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# Effects of the Loss and Correction of a Reference Rate on Japan's Economy and Financial System: Analysis Using the Financial Macro-econometric Model

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# EFFECTS OF THE LOSS AND CORRECTION OF A REFERENCE RATE ON JAPAN'S ECONOMY AND FINANCIAL SYSTEM:*

## ANALYSIS USING THE FINANCIAL MACRO-ECONOMETRIC MODEL

Hiroshi Kawata,† Tomiyuki Kitamura,‡ Koji Nakamura,§
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### ABSTRACT

This paper analyzes the effects on the financial system and the real economy of errors in a reference rate, and the subsequent rapid corrections of the rate. In this analysis, we use the Financial Macro-econometric Model, which reflects an adverse feedback loop between the financial system and the real economy. The main results are as follows. First, fluctuations of financial and economic activity may increase significantly when there is no correct and reliable reference rate and individual financial institutions extend loans based on different market rate indicators. Second, the transmission mechanism of monetary policy may weaken in the absence of a reference rate. And third, when errors are found in a reference rate, the subsequent upward corrections at a rapid pace may affect the real economy to a notable extent. The effects of the corrections can grow especially if such corrections occur at the time of a financial crisis. These results suggest that a correct and reliable reference rate is important for maintaining stability in the macroeconomy.

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* The views expressed here are those of the authors and should not be ascribed to the Bank of Japan or its Financial System and Bank Examination Department.

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## I. Introduction

Reference rates are used in the price setting of a wide range of financial transactions such as loans and derivatives. For example, reference rates such as the London interbank offered rate (Libor) and the Tokyo interbank offered rate (Tibor) are used in the interbank market. In the securities repo market, the Tokyo repo rate is used as a reference rate. For such rates to fulfill their functions, they need to appropriately reflect the market trend, and the precision of the rates must be sufficiently high to gain credibility from all market participants. Therefore, a high degree of transparency and fairness is warranted in developing reference rates.

Based on this view, this paper quantitatively analyzes the effects of a decline in the degree of precision of a reference rate on the financial system and the real economy. We provide estimates of the effects on financial and economic activity when there are errors in a reference rate and when an incorrect reference rate is suddenly revised upward to the correct level. In doing so, we use the Financial Macro-econometric Model (FMM), a macro-econometric model developed by the Bank of Japan. The FMM consists of two sectors, namely, the financial sector and the macroeconomic sector, and incorporates the feedback loop between these sectors. Another feature of the FMM is that it formulates variables of the financial sector by each bank.[1] This enables us to analyze the effects of developments in a reference rate on the financial system and the macroeconomy through changes in activity of individual banks.

The remainder of the paper is organized as follows. Section II offers a brief overview of the FMM. Section III analyzes the effects of the loss of a correct reference rate on the financial system and the real economy. Section IV examines the effects of the loss of a reference rate on the monetary policy effects. Section V assesses the impact on the financial system and the real economy of rapid corrections of a reference rate in which errors are found. Section VI draws a conclusion.

[1] For details on the FMM, see Ishikawa *et al.* (2012).

## II. Brief Overview of the FMM

The FMM is a medium-sized macro-econometric model for assessing the robustness of the financial system. It mainly consists of two sectors -- the financial sector and the macroeconomic sector -- and makes it possible to conduct quantitative analysis of the adverse feedback loop between the financial system and the real economy.

The spending activities of households and firms are modeled as functions of their income, banks' loans amounts, and banks' loan interest rates. These are key factors in analyzing the feedback loop between the financial system and the real economy.

Household expenditure
= 0.56 × labor income <0.00> + 0.02 × stock prices <0.01>
+ 0.15 × banks' loans to households <0.00> - 0.29 × loan interest rate <0.17>. (1)

The sample period is from the January-March quarter of 1981 to the January-March quarter of 2012. Adjusted $R^2$ = 0.78. *P*-value is shown in angular brackets.

Business fixed investment
= 9.2 × corporate profits <0.00> + 0.58 × expected growth rate <0.03>
- 1.93 × (loan interest rate - CPI) <0.01> + 0.72 × banks' loans to firms <0.00>. (2)

The sample period is from the January-March quarter of 1981 to the January-March quarter of 2012. Adjusted $R^2$ = 0.54. *P*-value is shown in angular brackets.

Another distinctive feature of the FMM is that individual banks are modeled in detail in terms of the functions for loan interest rates, the loan volume, capital, and credit costs. In particular, the credit cost functions are the core of the FMM, the structure of which is rarely observed in this type of model. The individual banks' credit cost functions are estimated using banks' actual data, and 117 functions are included in the FMM.

Bank *i*'s credit cost

= $\Sigma_m \Sigma_n$ (transition probability of Bank *i*'s self-assessment from *m* to *n*)

× (loss ratio at time of downgrading of Bank *i*'s self-assessment from *m* to *n*)

× (exposure of Bank *i*'s self-assessment from *m* to *n*), (3)

where the transition probability of Bank *i*'s self-assessment from *m* to *n* is given using the following formula:

Transition probability of Bank *i*'s self-assessment from *m* to *n* (after logit transformation)

= (coefficient of Bank *i*)

+ (coefficient common to all banks) × two-period mean of the semiannual growth rate of nominal GDP

+ (coefficient common to all banks) × two-period mean of (a borrower's financial indicator × semiannual growth rate of nominal GDP).

See Chart 1 for details of the estimation results.

