Accordingly, open market operation became a major policy instrument, which played a key role in enabling the central bank to not only fine-tune the level of market liquidity, but also adjust banks' reserves by directly affecting the call market.

In addition, the financial crisis invalidated the managed-floating exchange rate system, and the BOK adopted a freely floating system due to the premature conditions and openness of the financial market. Foreign investors began to attack the Korean won because they expected it to devalue against the US dollar during the crisis. Under the prevailing managed-floating exchange rate system, the efforts of policy authorities to defend its devaluation led to an outflow of foreign reserves, which subsequently created a lack of credibility in the financial market (Demetriades and Fattouh, 1999). As a result, their power to control the foreign exchange rate within the targeting band was restrained, and the exchange rate was eventually allowed to freely float in December 1997.[19] Although Korea has since officially adopted a freely floating exchange rate system, the Korean government still directly or indirectly intervenes in the foreign exchange market in order to keep the exchange rate at a certain target level (Martin, 2008).[20]

## 2. Evidence of Changes in the Monetary and Foreign Exchange Policy Regimes

Before the introduction and estimation of the VAR model, the presence of a

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[17] Over 90% of the transactions between financial institutions are made through the overnight call rate (Bank of Korea, 2001).

[18] Core inflation represents the basic trend of changes in prices, rather than wide short-term fluctuations.

[19] Hernández and Montiel (2003) do not identify Korea as a "pure" floater even though the exchange rate moved more flexibly in the post-crisis period than it had done in the pre-crisis period. However, Kim et al. (2009) find that Korea's exchange rate regime reached such a level of a freely floating exchange rate as that in Australia.

[20] For Korea's foreign exchange market intervention, see also Hernández and Montiel (2003), Willett and Kim (2006), and Willet et al. (2011).

structural break and a regime change in monetary and exchange rate policy will be deduced from monthly time series data of the call rate and the exchange rate.[21] The changeover month (i.e., structural break point) of the pre- and post-crisis periods is December 1997, namely when the exchange rate started to freely float. Accordingly, the pre-crisis period of the sample used in this study is from January 1987 to November 1997, while the post-crisis period is from December 1997 to July 2006.

Figure 1 shows that the movements before and after the financial crisis are markedly different. The first graph in Figure 1 highlights that the volatility of the exchange rate is relatively small in the pre-crisis period, but relatively large in the post-crisis period.[22] In particular, the exchange rate sharply rises to a higher level around the crisis period of late 1997 and stays at that level over the post-crisis period. This suggests that there is a structural break in the series and that the exchange rate policy regime switches to a more flexible or possibly, freely floating exchange rate system after the crisis.

Similarly, the third graph in Figure 1 shows that the variation in the call rate is relatively large in the pre-crisis period, but generally stable in the post-crisis period. In particular, the call rate suddenly rises around the crisis period, and drastically declines to a lower level at which it remains during the post-crisis period. As before, this again suggests that there is a structural break in the series and that the monetary policy regime changes to a call rate targeting approach after the crisis.

To confirm these graphical ex-ante indications of the presence of a structural break and a regime change in the two policy rates, a Chow test and a Markov switching model estimation are performed, respectively. For the structural break test, using a break date of December 1997, simple regressions of the exchange rate at level and the call rate are separately run only on a constant. The Chow test statistic strongly rejects the null hypothesis that there is no structural break, which indicates that there is a clear structural shift on the break date of the crisis period.[23]

In the Chow test, the two policy rates are assumed to have a single (known) structural break date. However, they may have different break dates. Thus, to identify the other potential breakpoints and break dates and to check that the previous Chow test results are sensitive to the choice of structural break test, a model with five potential breakpoints is estimated using a multiple structural break test.[24] For the exchange rate, October 1997 is found to be one of the break dates, which is close to the start of the post-crisis period, while for the call rate, August

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[21] The sample data is described in detail in Section IV-1.

[22] The exchange rate is in the form of logarithm.

[23] For exchange rate, $F(1,233) = 984.10$ at a significance level of 0.001 and for call rate, $F(1,233) = 228.66$ at a significance level of 0.001.

[24] Using the R statistical software package program, the multiple structural break test is performed by following the approach of Zeileis et al. (2003), which uses a dynamic programming algorithm of Bai and Perron (2003) for dating multiple structural changes.

