Estimating the Bank of Japan's monetary policy reaction function

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1. Introduction

Since the late 1980s and early 1990s, Japan's stagnant economy has become the subject for many studies. The Nikkei 225 stock index declined 79.9%, from a high of 38,916 in December 1989 to a low of 7,831 in April 2003. Since then, the stock index has recovered somewhat and risen by 36.3% to 10,677 in December 2003. During 1991-2001, land prices in six major urban cities declined 68%, resulting in substantial increases in bad loans, bankruptcies and foreclosures. There have been concerns about the pressure of deflation as evidenced by the declining consumer price index from 102.54 in 1998 to 99.84 in 2002. In the real sector, real GDP had a negative growth rate in 1998 and grew at a very slow pace of 0.16% in 2002. Due to deficiency in aggregate demand, the unemployment rate rose from a low of 2.10% in 1990 to a high of 5.38% in 2002. To stimulate the economy and to provide member banks with adequate liquidity at a very low cost, the Bank of Japan (BOJ) has lowered the discount rate from a high of 9% in 1974 to a low of 0.10% in December 2003. The overnight call rate, which is equivalent to the federal funds rate in the US, followed suit to decline to the lowest level of 0.001% for uncollateralized loans in December 2003. The success or failure of Japan's monetary policy may become a major lesson for other countries to learn.

Posen (1998) indicated that the weak Japanese economy was due to the government's domestic financial and macroeconomic policies

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and that it is important for other countries to take countercyclical policy to stimulate the economy. He proposed that expansionary fiscal policy, stabilization of monetary policy and reform in financial systems are needed for Japan to come out of the economic slowdown.

In their study of Japan's "Great recession", Kuttner and Posen (2001) found that the actual output for Japan in 1999 was 11% below potential output and that M2 had a relatively persistent impact on prices whereas the monetary base and prices were not cointegrated. Larger monetary base led to yen depreciation mainly through its effect on the interest rate. Over a 4-year period, the tax multiplier was estimated to be 4.84, and the government spending multiplier was 3.53. The effect of a tax cut was temporary whereas the impact of government spending was relatively enduring. Due to lack of evidence for Ricardian equivalence theory in Japan, they recommended an expansionary fiscal policy of more government spending or less tax or both to rescue the Japanese economy out of the stagnation.

This paper attempts to examine the monetary policy reaction function for the Bank of Japan and has several aspects that are different from previous studies. First, the author extends the Taylor rule by including the exchange rate and the stock market index in the reaction function in order to reflect the BOJ's emphasis on the stability of the exchange rate and the financial system. Second, the VAR model is employed in empirical work to consider possible simultaneous relationships among the endogenous variables and to avoid simultaneity bias. Third, potential output is estimated by the Hodrick and Prescott (1997) filtering process to find a long-term trend or a smoothed series for output by minimizing the variance of actual real GDP subject to a penalty that constrains the second difference of the smoothed series.

2. Literature survey

Judd and Rudebusch (1998) investigated and reviewed previous works and maintained that the Taylor rule is a valuable guide to characterize major relationships among variables in conducting monetary policy. They showed that the Taylor rule overpredicts the federal funds rate (FFR) during the Burns period, underpredicts most of FFR through-

out the Volcker era, and predicts FFR quite well during some of the Greenspan term.

David Romer (2001) analyzed several issues in applying the Taylor rule. The values for the coefficients of the output gap and the inflation gap would change the effectiveness of monetary policy. Larger values of the coefficients would cause the actual inflation rate and output to decline more than expected. Due to a lag in information, it would be more appropriate to use the lagged values for the output gap and the inflation gap. The exchange rate and the lagged federal funds rate need to be included to incorporate the open economy and the partial adjustment process. Potential GDP may be measured differently, causing the output gap to vary.

Applying the VAR model, Assane and Malamud (2000) examined the relationship between monetary policy and exchange rates. They found that after the federal funds rate rises, the US dollar appreciates and that a weak dollar causes the Fed to raise the federal funds rate. Kalyvitis and Michaelides (2001) showed that the US dollar was overshot instantaneously in response to a monetary shock.