The credit cost is a function of the transition probability of the self-assessment, the loss ratio, and the exposure. The transition probability is a function of the nominal GDP growth rate. We use the panel data on 117 banks and employ a quantile regression to estimate the transition functions. We run the 50 percent quantile regression and the 90 percent quantile regression, and use the parameter estimates from these quantile regressions to analyze the situation at normal times and at the time of the financial and economic crises.

In the current version of FMM used in this paper, the functions for loan interest rates are also estimated on an individual bank basis, and the aggregate interest rates in the overall loan market are the weighted averages of individual banks' interest rates. The aggregate interest rates affect spending activities of households and firms.

Loan interest rate of Bank *b*

= coefficient of Bank *b* <0.00> + 0.96 × interest rate on funding of Bank *b* <0.00>

- 0.006 × loan volume gap <0.00>. (4)

The sample period is from the January-March quarter of 1988 to the January-March quarter of 2012. Adjusted $R^2 = 0.97$. *P*-value is shown in angular brackets.

## III. Effects of Errors in a Reference Rate on the Financial System and the Real Economy

### A. Assumptions for the Simulation

Each bank decides on interest rates on funding and loan interest rates based on a reference rate in the interbank market. In the FMM, a reference rate affects most of the variables in the financial sector, including loan interest rates and net interest income, by changing individual banks' interest rates on funding. Specifically, the interest rates on funding are set by the following function.[2]

Funding rate of Bank *b*

= Fixed effect of Bank *b* <0.00> + 0.67 × reference rate <0.00>

- 0.08 × capital adequacy ratio gap of Bank *b* <0.00>. (5)

Capital adequacy ratio gap = capital adequacy ratio - required capital adequacy ratio. The sample period is from the July-September quarter of 1989 to the January-March quarter of 2012. Adjusted $R^2 = 0.94$. *P*-value is shown in angular brackets.

In the absence of the reference rate, each bank must set its interest rate by individually taking into account rates of various transactions that it observes.[3] In this case, each bank faces different transaction costs and some time is required for banks to determine the average rates of transactions in the markets. This situation is described

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[2] For further details on the function for banks' interest rates on funding on an individual basis, see Kawata *et al.* (2012).

[3] The call rate is used as the reference rate in the estimation using the FMM. There are other reference rates such as Tibor and Libor, but there are no major differences in the results of the simulation, regardless of which reference rate is used.

as follows: banks' funding costs include idiosyncratic shocks, which have a persistent impact on the funding costs.[4,5]

$$\text{Idiosyncratic shock}_{b,t,i} = \varrho \times \text{idiosyncratic shock}_{b,t-1,i} + \varepsilon_{b,t,i}, \qquad (6)$$

where $\varepsilon_{b,t,i} \sim N(0, \sigma^2)$.

Since banks cannot immediately acquire information on the correct level of the average rates of interest rates -- the reference rate -- they set their interest rates using available information and gradually adjust the interest rates as they acquire more information. The process of error correction is described by the autoregressive process of the shock. For the autoregressive parameter $\varrho$, we use the coefficient estimate obtained by fitting an autoregressive process to the residuals from the panel equation for banks' funding interest rates. Variance $\sigma^2$ is set to 0.5, which is the average variance between the panel equation for banks' interest rates on funding and the macro equation for all the banks' interest rates on funding.

Under these assumptions, we first calibrate the FMM to roughly reproduce the economic cycle of the past two decades in Japan, so that the degree of fluctuations in nominal GDP is consistent with the nominal GDP data of the past two decades, and set one particular path generated from this calibrated FMM as the baseline. We then conduct a stochastic simulation that subjects each bank's interest rate on funding to an idiosyncratic shock. When there are idiosyncratic shocks on interest rates on funding, each bank's funding rate fluctuates, moving up and down around the level of the correct reference rate. In the FMM, individual banks' loan interest rates are set by equation (4), and thus fluctuations in funding rates induce a similar degree of fluctuations in loan interest rates. The stochastic simulation is conducted 1,000 times.

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[4] Variables *b*, *t*, and *i* indicate banks, time, and an index for the conduct of the simulation, respectively.

[5] Muto (2012) provides a theoretical justification on this point by assuming imperfect information in island economy setting.

### B. Results of the Simulation

When banks' interest rates on funding are subject to idiosyncratic shocks, the standard deviation of loan interest rates from the baseline expands by 0.15 percentage point (Chart 2). In this case, fluctuations in the loan volume grow due to increased fluctuations in loan interest rates, and this ultimately magnifies the fluctuations in the real economy. As a result, the increases in the standard deviation from the baseline are 0.5 trillion yen for the loan volume and 2.1 trillion yen for nominal GDP.

## IV. Effects of Errors in a Reference Rate on Monetary Policy Effects

### A. Assumptions for the Simulation

Monetary policy affects the real economy through changes in interest rates in the loan market and other financial markets. Nevertheless, monetary policy effects may change if banks' interest rates on funding and loan interest rates are, as assumed in Section III, dispersed due to the loss of a reference rate. In this section, we examine the effects of the loss of the reference rate on the monetary policy by subjecting individual banks' interest rates on funding to idiosyncratic shocks as in Section III, and by adding a monetary policy shock on the reference rate.

We assume one standard deviation shock to the reference rate in the 1990s to represent the impulse responses to a monetary policy shock. The simulation is conducted 1,000 times.

### B. Results of the Simulation

When there is a monetary policy shock on the reference rate, the loan volume fluctuates due to changes in interest rates on funding and loan interest rates, and this affects nominal GDP. When interest rates on funding are subject to idiosyncratic shocks in addition to a monetary policy shock, the increase in the standard deviation is about 2.6 trillion yen for nominal GDP, compared with the case in which only a monetary policy shock is assumed (Chart 3). This implies that the idiosyncratic shocks have dampened the monetary policy effects.