**[Figure 1]** Exchange Rate, Call Rate, and Smoothed Probability
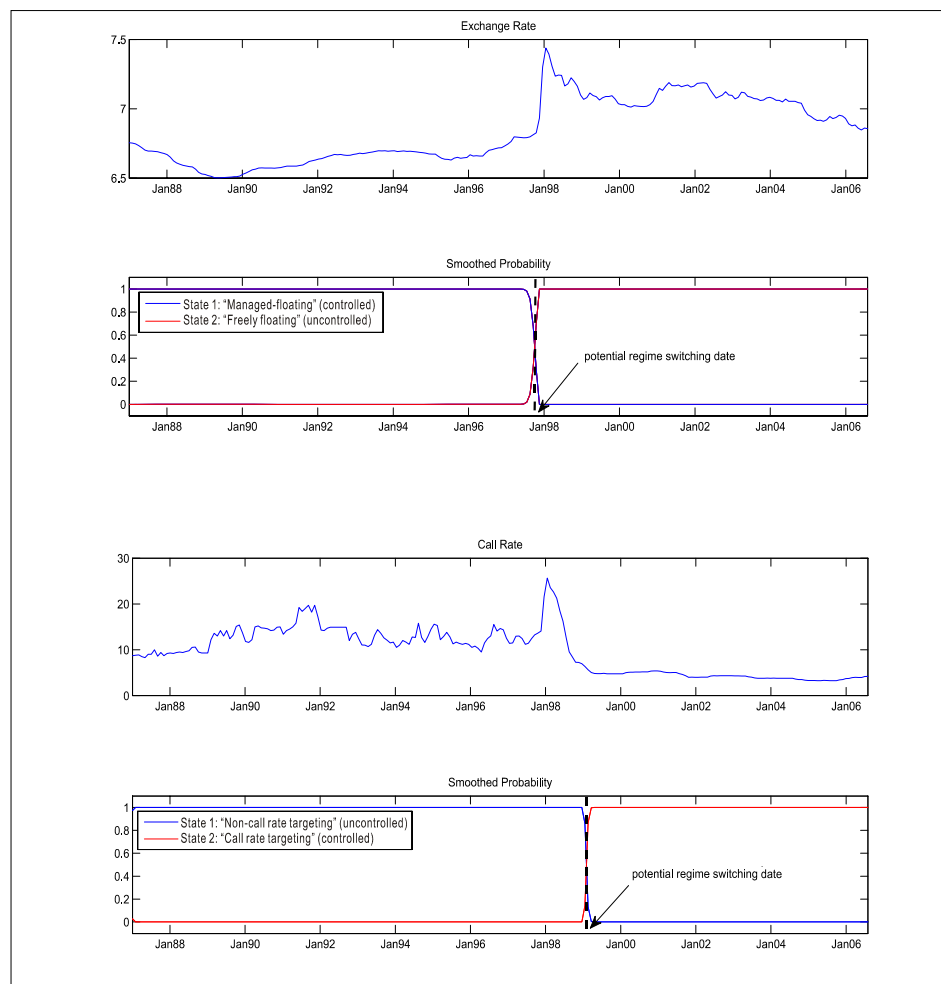


1998 is found to be such.[25]  This implies that the break dates for the exchange rate and call rate are different. Accordingly, a Chow test is re-performed with these new break dates, which are also found to be statistically significant at the 1% level.[26]

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[25] For the exchange rate, the Bayesian Information Criterion (BIC) selects a model with three breakpoints, while the minimal residual sum of square (RSS) selects a model with five breakpoints. The corresponding break dates are identified as 1992:2, 1997:10, and 2003:8 for the former, and 1991:12, 1994:11, 1997:10, 2000:9, and 2003:8 for the latter. For the call rate, the BIC chooses a model with four breakpoints, while the RSS chooses a model with five breakpoints. The corresponding break dates are identified as 1990:2, 1993:1, 1998:8, and 2001:8 for the former, and 1989:11, 1992:10, 1995:9, and 1998:8, and 2001:8 for the latter. Depending on the breakpoints the selected break dates appear to be somewhat different. Nonetheless, they commonly include 1997:10 for the exchange rate and 1998:8 for the call rate.

[26] The new break date for the call rate may be more reasonable than the previous one because, as

Although the multiple structural break test finds somewhat different structural break dates from December 1997, which was previously assumed to be a single breakpoint, the choice of the multiple structural break test does not significantly change the results.

In order to analyze a regime change, a simple univariate Markov switching regression model is formulated as shown in (1) and then estimated. Similar to the model used for the Chow test, $y_t$ depends only on a constant term ($\alpha_{s_t}$), but it is state-dependent with two states, 1 and 2. Disturbance ($\varepsilon_t$) is assumed to be normally distributed with a mean 0 and state-dependent variance ($\sigma_{s_t}^2$). In the case of state 1 (2) for time $t$, the expectation of the dependent variable ($y_t$) is $\alpha_1$ ($\alpha_2$) and the volatility of the disturbance is $\sigma_1^2$ ($\sigma_2^2$).

$$y_t = \alpha_{s_t} + \varepsilon_t \qquad\qquad (1)$$
$$\text{where} \quad \varepsilon_t \sim N(0, \sigma_{s_t}^2)$$
$$s_t = states\ 1\ and\ 2\ for\ time\ t$$

where $y_t$ is either the exchange rate or the call rate. When $y_t$ is the exchange rate, the low value of $\alpha_1$ (high value of $\alpha_2$) is the expected exchange rate on a controlled, that is, "managed-floating" (uncontrolled, i.e., "freely floating") foreign exchange policy state, which implies a low (high) volatility for $y_t$. By contrast, when $y_t$ is the call rate, the high value of $\alpha_1$ (low value of $\alpha_2$) is the expected call rate on an uncontrolled, that is, "non-call rate targeting" (controlled, i.e., "call rate targeting") monetary policy state, which implies a high (low) volatility for $y_t$.

The second and fourth graphs in Figure 1 illustrate the estimated smoothed probabilities of each state for the two variables. Based on the data of $y_t$ observed throughout future date $T$, the smoothed probabilities show that the model process was likely in the state at any given date $t$ in the sample.[27] As shown in the graphs, the smoothed probabilities of state 1 for the exchange rate and call rate are equal to 1 in the pre-crisis period and 0 in the post-crisis period. In contrast, the smoothed probabilities of state 2 are equal to 0 in the pre-crisis period and 1 in the post-crisis

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noted earlier, the adoption dates of inflation targeting and call rate targeting (April and September 1998, respectively) are much closer to August 1998.