Cogley (1999) and Bullard and Schaling (2002) maintained that the Fed should not interfere with the stock market mainly because it would be difficult to take actions timely and reduce its ability to reduce output and inflation variability. Tatom (2002) found that equity prices and the federal funds rate have an inverse relationship and that the Fed would not raise FFR to dampen equity prices. Rigobon and Sack (2003) revealed that monetary policy responds to equity prices significantly enough to have an impact on aggregate demand and that if the stock index rises by 5%, the probability of a 0.25 percentage point increase will go up by half.

Several recent studies examined Japan's monetary policy and related issues. Applying the VAR model, Asai and Shiba (1995) found that major macroeconomic variables affected stock prices and that proper macroeconomic policy would help the stock market. Ito and Iwaisako (1995) analyzed movements in land and stock prices during 1985-89. A substantial increase in bank lending caused initial increase in asset prices. Low interest rates and a strong economy explained only part of asset price changes. Basile and Joyce (2001) attempted to determine whether the bubbles in the land and equity markets in the early 1990s affected and were affected by other variables. They found that the money supply, bank lending, or output did not have any

significant impact on bubbles in the land and stock markets. Instead, they reported that the equity market bubble was influenced by its own lagged values and also affected the land price bubble.

Asako and Kanoh (1997) examined five determinants of Japan's monetary policy during 1968-93, which are inflation, exchange rate movements, trade balances, output and government bonds outstanding. They found that empirical results are consistent with the BOJ's statements when the discount rate was changed. Clarida, Galí and Gertler (1998) compared monetary policies for central banks in the G3 (US, Japan and Germany) and E3 (UK, Italy and France). They found that central banks in the G3 adopted implicit inflation targeting and were forward-looking responding to anticipated inflation and that central banks in the E3 were greatly affected by the German monetary policy and set the interest rates higher than those required by the domestic macroeconomic conditions. They suggested that targeting inflation may be better than fixing exchange rates in pursuing monetary policy. Bernanke and Gertler (1999) stressed the importance of both price stability and financial stability because higher volatility of stock prices would affect other sectors. They maintained that monetary policy should respond to stock prices if the latter raises inflation expectations. They proposed a flexible inflation targeting and used the forward-looking inflation in empirical work. In their analysis of the BOJ's monetary policy, they noticed that the BOJ responded to stock prices.

Meltzer (2001) examined Japan's economic slowdown during 1985-99. The recession in the early 1990s was due to a decrease in the growth of money supply whereas the more recent slowdown was caused by a decline in exports that was attributable to a failure to devalue the yen. He called for the BOJ to depreciate the yen and pursue expansionary policy to end the deflation. Applying the VAR model to investigate reasons for recessions in Japan during the 1990s, Bayoumi (2001) found that lack of consistent and valiant expansionary fiscal policy limited the role that the BOJ can play because of a potential liquidity trap, overinvestment and debt burden, and the trouble of financial intermediation due to asset bubbles. The last one was regarded as a major factor.

Saito (2001) reviewed monetary policy in Japan and found that the BOJ provided adequate market liquidity during the Asian financial crisis but did not provide proper guidance regarding business cycles

mainly because of inadequate awareness to the very elastic demand for money and the flat Phillips curve.

Miyao (2002) considered Japan's industrial production, the monetary base, the overnight call rate and the stock price, and applied the VAR model to find their interrelationships. He reported that the variation in industrial production was persistently influenced by monetary policy shocks, especially in the late 1980s. When a price variable is added, similar results were found. McCallum (2003) reviewed Japan's monetary policy during 1991-2001. He indicated that the BOJ's expansionary monetary policy was not adequate and that special problems arose due to almost zero interest rates. He advocated that the JOB should buy foreign exchange to increase monetary base to stimulate the economy. Applying the ARCH model and using daily date during October 1992-September 1993, Chang and Taylor (1998) found that the JPY/US$ exchange rates were influenced positively by the intervention by the BOJ especially with high frequency data. Schwartz (2000) reviewed exchange rate interventions by the US, Europe and Japan. She indicated that the US and Europe have given up the use of intervention to control exchange rates and that Japan is still intervening in the foreign exchange market. She showed why intervention would not work based on inconclusive findings of empirical work and the problems in implementing the intervention. Applying the VAR model, Miyao (2003) tested the effectiveness of yen depreciation on economic activities during 1975-2001. He showed that during 1975-2001, following yen depreciation imports declined substantially and exports did not rise significantly. However, yen depreciation stimulated exports before mid-1980s. Hence, he indicated that a possible structural break existed in the mid-1980s.