We now examine the effects of an idiosyncratic shock on the monetary policy by looking at the cross-correlation between a policy rate and nominal GDP. When there is an upward shock from monetary policy (monetary policy tightening), nominal GDP usually declines mainly due to a rise in loan interest rates and a decrease in the loan volume. As a result, a negative correlation emerges between the policy rate and nominal GDP. According to the results of the simulation, when only a monetary policy shock is assumed, the correlation coefficient between the policy rate and nominal GDP is about -0.8 at most (Chart 4). The negative correlation disappears in about 5 years. On the other hand, when both monetary policy shock and idiosyncratic shock are assumed, the correlation coefficient is about -0.3 at most, reducing the coefficient by about 0.5 compared with the case in which only the monetary policy shock is assumed. The negative correlation disappears in about 3.5 years, shortening the duration of negative correlation by about 1.5 years compared with the case in which only the monetary policy shock is assumed. These results show that the loss of the reference rate may weaken the transmission mechanism of monetary policy.

## V. Effects of Rapid Corrections in a Reference Rate on the Financial System and the Real Economy

### A. Assumptions for the Simulation

This section analyzes the effects on the real economy of the upward corrections at a rapid pace of a reference rate when errors in the rate are found.[6] The magnitude of the

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[6] The *Financial System Report*, which the Bank releases semiannually, also analyzes the resilience of the financial system against an upward shock to interest rates. However, to assess the resilience of Japan's financial system at the time of the analysis, this report takes into account the effects of unrealized gains on financial institutions' securities holdings acting as a buffer against possible losses on securities holdings due to a rise in interest rates. On the contrary, this paper, in light of its objective, shows a simulation that does not take account of unrealized gains on financial institutions' securities holdings to gauge the

effects depends on the degree of corrections. Accordingly, three cases are examined for the upward revisions of the reference rate: 0.1 percentage point, 0.5 percentage point, and 1.0 percentage point. For all three cases, a parallel shift scenario is assumed, in which interest rates for all maturities shift upward at the same pace within one quarter. The baseline is the same as in Section III.

**B. Results of the Simulation**

An upward shock to interest rates induces a rise in loan interest rates, and in turn reduces the loan volume. Moreover, banks' Tier I capital ratios decline due to unrealized losses on holdings of private bonds reflecting the rise in interest rates, which also reduces the loan volume.[7] Reflecting such a decrease in the loan volume, nominal GDP declines. The results of the simulation show that, when the reference rate increases by 0.1 percentage point, the nominal GDP growth rate deviates downward from the baseline by 0.2 percentage point at most. Similarly, the growth rates in the case with reference rates rising by 0.5 percentage point and 1.0 percentage point deviate downward from the baseline by 0.5 percentage point and 0.9 percentage point, respectively, at most (Chart 5). Therefore, when rapid corrections in the reference rate occur, the financial system and the real economy are affected to a notable extent.

**C. Effects of Corrections in Interest Rates at the Time of a Financial Crisis**

The magnitude of the effects of the corrections on the financial system and the real

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general effects stemming from a sudden upward shock to interest rates. Thus, it should be noted that the analysis in this paper does not necessarily assess the resilience of the financial system and the magnitude of the effects on the real economy if an upward shock to interest rates occurs in Japan at present.

[7] We assume that there are no corrections made to the yield curve for government bonds, and that only reference rates which are used as interest rates on transactions between private financial institutions are corrected. Thus, there would be no changes in the value of government bonds that the institutions hold. On the other hand, we assume that private bonds such as corporate bonds which are assessed by private reference rates change due to corrections of a reference rate.

economy varies depending on when the corrections occur. Using the parameter estimates from quantile regressions, the FMM can describe the situation in which credit costs increase nonlinearly, as corporate bankruptcies tend to emerge at the time of a financial crisis.[8] This enables us to conduct a simulation that assumes an upward shock to interest rates in the midst of the financial and economic crises. We compare the results with those of the simulation conducted to gauge the effects at normal times.

When an upward shock to interest rates of 0.5 percentage point occurs at the time of the financial and economic crises, the degree of downward deviation from the baseline in banks' Tier I capital ratios expands to 1.0 percentage point at the time of a financial crisis from the maximum of 0.1 percentage point at normal times (Chart 6). Such deterioration in banks' financial conditions induces cautious lending attitudes among banks and exerts further downward pressure on the real economy. Regarding the effects on the growth rate of nominal GDP, the rate of decline continues to expand at the time of financial and economic crises and reaches -0.6 percentage point in the third year. Therefore, the effects of an upward shock to interest rates would intensify further if the shock occurred at the time of financial and economic crises, when they would be amplified by the adverse feedback loop between the financial system and the real economy.

## VI. Conclusion

This paper analyzes the effects of errors in the reference rate and the subsequent rapid corrections in the rate on the financial system and the real economy by using the FMM.

The main results are as follows. First, fluctuations in the financial system and the real economy may grow when there is no correct and reliable reference rate because individual financial institutions extend loans based on different market information. Second, the transmission mechanism of monetary policy may weaken in the absence of the reference rate due to dispersion in activity of individual banks. And third, when

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[8] For details on the FMM, see Ishikawa *et al.* (2012).

errors are found in the reference rate, the subsequent upward corrections at a rapid pace affect the real economy to a notable extent, reflecting the rise in the loan interest rates and downward pressure on banks' business conditions. The effects on the macroeconomy may increase further especially if such corrections occur at the time of a financial crisis. Thus, a correct and reliable reference rate is important for maintaining stability in the macroeconomy.