[27] The state ($s_t$) is unobservable, so the inference is taken in the form of a probability. The computation of the smoothed inference, $p(s_t | \mathbf{y}_T)$ starts with the probability $p(s_{t+1}, s_t | \mathbf{y}_t) = p(s_{t+1} | s_t) \cdot p(s_t | \mathbf{y}_t)$ and the probability density function $p(y_{t+1} | s_{t+1}, s_t, \mathbf{y}_t)$ for the date $t+1$ Inference $p(s_{t+1} | \mathbf{y}_{t+1})$, where $\mathbf{y}_t \equiv (y_t, y_{t-1}, \ldots, y_1)$. Using $p(s_{t+1}, s_t | \mathbf{y}_{t+1}) = \frac{p(y_{t+1}, s_{t+1}, s_t | \mathbf{y}_t)}{p(y_{t+1} | \mathbf{y}_t)}$ from the calculation of the inference, we can obtain the smoothed inference $p(s_t | \mathbf{y}_T) = \sum_{s_T=1}^{2} p(s_T, s_t | \mathbf{y}_T)$. Further details are beyond the scope of this paper. See Hamilton (1989, pp. 370-371 and 1993, pp. 239-240).

period. These suggest that, based on the observations throughout the month of July 2006, the exchange rate was most likely in the managed-floating foreign exchange policy state in the pre-crisis period, and in the freely floating foreign exchange policy state in the post-crisis period. Likewise, the call rate was most likely in the non-call rate targeting monetary policy states in the pre- and post-crisis periods, and in the call rate targeting monetary policy state in the post-crisis period.

In line with this, Tables 1 and 2 report the estimates of the model. The transition matrix in the last two columns of Tables 1 and 2 show that the probabilities of switching to the other state ($P_{12}$ and $P_{21}$) are close to 0.[28] Moreover, as expected, both estimates of switching parameters in state 1 of the constant and the model's variance for the exchange rate in Table 1 appear to be smaller than those in state 2, whereas their estimates in state 1 for the call rate in Table 2 appear to be larger than those in state 2.

**[Table 1]** Regime Switching Estimates and Transition Matrix for Exchange Rate

|  | Switching Parameters | | Transition Matrix | |
| --- | --- | --- | --- | --- |
| Foreign Exchange Policy | Independent (Cons.) | Variance | State 1 | State 2 |
| State 1 (Managed-floating) | 6.647 | 0.006 | 0.99 | 0.00 |
|  | (0.016) | (0.001) | (0.90) | (0.00) |
| State 2 (Free-floating) | 7.071 | 0.013 | 0.01 | 1.00 |
|  | (0.002) | (0.000) | (0.01) | (0.92) |

Note: Standard errors are in parentheses.

**[Table 2]** Regime Switching Estimates and Transition Matrix for Call Rate

|  | Switching Parameters | | Transition Matrix | |
| --- | --- | --- | --- | --- |
| Monetary Policy | Independent (Cons.) | Variance | State 1 | State 2 |
| State 1 (Non-inflation targeting) | 12.899 | 10.636 | 0.99 | 0.03 |
|  | (0.335) | (1.872) | (0.88) | (0.84) |
| State 2 (Inflation targeting) | 4.248 | 0.419 | 0.01 | 0.97 |
|  | (0.162) | (0.038) | (0.01) | (0.91) |

Note: Standard errors are in parentheses.

These findings agree with the features previously shown in the first and third graphs of Figure 1 (i.e., the movements and changes in the exchange rate and call

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[28] In the Markov regime switching model, the transition of states is stochastically determined by a transition matrix $P = \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix}$ that controls the probability of switching from one state to the other, where $P_{ij}$ is the element in row $i$ and column $j$ for $i, j = 1, 2$. For example, $P_{11}$ is the probability of maintaining state 1, while $P_{12}$ is the probability of switching from state 2 to state 1 between date $t$ and $t + 1$.

rate before and after the crisis), and thus they confirm that regime changes occurred in monetary and exchange rate policy in the aftermath of the financial crisis.[29]

In addition, the smoothed probabilities show an intersection on different dates (i.e., the potential date of the regime switch). In other words, the smoothed probabilities of the exchange rate appear to cross on a date right after the crisis, whereas the smoothed probabilities of the call rate appear to cross on a date some time after the crisis. This indicates a clear difference in the dates of the regime change, which agrees with the previous finding from the multiple structural break test. The discrepancy in the dates is likely to be due to the difference in the date of the new policy adoption following the crisis. As noted earlier, the BOK adopted its foreign exchange policy of a freely floating exchange rate in December 1997 (i.e., right after the crisis). Under this regime, a large and sharp depreciation led to expectations of inflationary increases. As a result, the central bank needed a new anchor for its monetary policy in order to stabilize inflation, and thus it adopted inflation targeting, along with the call rate as its operating target in 1998.

# III. Structural VAR Model

The impact of monetary policy on the economy tends to be measured in terms of the disturbance of monetary aggregates (e.g., M2, M1, or the monetary base) or interest rates. Sims (1992) and Bernanke and Blinder (1992) both identify a monetary policy shock as the change in a single indicator, such as the US federal funds rate. Christiano and Eichenbaum (1991), Eichenbaum (1992), and Strongin (1995) each propose non-borrowed reserves as a new policy measure.[30]  Nonetheless, more than one indicator of monetary policy or a combination of monetary policy operating procedures may exist (Bernanke and Mihov, 1997 and 1998).

Bernanke and Mihov (1998) explore and develop US monetary policy measures based on the market for bank reserves using a structural VAR approach that does not restrict the relationships among the macroeconomic variables in the system, but

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[29] To check the robustness of the regime switching model, it is estimated with the data (1981:4 ~ 2008:7) of Mexico that experienced the financial crisis in 1994. The model correctly identifies the regime switches in monetary and foreign exchange policy of Mexico. The results are available upon request.