3. The model

The original Taylor rule can be expressed as

$$FFR = f(YG, IG) \tag{1}$$

where

FFR = the federal funds rate,

YG = the output gap ($Y - Y^*$),

IG = the inflation gap ($\pi - \pi^*$),

Y = actual output,

Y^* = potential output,

π = the actual inflation rate, and

π^* = the target inflation rate.

The extended Taylor rule can be written as

$$FFR = g(YG, IG, EX, SP) \tag{2}$$

where

EX = the exchange rate and

SP = stock prices.

Replacing *FFR* with the overnight call rate in Japan, equation 2 can be estimated by the following VAR model

$$\mathbf{X}_t = \boldsymbol{\beta}_1\mathbf{X}_{t-1} + \ldots + \boldsymbol{\beta}_m\mathbf{X}_{t-m} + \boldsymbol{\theta}\,\mathbf{Z}_t + \varepsilon_t \tag{3}$$

where

X is a vector of the endogenous variables [CR, YG, IG, EX, SP],

Z is a vector of any exogenous variable,

CR = the (overnight) call rate,

$\boldsymbol{\beta}$ and $\boldsymbol{\theta}$ = parameter matrices, and

ε = white noise error term.

As the Taylor rule indicates, I expect that *CR* would respond positively to a shock to *YG* or *IG*. I also anticipate that the response of *CR* to *EX* would be positive. In its Missions and Activities, the BOJ stated clearly: "The Bank closely monitors exchange rate developments. It intervenes in the foreign exchange market as an agent of the Minister of Finance, when necessary" (Bank of Japan 2004). When the Japanese yen becomes weaker or the exchange rate rises, the BOJ would attempt to stabilize the weak yen by raising the overnight call rate so that the demand for the yen would increase.

Following Bernanke and Gertler (1999) and Miyao (2002) and reflecting BOJ's concerns about the negative impact of poor stock mar-

ket performance in its *Monetary Policy: Outlook and Risk Assessment of the Economy and Prices* in October 2002 and April 2003, the stock index is included in the VAR model to test whether the BOJ may use its interest rate policy to maintain a healthy stock market. Specifically, the BOJ is likely to lower interest rates in response to poor stock market performance, which may signal poor economic conditions in the future.

Some of these variables may have simultaneous relationships. I expect that *CR* would respond to *YG*, *IG* or *EX*. On the other hand, after the BOJ lowers the interest rate, consumption and investment spending are expected to rise, thus shifting the aggregate demand curve to the right and causing equilibrium GDP to rise. A higher GDP would cause *YG* to increase. In the short run, as output rises, unemployment rates drop and inflation rates increases, causing *IG* to widen. Because of the application of the VAR model and because all the right-hand side variables are identical and lagged, simultaneity bias is not a concern, and the OLS estimates are as good as the GLS estimates.

4. Empirical results

The stock index for Nikkei 225 came from the Tokyo Stock Exchanges. Potential output was estimated based on the Hodrick and Prescott (1997) filtering process. The data for all other variables were taken from the *International Financial Statistics* published by the International Monetary Fund (2003). The inflation rate was derived from the consumer price index. Consistent with Bernanke and Gertler (1999), the sample begins in 1979.Q1 and ends in 2002.Q4.

The ADF unit root test is performed first (Table 1). The critical values are –3.50, –2.89 and –2.58 at the 1%, 5% and 10% level, respectively. In levels, *YG* is stationary at the 1% level and *IG*, *EX*, *SP* and *CR* have unit roots at the 1% level. In difference, all these variables are stationary at the 1% level. According to the Johansen cointegration test (Table 2), the null hypothesis that these variables have a zero cointegrating relationship is tested against the alternative hypothesis that these variables have one cointegrating relationship. The trace test statistic is 153.39 compared with the critical value of 96.58 at the 1% level. Hence, these variables have a long-term stable relationship.

Based on Schwarz information criterion, a lag length of one is chosen. For the CR regression, the adjusted R^2 is estimated to be 0.968. The F statistic is 573.266, which is greater than the critical value of 3.26 at the 1% level. Hence, the whole regression is significant.

