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Estimating the Bank of Korea's Monetary Policy Reaction Function: New Evidence and Implications

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Employing the VAR to estimate the Bank of Korea's reaction function, we find that the call rate reacts positively to a shock to the inflation gap, the output gap, the exchange rate gap, the stock price gap, and the lagged call rate during some of the quarters. In explaining the variance of the call rate, the inflation gap and the exchange rate gap are more influential in the short run whereas the output gap and the stock market gap are more important in the long run.

JEL Classification: E4, E5
Keywords: monetary policy reaction function, Taylor rule, VAR model, impulse response function, variance decomposition

1. INTRODUCTION

The objectives of the Bank of Korea (BOK) are to pursue price and financial stability for a sustainable economic growth. During the Asian financial crisis, monetary policy was pursued to achieve the above mentioned goals. During 1997.M7 – 1998.M1, the Korean won plunged by 91% as the exchange rate rose from a low of 890.50 won per U.S. dollar to a high of 1,701.53. Partly due to the depreciation, the inflation rate rose 6.32% during the same period. The industrial production index dropped 15.6% from a high of 118.21 in 1997.M10 to a low of 99.82 in 1998.M7. Real

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GDP at the 1995 value declined 21% from 115,952 billion won in 1997.Q4 to 91,580.7 billion won in 1998.Q1. Unemployment rates rose from a very low level of 2.1% in 1997.M10 to a high of 7.6% in 1998.M7. Industrial share prices dropped 49% from 83.09 in 1997.M6 to a low of 42.38 in 1997.M12. Faced with a recession, rising inflation, currency depreciation, and poor stock market performance, the Bank of Korea kept the discount rate at 5.0% but raised the call rate from 11.19% in 1997.M6 to a high of 25.63% in 1998.M1. To further defend the won and mitigate the inflationary pressure, seasonally adjusted M1 was reduced from 34,495 billion in 1997.M11 to 31,764.4 billion in 1997.M12 and 28,118.2 billion in 1998.M6. Several comments on the Bank of Korea's monetary policy during the Asian financial crisis can be made. The Bank of Korea changed the call rate more often than the discount rate. Due to the lags in information and recognition, the Bank of Korea implemented monetary policy with a lag. Monetary policy was employed to resolve several macroeconomic variables, which may be in conflict with one another. For example, real GDP in Korea declined during 1997.Q4 – 1998.Q1, but the call rate went up from 16.44% to 23.93% during the same period. During the turbulent times of the Asian financial crisis, the Bank of Korea raised the call rate to defend the won and address the concern of rising inflation. On the other hand, the recession would require the Bank of Korea to lower the call rate.

This paper studies the Bank of Korea's monetary policy reaction function. Extending the simple Taylor rule (1993, 1995, 1998a, 1998b, 1999), the paper considers three additional variables, namely, the exchange rate, stock market performance, and the lagged call rate. The inclusion of the exchange rate variable is consistent with the Bank of Korea's objectives of maintaining price and financial stability because a substantial depreciation of the won would cause domestic price and wage inflation and capital outflows. We follow Bernanke and Gertler (1999) and Rigobon and Sack (2003) that stock prices may enter into the reaction function as another variable. The paper also considers two exogenous variables, namely, the federal funds rate and a dummy variable for the Asian financial crisis. Hence, this paper extends Hsing's (2004) study, which does not consider stock prices and the two exogenous variables in examining the Bank of Canada's policy function. The VAR model is applied in empirical work in order to take into consideration potential simultaneous relationships among endogenous variables. In the impulse response function and the variance decomposition, we will present the possible response of monetary policy to a shock to each of the endogenous variables and the percent of the variance that can be attributable to each of the individual endogenous variables. The Hodrick-Prescott (1997) filter is employed to estimate potential output and trend values for other selected variables.