[30] In 1982, the Federal Open Market Committee (FOMC) discarded non-borrowed reserves targeting used as its operating procedure depending on discount window adminstration because the demand for discount window borrowing was unreliable and monetary aggregates were less effective than the interest rate in terms of the short-run control of monetary policy (Schwartz, 2005). In addition, there are several limitations in the use of the non-borrowed reserves innovation that 1) negative policy innovation raises the price level and 2) its measure does have a small explanatory power for real output and does not explain the variance of output in a VAR model that includes interest rates (Eichenbaum, 1992; Strongin, 1995).

rather imposes contemporaneous identification restrictions on a set of market variables. Their VAR model consists of "non-policy" and "policy" block equations: the former includes the non-policy variables that depend on their own current and lagged values and only lagged values of the policy variables, while the latter includes the policy variables that depend on the current and lagged values of both policy and non-policy variables. Bernanke and Mihov (1998) estimate the model using a two-step GMM procedure (which is similar to a maximum likelihood estimation) over different sample periods, thereby allowing changes in Federal Reserve operating procedures. They find evidence that either the federal funds rate for the period prior to 1979 or non-borrowed reserves for the period 1979-1982 acts as the best indicator of monetary policy in the US.

Using a modified version of this proposed model, Kasa and Popper (1997) investigate the monetary policy objectives and operating procedures of the Bank of Japan in order to identify its monetary policy indicator. They find that no single target can explain the Bank of Japan's stance on monetary policy and that the central bank targets both call rate and non-borrowed reserves.

Unlike the model of Kasa and Popper (1997), this paper extends the Bernanke and Mihov's (1998) structural VAR model to one under a small open economy in order to examine the changes in the monetary and foreign exchange policy in the aftermath of the financial crisis in Korea. The main differences between their model and that proposed in this paper are threefold. First, the system of structural equations is divided into three blocks, as shown in (2)-(4): a non-policy block, a policy block, and an "exogeneity" block. Second, a reaction function of the exchange rate to the call rate is incorporated into the market for bank reserves under a small-open economy, as shown in (10)-(13). Finally, the VAR model is estimated using a Bayesian method rather than a classical method.

The non-policy block in (2) includes those variables that the central bank cannot directly affect, whereas the policy block in (3) includes those variables that the central bank can directly affect. Furthermore, the exogeneity block in (4) contains the exogenous foreign variables that influence both policy and non-policy variables in the system.[31] We also make five important assumptions: 1) as shown in (2), policy shocks do not contemporaneously affect non-policy variables; 2) the policy block contains more than one policy variables, thus allowing the central bank to operate a hybrid procedure for monetary and exchange rate policy; 3) policy and non-policy variables do not Granger-cause exogeneity block variables; 4) the exogeneity block follows the $AR(q)$ process; and 5) $v_t$ is orthogonal to $\varepsilon_t^{np}$ and $\varepsilon_t^p$.

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[31] The variables in the three blocks are presented in Section IV-1.

$$NP_t = \sum_{j=0}^{k} A_j NP_{t-j} + \sum_{j=1}^{k} B_j P_{t-j} + K^{np} EX_t + E^{np} \varepsilon_t^{np} \tag{2}$$

$$P_t = \sum_{j=0}^{k} C_j NP_{t-j} + \sum_{j=0}^{k} D_j P_{t-j} + K^{p} EX_t + E^{p} \varepsilon_t^{p} \tag{3}$$

$$EX_t = \sum_{i=1}^{q} M_i EX_{t-i} + v_t \tag{4}$$

where $NP_t$ is $l \times 1$ vector, $P_t$ is $m \times 1$ vector, $EX_t$ is $n \times 1$ vector, $A_j$ is $l \times l$ coefficient matrix, $B_j$ is $l \times m$ coefficient matrix, $C_j$ is $m \times l$ coefficient matrix, $D_j$ is $m \times m$ coefficient matrix, $K^{np}$ is $l \times n$ coefficient matrix, $K^{p}$ is $m \times n$ coefficient matrix, $E^{np}$ is $l \times l$ coefficient matrix, $E^{p}$ is $m \times m$ coefficient matrix, and $M_i$ is $n \times n$ coefficient matrix. $\varepsilon_t^{np}$, $\varepsilon_t^{p}$, and $v_t$ are the disturbance vectors of non-policy, policy, and exogeneity blocks, respectively where $\varepsilon_t^{np} \sim N(0, \sum^{np}), \varepsilon_t^{p} \sim N(0, \sum^{p})$, and $v_t \sim N(0, \sum^{v})$. $\varepsilon_t$ is pre-multiplied by the general matrix E, which implies that any shock can appear in any equation within its own block.

To solve the system of (2)-(4), first, (4) is substituted into (2) and (3). In the next step, they are simultaneously solved for the non-policy and the policy block equations that only depend on the lagged values and disturbances, as shown in (5) and (7), respectively. Equation (5) shows that the endogenous variables in the non-policy block are expressed by its own lagged variables, the lagged policy and exogenous variables, and two disturbances: exogeneity block disturbance ($v_t$) and its own disturbance ($\varepsilon_t^{np}$). Similarly, (7) shows that the endogenous variables in the policy block are expressed by its own lagged variables, the lagged non-policy and exogenous variables, and three disturbances: non-policy block disturbance ($\varepsilon_t^{np}$), exogeneity block disturbance ($v_t$), and its own disturbance ($\varepsilon_t^{p}$).