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Kawata, Hiroshi, Yoshiyuki Kurachi, Koji Nakamura, and Yuki Teranishi, "Quantitative Analysis on Macroprudential Policy Tools: Can We Counter the 'Financial Cycle' with Macroprudential Tools?" mimeo.

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(Chart 1)

# Estimation Result of the Transition Probability Function

(Behavioral equation)

$$
\begin{aligned}
\ln\left(\frac{q_{i,t}^{mn}}{1-q_{i,t}^{mn}}\right) = {} & \alpha_i^{mn} \\
& + \beta^{mn} \times \text{two-period mean of the semiannual growth rate of nominal GDP} \\
& + \gamma^{mn} \times \text{two-period mean of (quick ratio} \\
& \qquad \times \text{semiannual growth rate of nominal GDP)} \\
& + \delta^{mn} \times \text{two-period mean of (interest coverage ratio} \\
& \qquad \times \text{semiannual growth rate of nominal GDP)}
\end{aligned}
$$

$q_{i,t}^{mn}$ is the transition probability of Bank $i$'s self-assessment from $m$ to $n$ at period $t$.

(1) Estimation Result of 50 Percent Quantile Regression

| Assessment $m$ \ Assessment $n$ | | Normal | | Needs Attention | | Special Attention | | In Danger of Bankruptcy | | Bankruptcy / de facto Bankruptcy | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coefficient | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value |
| Normal | $\beta^{mn}$ | | | -23.6 | 0.00 | -8.0 | 0.25 | -32.2 | 0.00 | -12.1 | 0.00 |
| | $\gamma^{mn}$ | | | 21.2 | 0.00 | - | - | 24.0 | 0.06 | - | - |
| | $\delta^{mn}$ | | | - | - | 2.5 | 0.25 | - | - | - | - |
| Needs Attention | $\beta^{mn}$ | 5.9 | 0.00 | | | | | -15.5 | 0.01 | -7.4 | 0.00 |
| | $\gamma^{mn}$ | - | - | | | | | 16.9 | 0.02 | - | - |
| | $\delta^{mn}$ | - | - | | | | | - | - | - | - |
| Special Attention | $\beta^{mn}$ | 29.6 | 0.12 | | | | | -13.6 | 0.20 | -36.0 | 0.00 |
| | $\gamma^{mn}$ | -45.7 | 0.06 | | | | | 26.9 | 0.04 | 37.8 | 0.00 |
| | $\delta^{mn}$ | - | - | | | | | - | - | - | - |
| In Danger of Bankruptcy | $\beta^{mn}$ | | | | | 13.4 | 0.01 | | | | |
| | $\gamma^{mn}$ | | | | | - | - | | | | |
| | $\delta^{mn}$ | | | | | - | - | | | | |

(2) Estimation Result of 90 Percent Quantile Regression

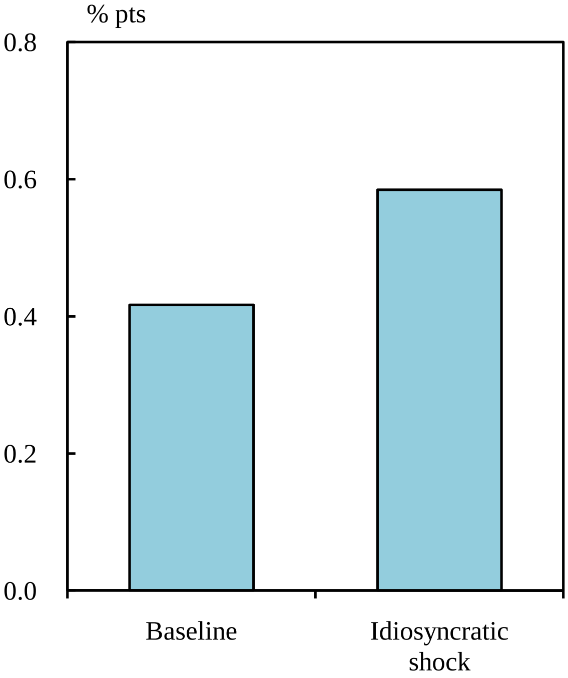
| Assessment $m$ \ Assessment $n$ | | Normal | | Needs Attention | | Special Attention | | In Danger of Bankruptcy | | Bankruptcy / de facto Bankruptcy | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coefficient | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value | Coefficient | *p*-value |
| Normal | $\beta^{mn}$ | | | -23.6 | 0.00 | -8.0 | 0.25 | -32.2 | 0.00 | -32.6 | 0.00 |
| | $\gamma^{mn}$ | | | 21.2 | 0.00 | - | - | 24.0 | 0.06 | - | - |
| | $\delta^{mn}$ | | | - | - | 2.5 | 0.25 | - | - | - | - |
| Needs Attention | $\beta^{mn}$ | 5.9 | 0.00 | | | | | -15.5 | 0.01 | -14.9 | 0.00 |
| | $\gamma^{mn}$ | - | - | | | | | 16.9 | 0.02 | - | - |
| | $\delta^{mn}$ | - | - | | | | | - | - | - | - |
| Special Attention | $\beta^{mn}$ | 29.6 | 0.12 | | | | | -13.6 | 0.20 | -46.0 | 0.38 |
| | $\gamma^{mn}$ | -45.7 | 0.06 | | | | | 26.9 | 0.04 | 47.4 | 0.49 |
| | $\delta^{mn}$ | - | - | | | | | - | - | - | - |
| In Danger of Bankruptcy | $\beta^{mn}$ | | | | | 13.4 | 0.01 | | | | |
| | $\gamma^{mn}$ | | | | | - | - | | | | |
| | $\delta^{mn}$ | | | | | - | - | | | | |

Notes: *1.* Estimation period: the first half of fiscal 2004 through the second half of fiscal 2011. Estimation method: fixed-effect model.
*2.* Shaded areas denote that the transition probability is exogenous since estimates are not statistically significant.
*3.* In (2), only "Normal," "Needs Attention," and "Special Attention" that have shifted to "Bankruptcy/de facto Bankruptcy" are estimated by 90 percent quantile regression; the other categories are the same as the 50 percent quantile regression.