2. LITERATURE SURVEY

Several major articles related to the monetary policy reaction function and the Taylor rule are surveyed and summarized. Judd and Rudebusch (1998) found that the performance of a Taylor-rule type function varies during the periods of Burns, Volcker, and Greenspan and suggested that the Taylor rule framework is useful in summarizing major variables of monetary policy. In comparison, they indicated that the Taylor rule yields less standard deviation during the Greenspan period than the Volcker period and cannot converge during the Burns period mainly because monetary policy under Burns was less responsive to inflation and more sensitive to business cycles. Clarida, Gali and Gertler (1998) estimated the reaction functions for the G3 (U.S., Japan, and Germany) and E3 (U.K., France, and Italy) countries. According to their findings, central banks in the G3 countries pursued inflation targeting implicitly, were forward-looking, and reacted to the expected inflation instead of the past inflation. On the other hand, central banks in the E3 countries relied too much on the German monetary policy and kept interest rates higher than the domestic economic conditions required. They suggested that targeting inflation may be better than fixing the exchange rate. David Romer (2001) made several comments on the Taylor rule. Relatively large values of the coefficients for the inflation and output gaps would cause the actual inflation rate and output to decline faster than expected. It would be proper to use the lagged inflation gap and the output gap. To deal with an open economy, the exchange rate may need to be considered. The lagged federal funds rate should be considered to capture partial adjustment. The output gap may vary due to different estimates for potential output.

Bernanke and Gertler (1999) stressed the role of asset prices in monetary policy mainly because it would affect the balance sheet and the cost of borrowing. They empirically tested the model using the U.S. and Japan as samples. They criticized Japan's monetary policy in dealing with asset prices and inflation during the 1980s and 1990s and found that the Fed reacted preemptively to inflation and did not respond to asset prices independently. They suggested that a central bank should react to asset prices only if rising asset prices would raise inflation expectations. Rigobon and Sack (2003) showed that monetary policy responds significantly to stock market performance in that there is a 50% probability that the Fed would reduce the federal funds rate by 25 base points if the S&P index drops by 5%. However, Bullard and Schaling (2002) showed that including asset prices in the Taylor rule would result in an indeterminate equilibrium and more unpredictable volatility and suggested that asset prices should not be included in Fed's reaction function.

Hsing (2004) studied the Bank of Canada's reaction function and found that the extended Taylor rule including the exchange rate applies to Canada because one of the objectives of the Bank of Canada is to maintain currency stability in order to promote international trade. Applying the VAR model, he estimated the impulse-response function and variance decomposition for the call rate. He showed that the Bank of Canada would raise the call rate in response to a depreciation of the Canadian dollar and that more variation in the call rate can be attributable to a shock to the output gap.

Cargill (2001) reviewed the impact of the amended Bank of Korea Act in 1997 that strengthened its independence, required setting an inflation target range, focused its efforts on price stability, and shifted its supervisory authority to a new agency. Kim (2002) indicated that the optimal policy and feedback horizons for inflation targeting are estimated to be 4-9 and 3-6 quarterly, respectively. Hence, the Bank of Korea needs to take preemptive actions ahead of the time in order to reduce the volatility of a shock. Kim (2000) showed that the high interest rate policy in the 1997 as required by the IMF did not lead to the appreciation of the won. Instead, the won depreciated. Thus, he maintained that the IMF policy may be ill-advised. Applying the FIGARCH model, Han (2003) found, among other things, that during the Asian financial crisis, the Bank of Korea's interventions to defend the won was not effective and did not impact the excess return or risk premium.

3. THE MODEL

The simple Taylor rule in general form can be written as

$$\text{FFR} = f(\text{ID}, \text{YD}) \quad (1)$$

where,

FFR = the federal funds rate,
YD = the output gap ($Y - \overline{Y}$),
ID= the inflation gap ($\pi - \overline{\pi}$),
Y= actual output,
$\overline{Y}$ = potential output,
π = the actual inflation rate, and
$\overline{\pi}$ = the target inflation rate.

The simple Taylor rule can be extended to consider the exchange rate and stock market performance for Korea and expressed as

$$\text{R} = f(\text{YD}, \text{ID}, \text{ED}, \text{SD}) \quad (2)$$

where,

R= the call rate in Korea,

ED= deviation of the exchange rate from the trend, and

SD= deviation of stock prices from the trend.

To consider potential simultaneous relationships and avoid simultaneity, equation (2) can be expressed by the VAR model

$$\mathbf{E}_t = \boldsymbol{\beta}_1\mathbf{E}_{t-1} + \ldots + \boldsymbol{\beta}_m\mathbf{E}_{t-m} + \boldsymbol{\theta}\,\mathbf{X}_t + \boldsymbol{\varepsilon}_t \qquad (3)$$

where,

E= a vector of the endogenous variables [R, ID, YD, ED, SD],

X = a vector of the exogenous variables [FFR, DUM],

β and **θ** = parameter matrices, and

ε = white noise error term.