The reduced-form (5) and (7) can be equivalently expressed as (6) and (8), respectively, by combining the residuals in relation to the exogenous disturbance ($v_t$) and its own disturbance ($\varepsilon_t$) as a new reduced-form residual ($u_t$), namely, $u_t^{np} \equiv Q^{np} v_t + e_t^{np}$ and $u_t^{p} \equiv Q^{p} v_t + e_t^{p}$.

$$NP_t = \sum_{j=1}^{k} H_j^{np} NP_{t-j} + \sum_{j=1}^{k} H_j^{p} P_{t-j} + \sum_{i=1}^{q} N_i EX_{t-i} + \underbrace{Q^{np} v_t + e_t^{np}}_{u_t^{np}}, \tag{5}$$

$$\leftrightarrow NP_t = \sum_{j=1}^{k} H_j^{np} NP_{t-j} + \sum_{j=1}^{k} H_j^{p} P_{t-j} + \sum_{i=1}^{q} N_i EX_{t-i} + u_t^{np}, \tag{6}$$

$$where \ Q^{np} = (I_m - A_0)^{-1} K^{np}, e_t^{np} = (I_m - A_0)^{-1} E^{np} \varepsilon_t^{np},$$

$$P_t = \sum_{j=1}^{k} L_j^{np} NP_{t-j} + \sum_{j=1}^{k} L_j^{p} P_{t-j} + \sum_{i=1}^{q} G_i EX_{t-i} + Fe_t^{np} + \underbrace{Q^p v_t + e_t^p}_{u_t^p} , \tag{7}$$

$$\leftrightarrow P_t = \sum_{j=1}^{k} L_j^{np} NP_{t-j} + \sum_{j=1}^{k} L_j^{p} P_{t-j} + \sum_{i=1}^{q} G_i EX_{t-i} + Fe_t^{np} + u_t^p , \tag{8}$$

$where \ F = (I_n - D_0)^{-1} C_0 , Q^p = (I_m - D_0)^{-1}[C_0 Q^{np} + K^p], e_t^p = (I_n - D_0)^{-1} E^p \varepsilon_t^p .$

The reduced-form residual ($Fe_t^{np} + u_t^p$) of the policy block in (8) contains information from the residuals, both $e_t^{np}$ from the non-policy block equation and $u_t^p$ from the exogeneity and policy block equations. Thus, by leaving the impact of the non-policy shock on policy variables unchanged, the relationship between the observable policy residual ($u_t^p$) and the unobservable structural policy shock ($\xi_t^p$) can be extracted from the residual information, as shown in (9) where $\xi_t^p$ is a linear combination of the exogenous shock ($v_t$) and the structural policy shock ($\varepsilon_t^p$).[32]

$$(I_n - D_0)u_t^p = E^p \xi_t^p \tag{9}$$

Based on the relationship in (9), the bank reserves market is modeled as shown in (10)-(13). To simplify the analysis, we assume that the central bank controls the exchange rate indirectly by adjusting the call rate and that its policy shock is transmitted to the market for bank reserves. Accordingly, the model incorporates a reaction function of the exchange rate to the call rate in (12) in order to characterize how the exchange rate policy operates in a small-open economy.

$$u^{tr} = -\alpha u^{cr} + \xi^d \tag{10}$$

$$u^{br} = \gamma u^{cr} + \xi^b \tag{11}$$

$$u^{exr} = -\varphi u^{cr} + \xi^e \tag{12}$$

$$u^{nbr} = \delta^{tr} \xi^d + \delta^{br} \xi^b + \delta^{exr} \xi^e + \xi^s \tag{13}$$

where *tr*, *br*, *nbr*, *cr*, *exr*, and *s* represent total reserves, borrowed reserves, non-borrowed reserves, the call rate, the exchange rate, and a policy shock, respectively.

Equation (10) represents demand for total reserves in the bank reserves market, showing that it has an inverse relationship with the call rate and responds to its own

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[32] Running a regression of the entire reduced-form residual in (8) only on the residual of $e_t^{np}$ obtained from (5) extracts information about the residuals of $u_t^p$. This "cleans up" the effect of shocks of the macroeconomic variables in the non-policy block on the policy variables. More detailed descriptions of the regression are presented in Section IV-2.

disturbance.[33] Thus, an increase in the interest rate leads to a decrease in demand for total reserves. Equation (11) represents demand for borrowed reserves in the market. This has a positive relationship with the call rate, which implies that a higher call rate increases borrowing from the central bank rather than borrowing from the call market and that it responds to its own disturbance.

Equation (12) describes the inverse relationship between exchange rate and the call rate and show that it also responds to its own disturbance. A higher interest rate drives the exchange rate to appreciate the local currency by inducing capital inflows.[34] Equation (13) characterizes the policy action of the BOK in terms of the supply of non-borrowed reserves.[35] This shows that the observable innovation of non-borrowed reserves accommodates all unobservable shocks (i.e., those of total reserves, borrowed reserves, and the exchange rate) as well as its own shock. We assume that the current account balance changes partly because the exchange rate shock leads to a shortage in or excess of liquidity, which subsequently affects the supply of non-borrowed reserves.