TABLE 1

ADF UNIT ROOT TEST

Variable	Test statistic	
	Level	Difference
IG	–1.72	–12.95
YG	–4.54	–16.39
EX	–1.19	–6.91
SP	–1.49	–6.86
CR	–1.62	5.50

Graph 1 and Table 3 present the impulse response function of the overnight call rate for 16 quarters.[1] As shown, within a 95% confidence interval, *CR* has a positive response to a shock to *YG*, *IG*, *EX*, *SP*, or the lagged *CR* during some of the quarters. In other words, the BOJ would raise the overnight call rate if the output gap rises, the inflation gap widens, the Japanese yen depreciates, the stock index rises, or the lagged overnight call rate increases. There are several points worth noting. First, the response of the overnight call rate to yen depreciation lasts longer than other variables, suggesting that the BOJ is persistent in maintaining exchange rate stability. Second, if stock prices decline, the BOJ would drop the overnight call rate to stimulate the stock market, and vice versa. Third, the overnight call rate responds more to the inflation gap than to the output gap probably because the BOJ is more sensitive to inflationary pressure. This observation may partly explain why Japan had experienced a long-term economic slowdown in the 1990s and early 2000s.

[1] Because the system is cointegrated, the orthogonalized impulse responses and the variance decomposition can be calculated exactly as stationary VAR models. For details, please see Lütkepohl and Reimers (1992) and Mellander, Vredin and Warne (1992).

TABLE 2

JOHANSEN COINTEGRATION TESTS

Sample: 1979:1-2002:4
Included observations: 96
Trend assumption: Linear deterministic trend (restricted)
Series: CR, YG, IG, EX and SP
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test

Hypothesized no. of CE(s)[a]	Eigenvalue	Trace statistic	5% critical value	1% critical value
None **	0.482706	153.3861	87.31	96.58
At most 1 **	0.381810	90.10830	62.99	70.05
At most 2 *	0.260235	43.93622	42.44	48.45
At most 3	0.102048	14.99969	25.32	30.45
At most 4	0.047445	4.666352	12.25	16.26

[a] CE(s) = cointegrating relations.
*,** denotes rejection of the hypothesis respectively at the 5% and 1% level.
Trace test indicates 3 cointegrating equation(s) at the 5% level.
Trace test indicates 2 cointegrating equation(s) at the 1% level.

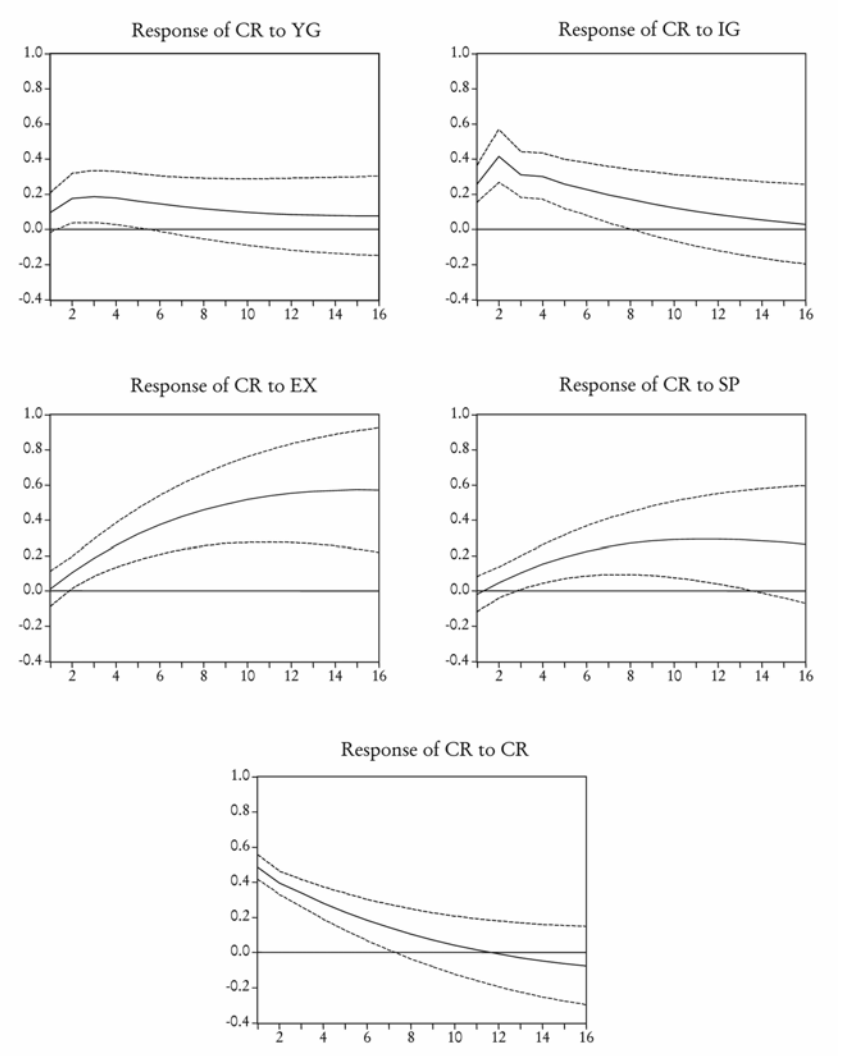
Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	5% critical value	1% critical value
None **	0.482706	63.27781	37.52	42.36
At most 1 **	0.381810	46.17209	31.46	36.65
At most 2 *	0.260235	28.93652	25.54	30.34
At most 3	0.102048	10.33334	18.96	23.65
At most 4	0.047445	4.666352	12.25	16.26