DUM = a dummy variable (1997.Q4 – 1998.Q3) for the Asian financial crisis.

According to the Taylor rule, the call rate is expected to react positively to a shock to the inflation gap or the output gap. In its Objectives of Monetary Policy, the Bank of Korea stated that it "takes price stability as the most important objective of its monetary policy" for a sustainable economic growth. We also anticipate that the response of R to ED would be positive. In its Objectives of Monetary Policy, the Bank of Korea stated clearly: "Financial stability has become another important objective of monetary policy…Financial instability can trigger serious economic crises." When the Korean won depreciates beyond the level that the Bank of Korea can tolerate, it would raise the call rate to strengthen the won so that it would not lead to domestic inflation.

Following Bernanke and Gertler (1999) and Rigobon and Sack (2003), the stock price is included in the VAR model to test whether the Bank of Korea may use its interest rate policy to maintain a healthy stock market. In the monetary transmission mechanism (Mishkin, 1995), the stock market plays an important role as higher stock prices would cause households to spend more via the wealth effect and firms to invest more via Tobin's q theory or the balance-sheet channel (Bernanke and Gertler, 1995).

These variables may affect each other. The call rate is expected to be influenced by the output gap, the inflation gap, the exchange rate gap, and the stock price gap. After the Bank of Korea reduces the benchmark call rate, banks would follow suit to reduce short- term interest rates. The lower rate would cause household consumption and business investment spending to rise, shift the aggregate demand curve upward, and result in a higher GDP, which, in turn, would cause the output gap to rise. When the GDP increases, the unemployment rate would decline and the inflation rate would rise, causing the inflation gap to increase. It may be possible that an increase in the exchange rate gap would have a direct effect on the inflation gap and that an increase in the stock price gap would impact the output gap positively. Because we apply the VAR in empirical work and because all the endogenous variables are the same and have lag values, the simultaneity problem is not a concern and OLS yields efficient and consistent estimates.

4. EMPIRICAL RESULTS

The sample consists of quarterly data ranging from 1978.Q1 to 2003.Q2. Data for industrial share prices earlier than 1978.Q1 is not available. All the data were obtained from the *International Financial Statistics* published by the International Monetary Fund. R is call rate expressed as percent. The inflation rate is derived from the consumer price index and includes the current plus past three quarters. The inflation gap is the difference between the average inflation rate and the target inflation rate of 2.0%. Real GDP is expressed in billions of the won. The nominal exchange rate is expressed as units of the won per U.S. dollar. The industrial share price is used to represent the stock price index. Trend values for real output, the exchange rate, and the stock index are estimated by the filtering process developed by Hodrick-Prescott (1997).

The ADF test with an intercept in the equation is employed to determine whether each of the time series would have a unit root. We find that ED and SD in levels are stationary, ID, YD, and R in levels are not stationary, and ID,

Table 1 Vector Error Correction Model

Vector Error Correction Estimates
Sample: 1978:1 2003:2
Included observations: 102
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		
R(-1)	1.000000		
ID(-1)	-0.942474		
	(0.23559)		
	[-4.00048]		
YD(-1)	0.217235		
	(0.51466)		
	[0.42209]		
C	-7.351479		
Error Correction:	**D(R)**	**D(ID)**	**D(YD)**
CointEq1	-0.068462	0.081752	0.015929
	(0.05126)	(0.05064)	(0.03491)
	[-1.33547]	[1.61449]	[0.45625]
D(R(-1))	0.290136	0.132976	0.023015
	(0.10302)	(0.10176)	(0.07016)
	[2.81625]	[1.30675]	[0.32803]
D(R(-2))	-0.259093	0.047067	0.076145
	(0.10607)	(0.10477)	(0.07224)
	[-2.44258]	[0.44922]	[1.05408]
D(ID(-1))	-0.097764	0.050578	0.097790
	(0.11031)	(0.10896)	(0.07513)
	[-0.88624]	[0.46418]	[1.30169]
D(ID(-2))	-0.049160	0.138076	0.068995
	(0.10783)	(0.10651)	(0.07343)
	[-0.45592]	[1.29641]	[0.93957]
D(YD(-1))	0.406084	0.202181	-0.322789
	(0.15048)	(0.14864)	(0.10248)
	[2.69860]	[1.36024]	[-3.14980]
D(YD(-2))	0.316857	0.093254	-0.201953
	(0.15322)	(0.15134)	(0.10434)
	[2.06801]	[0.61618]	[-1.93545]
C	-0.150642	-0.034983	0.056473
	(0.16928)	(0.16721)	(0.11528)
	[-0.88990]	[-0.20922]	[0.48987]
R-squared	0.219801	0.144449	0.136792
Adj. R-squared	0.161701	0.080738	0.072510
Sum sq. resids	271.5618	264.9501	125.9468
S.E. equation	1.699693	1.678874	1.157523
F-statistic	3.783145	2.267243	2.128012
Log likelihood	-194.6718	-193.4147	-155.4869
Akaike AIC	3.973957	3.949308	3.205626
Schwarz SC	4.179837	4.155189	3.411507
Mean dependent	-0.134314	-0.067265	0.022922
S.D. dependent	1.856397	1.751049	1.201919
Determinant Residual Covariance	8.624029		
Log Likelihood	-531.5806		
Log Likelihood (d.f. adjusted)	-544.0774		
Akaike Information Criteria	11.19760		
Schwarz Criteria	11.89244		