These equations can be arranged in the form of a matrix, as shown in (14). The parameters on the left-hand side represent the structural parameters, while those on the right-hand side represent the policy parameters. Altogether, 10 parameters are estimated (i.e., $\alpha$, $\gamma$, $\varphi$, $\delta^{tr}$, $\delta^{br}$, $\delta^{exr}$, and four structural variances). Therefore, at least 10 pieces of information are required to identify the model. Because the variance-covariance matrix of the policy block residuals provides those 10 pieces, the model is just-identified.

$$
\begin{bmatrix} 1 & 0 & \alpha & 0 \\ 0 & 1 & 0 & 0 \\ 1 & -1 & -\gamma & 0 \\ 0 & 0 & \varphi & 1 \end{bmatrix} \begin{bmatrix} u^{tr} \\ u^{nbr} \\ u^{cr} \\ u^{exr} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ \delta^{tr} & 1 & \delta^{br} & \delta^{exr} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \xi^d \\ \xi^s \\ \xi^b \\ \xi^e \end{bmatrix} \tag{14}
$$

In addition, by solving (10)-(13) simultaneously, a policy shock equation can be identified as a linear combination of the residuals $u^{tr}$, $u^{br}$, $u^{cr}$, and $u^{exr}$, as shown in (15).[36] The policy shock can accommodate the changes in all policy indicators. However, if the central bank targets the call rate, the target variable is

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[33]  Total reserves = borrowed reserves + non-borrowed reserves.

[34]  A change in interest rate affects net capital flow, which in turn affects the supply of local currency in the foreign exchange market. As a result, a change in the currency supply leads to the exchange rate either appreciating or depreciating.

[35]  The non-borrow reserves residual in (13) does not necessarily imply the policy stance. See Kasa and Popper (1997) for further details.

[36]  Equation (15) can be equivalently expressed as a residual equation for the call rate by accommodating all the structural shocks as follows:  $u^{cr} = \frac{1-\delta^{tr}}{\alpha+\gamma}\xi^d - \frac{1+\delta^{br}}{\alpha+\gamma}\xi^b - \frac{\delta^{exr}}{\alpha+\gamma}\xi^e - \frac{1}{\alpha+\gamma}\xi^s$ .

only adjusted in response to a policy shock. This suggests that zero restrictions should be imposed on all coefficients, except for that of $u^{cr}$ in (15), thereby restricting the call rate targeting in (16).[37]

$$\xi^s = (1-\delta^{tr})u^{tr} - (1+\delta^{br})u^{br} + (\gamma\delta^{br} - \alpha\delta^{tr} - \varphi\delta^{exr})u^{cr} - \delta^{exr}u^{exr} \tag{15}$$

$$\delta^{tr} = 1, \quad \delta^{br} = -1, \quad \delta^{exr} = 0 \tag{16}$$

It is also likely that the BOK operates a hybrid target for monetary and exchange rate policy, that is, the central bank uses the mixed operating procedures based on both the call rate and the exchange rate. Thus, to test this weighted targeting hypothesis, Kasa and Popper's (1997) approach is adopted. A policy shock equation for weighted targeting is obtained as shown in (17) by solving (10)-(13) with the weighted average of the two targeting residuals and a weighting parameter ( $u^w = w^{cr}u^{cr} + w^{exr}u^{exr}$ and $w = \frac{w^{cr}}{w^{exr}}$, respectively). Similar to single targeting, imposing zero restrictions on all coefficients in the equation, except for that of the weighted residual ( $u^w$ ) restricts the weighted targeting in (18).

$$\xi^s = \frac{\gamma\delta^{br} - \alpha\delta^{tr} - \varphi\delta^{exr}}{w^{cr}}u^w - (\delta^{tr} + \delta^{br})u^{tr} + (1+\delta^{br})u^{br}$$

$$- \left[\frac{\gamma\delta^{br} - \alpha\delta^{tr} - \varphi\delta^{exr}}{w} + \delta^{exr}\right]u^{exr} \tag{17}$$

$$\delta^{tr} = 1, \quad \delta^{br} = -1, \quad \delta^{exr} = \frac{\alpha+\gamma}{w-\varphi} \tag{18}$$

The single and weighted targeting restrictions discussed above are thus used to estimate the restricted covariance model of (14), and in turn, to test the targeting hypotheses of the monetary and exchange rate policies in Section IV.

# IV. Econometric Methodology

## 1. Variables and Data

The VAR model in (2)-(4) uses six endogenous variables and four exogenous variables. The non-policy block in (2) includes the CPI and the industrial

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[37] The same restrictions can be obtained by imposing zero restrictions on all coefficients in the equation in footnote 36, except for that of the policy shock. Similarly, restrictions on the exchange rate targeting are found as follows: $\delta^{tr} = 1, \delta^{br} = -1, \delta^{exr} = -\frac{\alpha+\gamma}{\varphi}$.

production index, both of which are good monthly economic indicators. In particular, industrial production is widely used as a proxy for the real sector variable GDP. The policy block in (3) includes total reserves, non-borrowed reserves, the exchange rate, and the call rate. The exchange rate of the Korean won relative to the US dollar is included in order to characterize the exchange rate policy under a small-open economy. The other variables relate to the market for bank reserves.

The exogeneity block in (4) contains foreign variables such as the US federal funds rate, commodity price index, and exchange rates of the Japanese yen and Chinese yuan against the US dollar. These foreign exogenous variables are selected because they are the most likely to affect domestic economic activities and policy decisions, and thus they can help identify the BOK's stance on the prevailing monetary and exchange rate policies.[38] In particular, the commodity price index is included because it captures any additional information that is available to the monetary authorities and controls for anticipated inflation (Sims, 1992).[39] All variables are measured in a logarithm multiplied by 100 except for the call rate, which is measured in percentage terms.