*,** denotes rejection of the hypothesis respectively at the 5% and 1% level.
Max-eigenvalue test indicates 3 cointegrating equation(s) at the 5% level.
Max-eigenvalue test indicates 2 cointegrating equation(s) at the 1% level.

Table 4 reports the variance decomposition of the overnight call rate. As shown, except for the lagged call rate, the exchange rate is the most influential variable as it can explain up to 55.07% of the variation in *CR*, followed by the inflation gap of 35.16%, the stock index of 15.32% and the output gap of 8.58%. These statistics suggest that BOJ's interest rate policy is affected more by the exchange rate and the inflation gap than by the output gap and stock prices.

GRAPH 1

IMPULSE RESPONSE FUNCTION OF THE OVERNIGHT CALL RATE
RESPONSE TO CHOLESKY ONE S.D. INNOVATIONS ±2 S.E.



The ordering of *YG*, *IG*, *EX*, *SP*, *CR* and *Y* is based on the simple Taylor rule extended to include the exchange rate and the stock market performance. Placing *EX* in front of *SP* is justified because of BOJ's emphasis on maintaining the stability of the exchange rate. To emphasise price stability by placing *IG* in front of *YG* and test the

robustness of empirical outcomes, I find that the results are similar except that within a 95% confidence interval, the response of *CR* to *YG* is marginally significant during some quarters. It may suggest that the interest rate is so low that a further decline in the interest rate would not cause real GDP to rise.

TABLE 3

IMPULSE RESPONSE FUNCTION OF THE OVERNIGHT CALL RATE

Period	YG	IG	EX	SP	CR
1	0.097069	0.261447	0.013544	−0.017584	0.484907
	(0.05671)	(0.05301)	(0.04953)	(0.04951)	(0.03500)
2	0.177148	0.416755	0.105282	0.047844	0.395775
	(0.07064)	(0.07490)	(0.04541)	(0.04353)	(0.03299)
3	0.186837	0.312089	0.187771	0.103742	0.338680
	(0.07409)	(0.06462)	(0.05317)	(0.04736)	(0.03884)
4	0.178175	0.301504	0.258623	0.152478	0.280276
	(0.07567)	(0.06560)	(0.06278)	(0.05378)	(0.04553)
5	0.162061	0.257228	0.320678	0.192627	0.230436
	(0.07669)	(0.07001)	(0.07330)	(0.06208)	(0.05265)
6	0.145811	0.228489	0.374136	0.225193	0.184277
	(0.07888)	(0.07432)	(0.08327)	(0.07069)	(0.05910)
7	0.130815	0.197387	0.419902	0.250627	0.142954
	(0.08216)	(0.07979)	(0.09294)	(0.07961)	(0.06523)
8	0.117904	0.170658	0.458493	0.269678	0.105572
	(0.08612)	(0.08493)	(0.10237)	(0.08874)	(0.07106)
9	0.107068	0.145685	0.490506	0.282985	0.072084
	(0.09033)	(0.08997)	(0.11173)	(0.09814)	(0.07678)
10	0.098219	0.123286	0.516462	0.291187	0.042162
	(0.09449)	(0.09461)	(0.12110)	(0.10778)	(0.08239)
11	0.091168	0.102976	0.536878	0.294874	0.015602
	(0.09843)	(0.09886)	(0.13050)	(0.11762)	(0.08790)
12	0.085722	0.084750	0.552235	0.294597	−0.007835
	(0.10207)	(0.10269)	(0.13991)	(0.12759)	(0.09324)
13	0.081691	0.068426	0.562996	0.290868	−0.028364
	(0.10538)	(0.10607)	(0.14927)	(0.13759)	(0.09833)
14	0.078895	0.053892	0.569599	0.284159	−0.046198
	(0.10835)	(0.10899)	(0.15852)	(0.14754)	(0.10309)
15	0.077168	0.041017	0.572458	0.274907	−0.061539
	(0.11099)	(0.11145)	(0.16759)	(0.15734)	(0.10743)
16	0.076356	0.029680	0.571964	0.263510	−0.074584
	(0.11334)	(0.11344)	(0.17643)	(0.16691)	(0.11128)