YD, ED, SD and R in difference are stationary.[1] The Johansen cointegration test including R, ID and YD and excluding ED and SD is performed. The trace statistic is estimated to be 53.25 compared with the critical value of 48.45 at the 1% level. Hence, we find that R, ID, and YD have a long-term stable relationship. For the nonstationary variables that are cointegrated (Hayashi, 2000), a VECM is estimated and presented in Table 1.

Based on the Akaike, Schwarz and other information criteria and the level form, a lag length of 5 for the VAR model is chosen.[2] Thus, the actual sample runs from 1979.Q2 to 2003.Q2. The regression for the call rate has an adjusted R^2 of 0.924 and the F test statistic of 44.13. Compared with the approximate critical value of 2.12 with 27 and 69 degrees of freedom at the 1% level, the whole regression is significant.

The impulse-response function for the call rate is presented in Figure 1. The response of the call rate to a shock to the inflation gap, the output gap, the exchange rate gap, the stock market gap, or the lagged call rate is positive and significant during some of the periods. There are several comments on the results. Generally speaking, the Bank of Korea's reaction function follows the simple Taylor rule that a central bank would raise the interest rate in response to an increase in the inflation gap or the output gap. Furthermore, the Bank of Korea would also take actions if the exchange rate deviates from its trend. If currency depreciation is greater than what the central bank would expect, the Bank of Korea would intervene in the foreign exchange market by raising the call rate, and vice versa. The Bank of Korea also monitors the stock market performance. If the stock market

[1] A different trending method with a linear trend and the intercept included in the test equation and the GLS-ADF test were employed to test unit roots. The results show that ID and YD are nonstationary at the 5% level.

[2] We ran the VAR in first difference and find that within a 95% confidence interval, the call rate does not respond to the inflation gap and the stock price gap significantly and that it reacts positively to the output gap and negatively to the exchange rate gap. The insignificant response of the call rate to the inflation gap and the negative response of the call rate to the exchange rate gap seem to be inconsistent with the BOK's monetary policy. Hamilton (1994) indicated that the level form would be acceptable in running VARs because differencing may throw away valuable information and does not yield asymptotic efficiency in an autoregressive time series