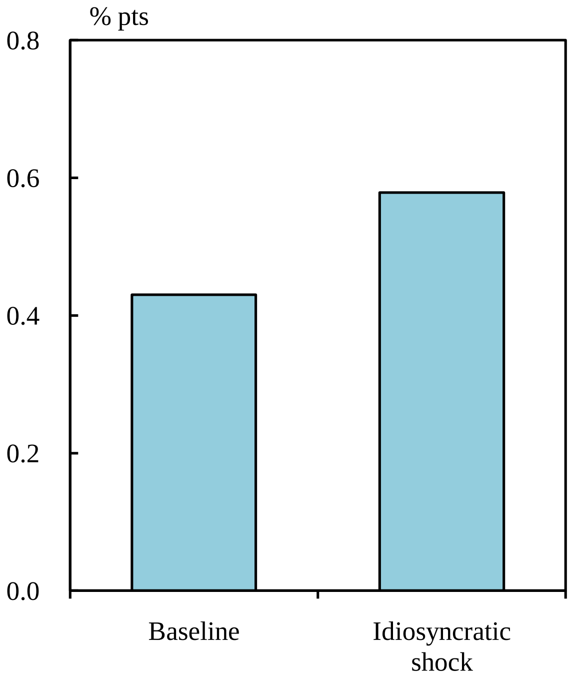
(Chart 2)