Monthly data are collected from the International Financial Statistics of the IMF, except for commodity price index data, which come from the database of IMF primary commodity prices. The sample period is from January 1987 to July 2006. As noted in Section II-2, based on the starting period of the freely floating exchange rate system in Korea, the total sample is divided into two subsamples. The first subsample for the pre-crisis period comprises data from January 1987 to November 1997, while the second subsample for the post-crisis period runs from December 1997 to July 2006.

## 2. Estimation

The reduced-form VAR system shown in (5) and (7) is initially estimated using a Bayesian method. From the resulting residual information, the structural and policy parameters in (14) are estimated using the BFGS method. In these estimations, all hidden information and irregular movements in the data around the crisis period are used. In the next step, to check the robustness of the estimation results, they are dropped from sample.

First, the optimal lag length is determined for the variables in the exogeneity block equation to be substituted into the non-policy and policy block equations.

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[38] The US policy rate shock has an immediate impact on the foreign exchange rate in the financial market of India, and subsequently inflation and output are affected directly via an exchange rate channel and indirectly via an interest rate channel (Bhattacharya et al., 2011).

[39] Leeper et al. (1996) note that although variables that contain information on future inflation are available to monetary authorities, if they are not included in the model, the interest rate can respond unpredictably to inflation information.

The Akaike Information Criterion and Schwarz Information Criterion for lag length test find the optimal number of lags to be two. In other words, the AR(2) process is used for both subsamples.

Next, the estimation begins with a regression using AR(2) on the exogenous block equation in order to obtain the residual of $v_t$. After substituting the residual information into the reduced-form system, a regression is run with four lags and a full set of seasonal dummies in order to extract information on the non-policy residual $e_t^{np}$ from (5).[40] Similar to the residual of $v_t$, after substituting the residual $e_t^{np}$ into the system, a regression is rerun in order to obtain information on the policy residual $u_t^p$ from (8).[41] This last regression "cleans up" the effect of the non-policy shock on policy variables from all residuals in the policy block.

The variance-covariance matrix of $u_t^p$ contains the 10 pieces of information that are to be used to estimate the 10 parameters. In other words, (14) maps, on a one-to-one basis, the elements of the variance-covariance matrix of the residuals on the left-hand side into the elements of the (diagonal) variance-covariance matrix of structural shocks on the right-hand side and the coefficient matrices in both sides. As the mapping is non-linear in terms of parameters, the covariance model of (14) is estimated using the BFGS method, which is a gradient-based, non-linear estimation technique, using the policy residual information.[42]

The estimation is performed first without restrictions on the policy parameters in the model and then with restrictions (e.g., for call rate targeting in (16) and for weighted targeting in (18)).[43] Based on the two pieces of estimated likelihood information, a targeting hypothesis for the monetary and exchange rate policies is tested using both the Bayes factor and the likelihood ratio.

The likelihood ratio test determines whether the restricted model should be preferred over the unrestricted model. In other words, the test decides whether to reject the targeting hypothesis (e.g., call rate targeting restrictions) or not. If the test statistic is less than a critical value of chi-square statistics ($\chi^2$), the hypothesis is not rejected, which implies that the central bank takes an action on the call rate targeting in monetary policy. Since the likelihood ratio is in the form of logarithm, the statistic is computed using twice the difference between log-likelihoods,

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[40] Non-informative (uniform) prior is used for the deterministic variables, a prior mean of 1 for all endogenous variables' first own lags, and 0 for the rest of lag. Based on these characteristics of standard priors, the overall tightness parameter is set to 0.2, and the relative tightness parameter is set to 1 if $i = j$, and 0.5 otherwise for variable $j$ in equation $i$. To tighten up the prior with increasing lags, a harmonic type is used with a decay parameter value of 2.0.

[41] Alternatively, to extract information for $u_t^p$, the regression can be run with all residuals in (8) as a dependent variable on $e_t^{np}$ as independent variables.

[42] The BFGS algorithm is sensitive to the initial value, so initial estimates are refined using the "generic" method.

[43] Most model parameters are correctly estimated with the conventional signs and levels of statistical significance. The results are available upon request.

$2[\log(L_{un}) - \log(L_r)]$ , where $L_{un}$ and $L_n$ are unrestricted and restricted likelihoods, respectively.

The Bayes factor (i.e., the ratio of marginal likelihoods) in Bayesian analysis is an alternative to the likelihood ratio in the classical hypothesis test.[44] Similar to the likelihood ratio, it serves as a criterion for selecting the model and evaluates the strength of evidence for the targeting hypothesis. The Bayes factor statistic is calculated using the Schwarz criterion, which acts as a good approximation of its logarithm (Kass and Raftery, 1995).[45]

Table 3 reports the results for the single and weighted targeting hypotheses of the call rate and the exchange rate for the pre- and post-crisis periods. The results for the Bayes factor shown in the first and second columns show strong evidence against the call rate targeting hypothesis in the pre-crisis period, but no evidence against this hypothesis in the post-crisis period, suggesting that the restrictions in (16) cannot be rejected. This implies that the operating procedure of monetary policy in Korea switched to call rate targeting in the post-crisis period. The results also show weak evidence against the exchange rate targeting hypothesis in the pre-crisis period, but strong evidence against this hypothesis in the post-crisis period, which implies that the exchange rate is not targeted (controlled) in the post-crisis period.

The results for the likelihood ratio test shown in the third and fourth columns all correspond with those just presented for the Bayes factor, except the exchange rate targeting hypothesis is not rejected in the pre-crisis period. These findings are consistent with those of Parsley and Popper (2009), namely demonstrating that the BOK targets inflation, not the exchange rate in the post-crisis period. Overall, the outcomes support the previous findings described in Section II-2 for the monetary and exchange rate policy regime changes after the financial crisis.