Figure 1 Impulse Response Function of the Call Rate

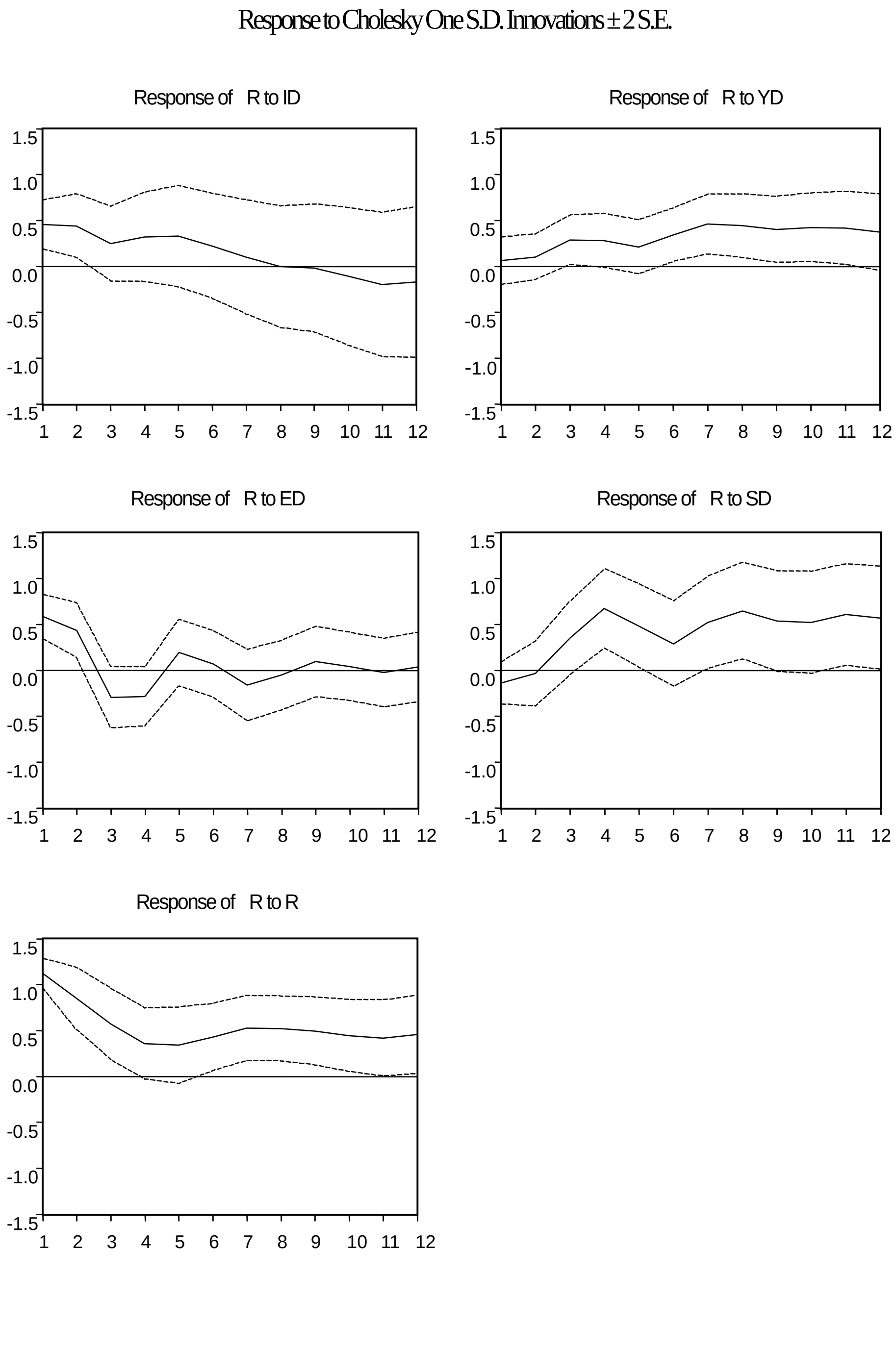

Table 2 Impulse Response Function of the Call Rate

Period	ID	YD	ED	SD	R
1	0.455641	0.060456	0.584179	-0.140827	1.122541
	(0.13350)	(0.12935)	(0.12229)	(0.11442)	(0.08059)
2	0.441463	0.103313	0.432849	-0.037464	0.847930
	(0.17302)	(0.12322)	(0.15044)	(0.17743)	(0.16885)
3	0.245786	0.287001	-0.295443	0.352401	0.568674
	(0.20288)	(0.13485)	(0.16691)	(0.19875)	(0.19478)
4	0.317277	0.282426	-0.286871	0.672325	0.358527
	(0.24255)	(0.14778)	(0.16083)	(0.21552)	(0.19380)
5	0.327320	0.209117	0.191765	0.483721	0.338275
	(0.27585)	(0.14650)	(0.18090)	(0.22808)	(0.20838)
6	0.221417	0.343562	0.065816	0.286938	0.428366
	(0.28746)	(0.14533)	(0.18169)	(0.23342)	(0.18206)
7	0.102019	0.458315	-0.162642	0.521128	0.525636
	(0.31165)	(0.16195)	(0.19445)	(0.24982)	(0.17646)
8	-0.004569	0.443490	-0.053866	0.647785	0.520150
	(0.33101)	(0.17289)	(0.18866)	(0.26352)	(0.17748)
9	-0.019651	0.402620	0.093232	0.535852	0.492820
	(0.34926)	(0.17973)	(0.19294)	(0.27470)	(0.18479)
10	-0.107522	0.424785	0.040770	0.520890	0.443687
	(0.37497)	(0.18782)	(0.18464)	(0.27940)	(0.19574)
11	-0.200447	0.419279	-0.026163	0.605834	0.417406
	(0.39280)	(0.19874)	(0.18690)	(0.27717)	(0.20753)
12	-0.172877	0.370958	0.034412	0.568455	0.455611
	(0.41097)	(0.20886)	(0.19002)	(0.28098)	(0.21365)

Note: Cholesky Ordering: ID YD ED SD R.

performance is below its trend, the Bank of Korea would drop the call rate to make the credit available and reduce the cost of borrowing. Table 2 reports the impulse-response function for the call rate with numerical values.