# Change in Standard Deviation

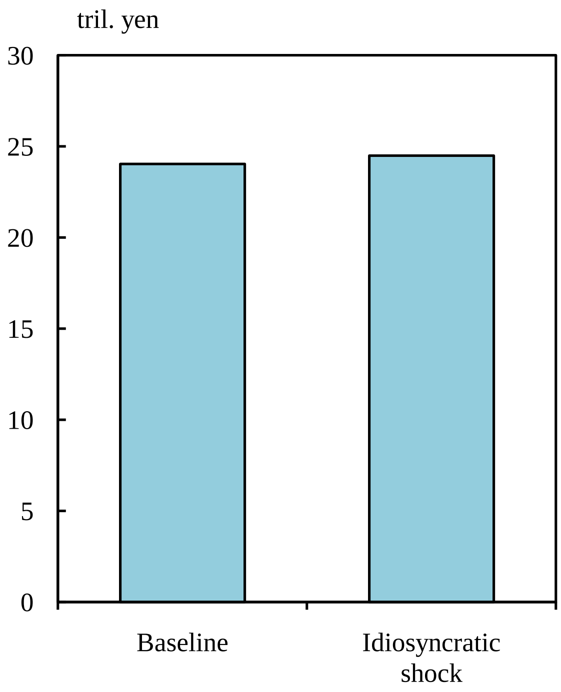
(1) Funding Interest Rates



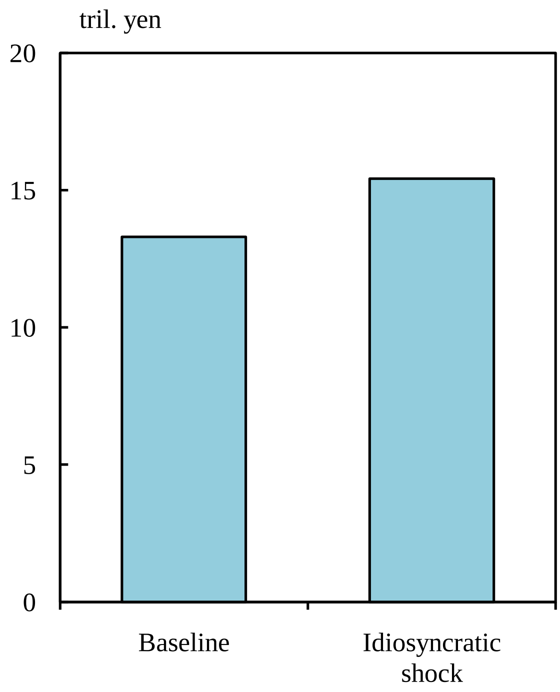

(2) Loan Interest Rates




(3) Loan Volume

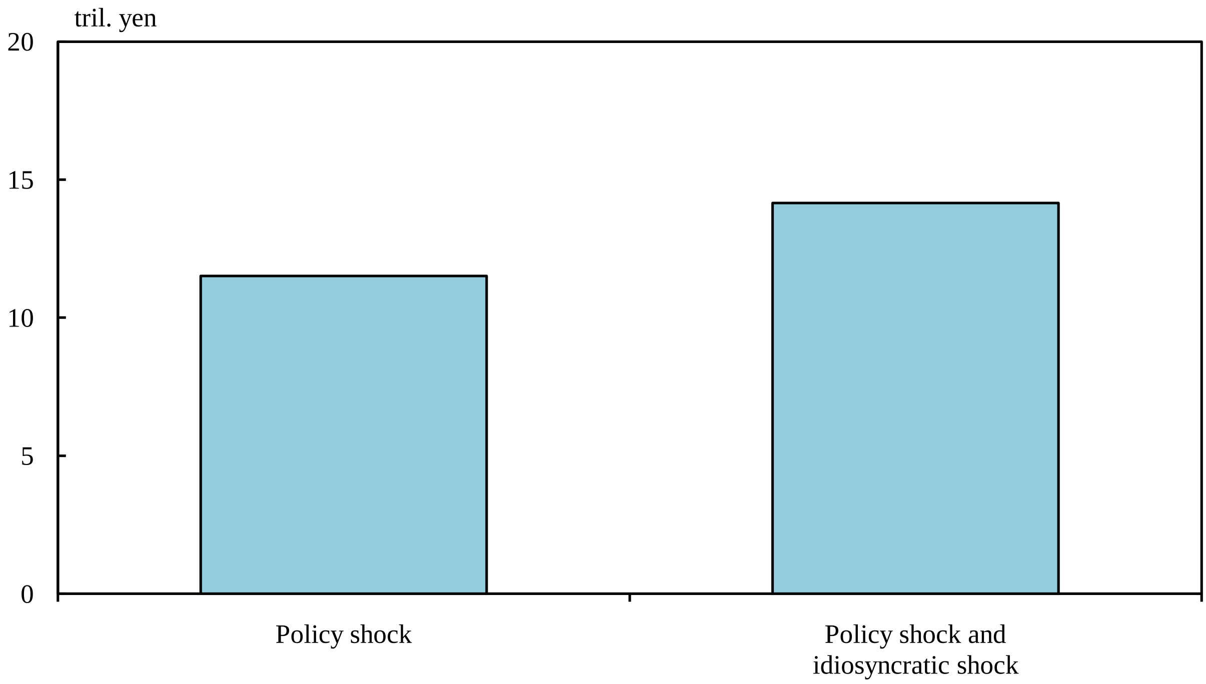



(4) Nominal GDP



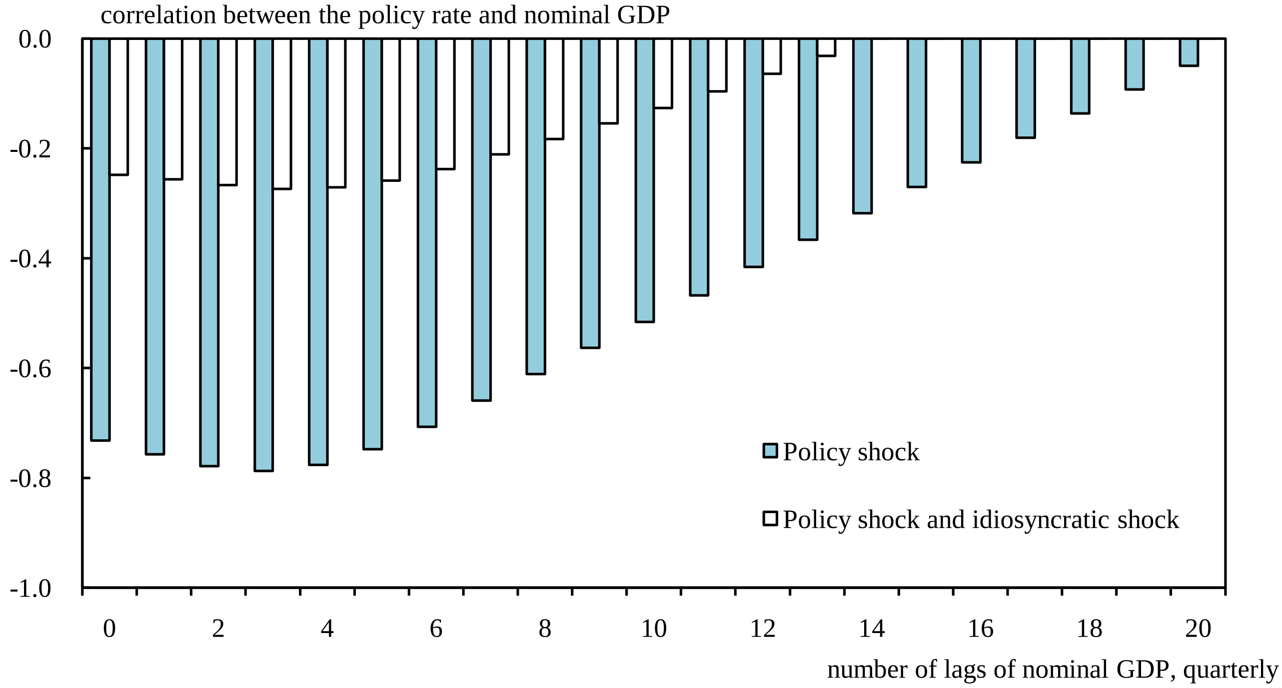
(Chart 3)

# Change in Standard Deviation of Nominal GDP to a Policy Shock



(Chart 4)