Cholesky ordering: YG, IG, EX, SP and CR.
Standard errors: analytic.

TABLE 4

VARIANCE DECOMPOSITION OF THE OVERNIGHT CALL RATE

Period	S.E.	YG	IG	EX	SP	CR
1	0.940758	3.006493	21.81026	0.058531	0.098654	75.02607
2	1.017489	5.926660	35.15552	1.636593	0.377389	56.90384
3	1.026874	7.713797	34.58321	4.740182	1.361231	51.60158
4	1.031049	8.442304	33.80931	8.910011	2.876231	45.96214
5	1.034509	8.581145	31.86175	13.87683	4.730413	40.94986
6	1.038363	8.348384	29.55747	19.18855	6.702458	36.20314
7	1.042443	7.923060	27.05601	24.51757	8.620338	31.88302
8	1.046718	7.412608	24.58169	29.60143	10.36058	28.04369
9	1.051124	6.885534	22.24830	34.29001	11.85763	24.71853
10	1.055618	6.380577	20.12464	38.51276	13.08843	21.89358
11	1.060155	5.917695	18.23585	42.25876	14.05915	19.52855
12	1.064690	5.505056	16.58217	45.55160	14.79209	17.56909
13	1.069183	5.144037	15.14902	48.43266	15.31683	15.95746
14	1.073593	4.832395	13.91492	50.94957	15.66458	14.63853
15	1.077884	4.566205	12.85617	53.14966	15.86512	13.56284
16	1.082026	4.340976	11.94952	55.07653	15.94534	12.68764

Cholesky ordering: YG, IG, EX, SP and CR.

Efforts were made to estimate the policy reaction function using the call rate (*CR*) during 1979.Q1-1995.Q2 when *CR* was greater than 1%, and using official reserves during 1995.Q3-2002.Q4 when *CR* was below 1%. When *CR* is considered, outcomes are similar to those reported above. When official reserves are considered, the results show that there is no significant response of official reserves to a shock to exchange rate fluctuations probably because the sample size is relatively small, and because the Taylor rule is employed to determine the behavior of the official interest rate.

5. Summary and conclusions

In this paper, I have extended the Taylor rule and applied VAR model to examine the monetary policy reaction function for the BOJ. Major findings are summarized below. The overnight call rate reacts positively to a shock to the output gap, the inflation gap, yen depreciation, stock prices, or the lagged overnight call rate during some of the

quarters. The response of the overnight call rate to yen depreciation or stock prices lasts longer. The reaction of the overnight call rate to the inflation gap goes on longer than that of the overnight call rate to the output gap. Except for the lagged overnight call rate, the exchange rate and the inflation gap are more influential than the output gap and stock prices in explaining the variance of the overnight call rate. Therefore, we may reach an interesting conclusion that the BOJ did not respond to the output gap adequately to raise actual output to potential output, partly because the overnight call rate has been near zero bound and could not be reduced further to deal with the economic slowdown effectively.

There may be areas for future research. The Taylor rule describes how the interest rate is determined by a central bank. The BOJ also considers the monetary base and M2+CD as monetary policy tools. How to incorporate monetary base or M2+CD into the Taylor rule would be interesting to study. In this paper, the JPY/USD exchange rate is employed. Researchers may consider a weighted exchange rate index containing major currencies. It would be interesting to incorporate the forward-looking model that uses future values for the inflation rate into the VAR model that normally employs lagged values for the endogenous variables.

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