The variance decomposition for the call rate is presented in Table 3. Each value represents the proportion of the variance of the call rate that can be explained by the variable in that column. As shown in the table, within

Table 3 Variance Decomposition of the Call Rate

Period	S.E.	ID	YD	ED	SD	R
1	1.287480	11.32950	0.199454	18.62334	1.082275	68.76543
2	1.933572	13.66359	0.486412	17.94518	0.720893	67.18393
3	2.426309	12.77548	2.668700	16.99807	4.013408	63.54434
4	3.073344	12.61722	3.950628	15.63135	13.37548	54.42532
5	3.374264	13.40684	4.401425	14.69148	16.61940	50.88086
6	3.595753	13.23051	6.217435	13.59033	16.79715	50.16458
7	3.768123	11.71088	8.793919	12.28217	19.01173	48.20131
8	3.883745	10.24860	10.45629	10.78897	22.52720	45.97895
9	4.009896	9.335251	11.59080	9.933345	24.17788	44.96272
10	4.120590	8.743512	12.81292	9.178340	25.48927	43.77596
11	4.237787	8.461321	13.66396	8.433330	27.36960	42.07179
12	4.331688	8.166777	14.08673	7.852141	28.69407	41.20028

Notes: 1) Cholesky Ordering: ID YD ED SD R.
2) Standard Errors: Analytic.

the 95% confidence interval, the lagged call rate is the most influential variable as it can explain up to 68.8% of the variation in the call rate. In the first year, the inflation gap and the exchange rate gap can explain up to 11.3% and 18.6% of the variance, respectively. In the long run, the stock market gap can explain up to 28.7% of the variation in the call rate. The call rate reacts positively to the output gap, which can explain up to 13.7% of the variance.

In its Objectives of Monetary Policy, the BOK "takes price stability as the most important objective of its monetary policy" for a sustainable economic growth and states that "financial stability has become another important objective of monetary policy." In the original Taylor rule, the ordering is ID and YD. Considering the views that a large depreciation of the won may cause domestic inflation and that stock prices are difficult to predict in the short run, the ordering of ID, YD, ED, and SD should be appropriate. To check the robustness of empirical results, we change the ordering of the endogenous variables from ID, YD, ED, SD, R to YD, ID, ED, SD, and R.

The results are similar. To save space, the graph and tables will be available upon request and are not printed here.

5. SUMMARY AND CONCLUSIONS

In this paper, we have investigated the Bank of Korea's monetary policy reaction function. We extend the simple Taylor rule by including the exchange rate gap, the stock price gap, and the lagged call rate. The VAR model is employed in empirical work. Major findings are summarized as follows. The call rate reacts positively to a shock to the inflation gap, the output gap, the exchange rate gap, the stock market gap, or the lagged call rate in some of the periods. Except for the lagged call rate, the inflation gap and the exchange rate gap are more influential in the short run whereas the output gap and the stock price gap are more influential in the long run. There are several policy implications. First, the concept of the Taylor rule can be applied to the case of Korea as the call rate is positively associated with the inflation gap and the output gap. The extended Taylor rule including the exchange rate gap, the stock price gap, and the lagged call rate is a better model because it captures how a small open economy attempts to stabilize the exchange rate and the equity market. It would be appropriate for the Bank of Korea to set up priorities when conflicting goals are involved. For example, raising the interest rate to defend the won exchange rate may be in conflict with stimulating investment spending, and lowering the interest rate to devaluate the won to encourage exports may cause import prices and domestic inflation to rise.

Future research may consider the following areas. The inflation gap and the output gap did not explain as much variation in the call rate as we had expected. It may be possible to reconstruct these two variables differently. Other monetary policy tools such as the monetary base and the discount rate may be considered in empirical work. The conventional single-equation model may be considered to compare with the VAR model.

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