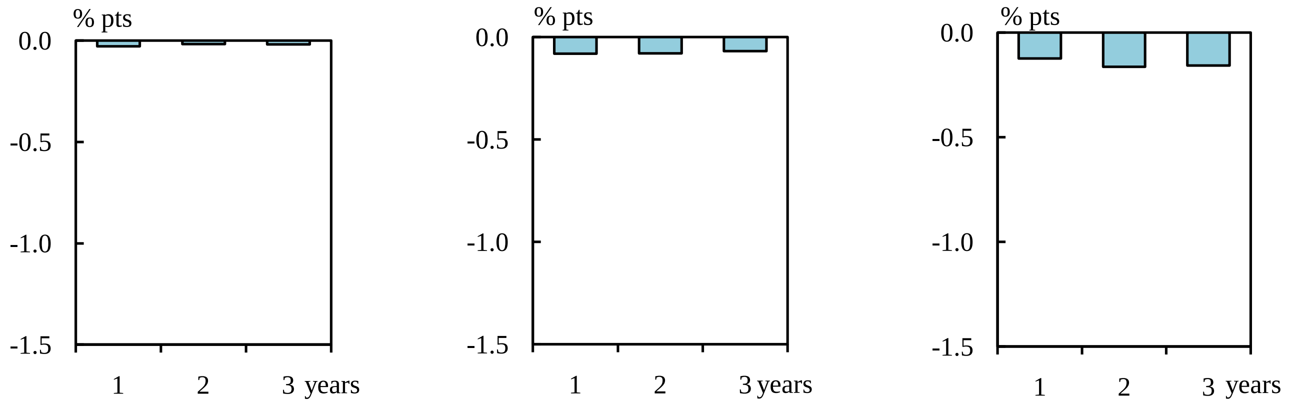
# Impact on Monetary Policy Effects



# Effects of an Upward Shock to Interest Rates

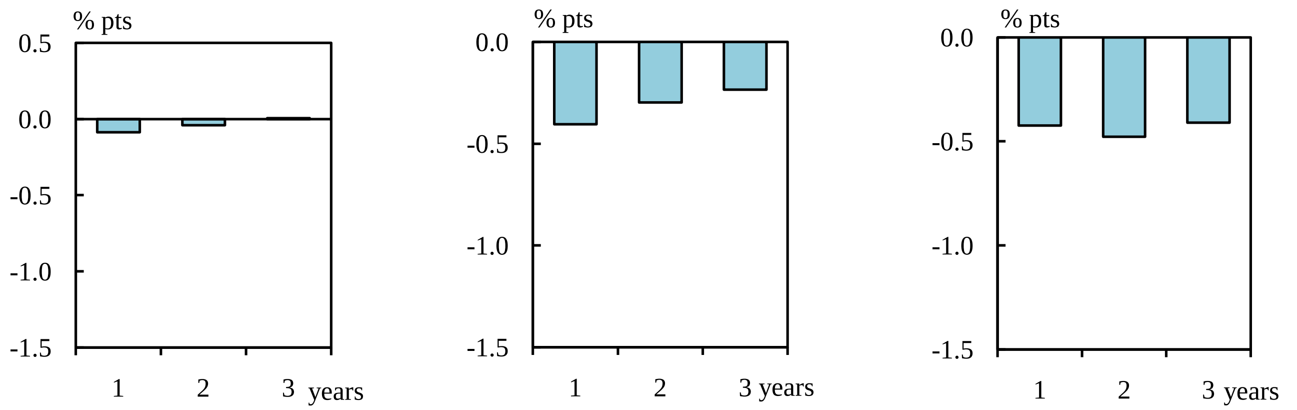
(1) +0.1 Percentage Point Shock

(a) Tier I Ratio (b) Loan Volume (c) Nominal GDP



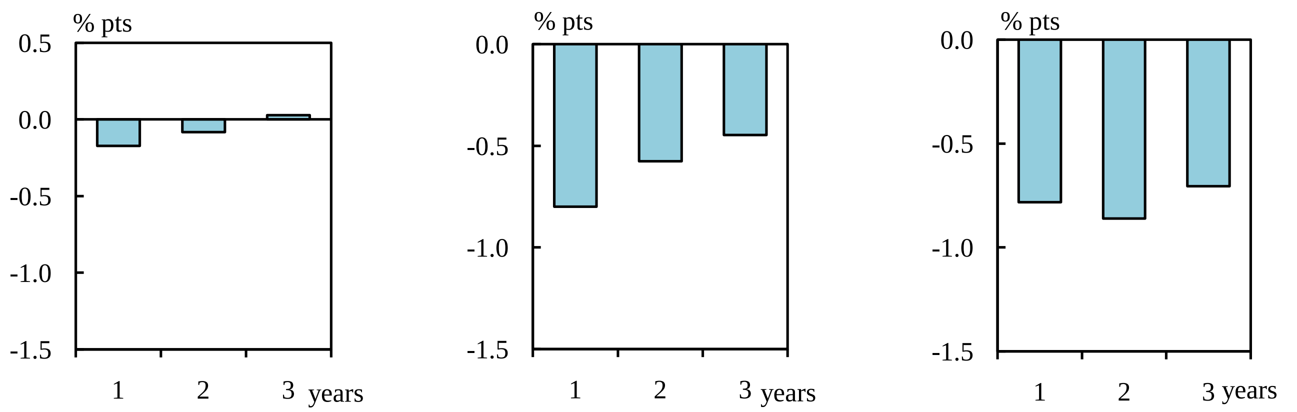

(2) +0.5 Percentage Point Shock

(a) Tier I Ratio (b) Loan Volume (c) Nominal GDP




(3) +1.0 Percentage Point Shock

(a) Tier I Ratio (b) Loan Volume (c) Nominal GDP



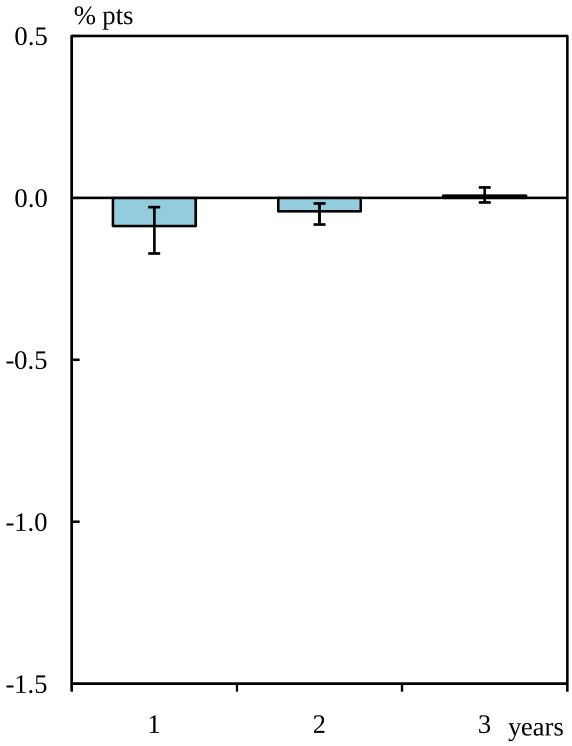

Note: Figures show responses of variables to shocks.