The BOK has been identified as a single targeter in both the pre- and the post-crisis periods. However, it is also likely that the central bank targets both the call rate and the exchange rate in the form of a hybrid target. The bottom half of Table 3 reports the results of the weighted targeting hypothesis of the call rate and the exchange rate. The Bayes factor statistics provide no evidence against the targeting hypothesis in the post-crisis period, while the likelihood ratio statistics do not reject this hypothesis. In contrast to the previously presented result for the exchange rate targeting hypothesis, this finding implies that the BOK may still target the exchange rate with the call rate in the post-crisis period, namely by placing more weight on

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[44] From Bayes' theorem, we obtain $\frac{pr(H_1|\mathbf{D})}{pr(H_0|\mathbf{D})} = \frac{pr(\mathbf{D}|H_1)}{pr(\mathbf{D}|H_0)} \frac{pr(H_1)}{pr(H_0)}$ where $\mathbf{D}$ is data, $H_k$ is hypothesis, $pr(H_k|\mathbf{D})$ is posteriori probability, $pr(\mathbf{D}|H_k)$ is probability density, and $pr(H_k)$ is priori probability ( $k = 0, 1$ ). In words, posterior odds = Bayes factor × prior odds.

[45] The Schwarz criterion (S) is defined as follows: $\log B_{10} \approx S = \log pr(\mathbf{D}|\hat{\theta}_1, H_1) - \log pr(\mathbf{D}|\hat{\theta}_0, H_0) - \frac{1}{2}(d_1 - d_0)\log(n)$ where $\hat{\theta}_k$ is the maximum likelihood estimation under $H_k$, $d_k$ is the dimension of $\theta_k$, and $n$ is the number of observations (Kass and Raftery, 1995).

the call rate (0.780) than it does on the exchange rate (0.220). Further, this implies that its operating target for monetary policy has not yet completely switched to the call rate in the post-crisis period.

These findings suggest that under the inflation targeting framework, the exchange rate presumably plays an important role in monetary policy or as an intermediate target for monetary policy in order to stabilize prices. Further, they imply that the central bank may still implicitly (i.e., "unofficially") intervene in the foreign exchange market even though it has officially adopted a freely floating exchange rate regime in the post-crisis period.[46]

**[Table 3]** Targeting Hypothesis Test using the Bayes Factor and Likelihood Ratio

| Target | Bayes Factor | | Likelihood Ratio | |
|---|---|---|---|---|
| Single | Pre-crisis | Post-crisis | Pre-crisis | Post-crisis |
| Call Rate | 425.87(VS) | **-5.17(NA)** | 440.41(Reject) | **8.76(NR)** |
| Exchange Rate | 0.26(Weak) | **20.95(VS)** | 14.79 (NR) | **34.88(Reject)** |
| Weighted | | | | |
| Exchange and Call Rates | 4.58(Positive) | **-0.52(NA)** | 14.26(Reject) | **8.76(NR)** |
| Weighting Parameter | | | | |
| $W$ | 0.492 | 3.541 | | |
| Call Rate ($w^{cr}$) | 0.330 | **0.780** | | |
| Exchange Rate ($w^{exr}$) | 0.670 | **0.220** | | |

Notes: 1) The Bayes factor statistics are evaluated at $2\log(B_{10})$. 2) The critical values and interpretation of the Bayes factor for evidence against $H_0$ are defined as follows (Kass and Raftery, 1995): 0 to 2 "not worth more than a bare mention" or "weak" (Cameron and Trivedi, 2005), 2 to 6 "positive", 6 to 10 "strong", > 10 "very strong". 3) VS, NA, and NR represent Very Strong, Not Against, and Not Rejected, respectively. 4) The weights of the exchange rate and the call rate are computed based on $w = \frac{w^{cr}}{w^{exr}}$ and $w^{cr} + w^{exr} = 1$. 5) The likelihood ratio statistics are distributed as $\chi$ (3) for the single targeting hypothesis and $\chi$ (2) for the weighted targeting hypothesis, and they are evaluated at the significance level of 0.001.

To check the robustness of the above described results, the data biased by the financial crisis are excluded from the subsamples. The same number of observations (10) is thus deleted from both the pre-crisis and the post-crisis subsamples.[47]

Table 4 shows robust results for both the single and the weighted targeting hypotheses. Overall, the outcomes are similar, even though they are shown to be somewhat different to the previous findings. The exchange rate targeting hypothesis

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[46] See Willett et al. (2011) and Eichengreen (2004).

[47] The periods of deletion are determined based on Park et el.'s (2001) definition of the crisis period from October 1997 to September 1998. However, to equate the number of observations eliminated from each subsample, the period of deletion for the pre-crisis sample starts in February 1997, not in October 1997.

Second, the paper finds that the BOK is not a sole exchange rate targeter under the freely floating exchange rate regime in the post-crisis period. However, it is demonstrated herein that the central bank uses the call rate as a new operating target (i.e., as a single targeter) for monetary policy. This suggests that it currently adopts the use of inflation targeting to anchor monetary policy. Moreover, the central bank adopts a hybrid operating procedure of targeting both the call rate and the exchange rate, placing more weight on the call rate than it does on the exchange rate.

The implications for monetary policy in Korea are that the central bank changed its operating target for monetary policy from monetary aggregates to the call rate in the post-crisis period, but that its stance on monetary policy is likely to remain in transition under such an inflation targeting framework and a freely floating exchange rate regime. Finally, the exchange rate presumably plays a significant role in monetary policy or as an intermediate monetary policy target to stabilize prices.

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