(Chart 6)

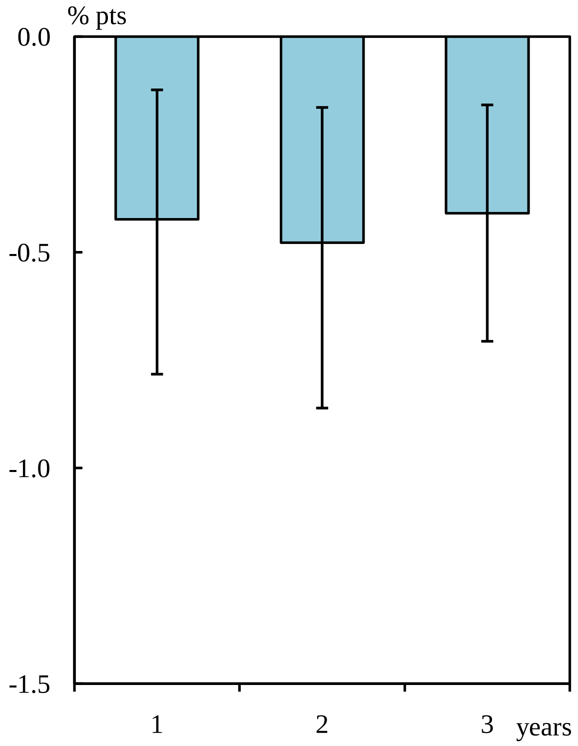
# Effects of an Upward Shock to Interest Rates at the Time of a Financial Crisis

(1) At Normal Times

(a) Tier I Ratio

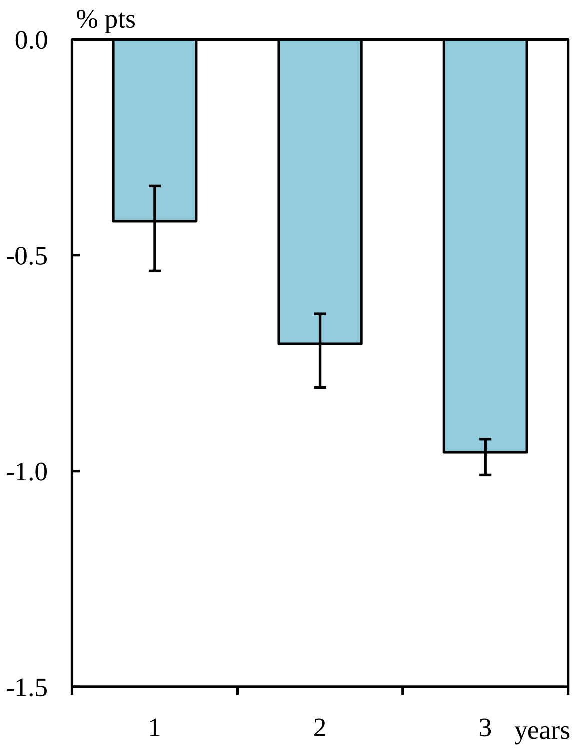



(b) Nominal GDP Growth Rate

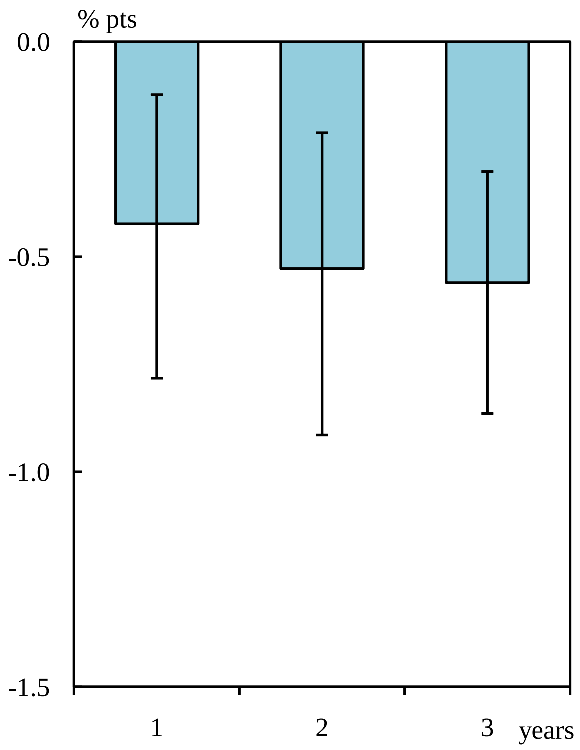



(2) At the Time of a Financial Crisis

(a) Tier I Ratio




(b) Nominal GDP Growth Rate




Notes: 1. Error range indicates variation in interest rate shocks from +0.1 to +1.0 percentage point.
2. Figures show responses of variables to shocks.