BOJ Reports & Research Papers

October 2014

Macro Stress Testing at the Bank of Japan

Financial System and Bank Examination Department, Bank of Japan
Tomiyuki Kitamura
Satoko Kojima
Koji Nakamura
Kojiro Takahashi
Ikuo Takei

Financial System and Bank Examination Department, Bank of Japan
P.O. BOX30,Nihonbashi,Tokyo 103-8660, Japan
Facsimile: +81-3-5255-6738
e-mail: post.bsd1@boj.or.jp

October 2014

Financial System and Bank Examination Department, Bank of Japan
Tomiyuki Kitamura[†]
Satoko Kojima[‡]
Koji Nakamura[§]
Kojiro Takahashi[**]
Ikuo Takei[††]

Macro Stress Testing at the Bank of Japan[*]

■ Abstract ■

Since the global financial crisis, macro stress testing has attracted much attention in many countries as a method to evaluate potential risks of financial system. The Bank of Japan has conducted macro stress testing with various scenarios reflecting financial and economic conditions at each point in time, and published the results in the semi-annual Financial System Report. This paper explains the framework of macro stress testing reported in the Financial System Report. The framework has been improved over time to ensure it appropriately analyzes risk factors in Japan's financial system. Current notable features of the Bank's macro stress testing are as follows. First, it includes a mechanism reflecting the feedback loop between the financial and economic sectors by using the FMM, a medium-sized structural macro model comprising two sectors: financial and macroeconomic. Second, it can analyze not only aggregate figures such as capital adequacy ratios and net interest income, but also those for individual financial institutions.

[†] Financial System and Bank Examination Department; currently at the Bank of England <E-mail; Tomiyuki.Kitamura@bankofengland.co.uk>

[‡] Financial System and Bank Examination Department <E-mail; satoko.kojima@boj.or.jp>

[§] Financial System and Bank Examination Department <E-mail; kouji.nakamura@boj.or.jp>

[**] Financial System and Bank Examination Department <E-mail; koujirou.takahashi@boj.or.jp>

[††] Financial System and Bank Examination Department <E-mail; ikuo.takei@boj.or.jp>

[*] We received generous support from Etsuko Kimura and Minako Noutomi. The authors would like to thank the staff of the Bank of Japan for their helpful comments. Any errors or omissions are the responsibility of the authors. 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.

[Contents]

I. Introduction

Macro stress testing is one of the important analytical tools to quantitatively evaluate the resilience of the financial system. When conducting macro stress testing, we assume exceptional but plausible macroeconomic shocks on the financial system and investigate how the shocks will propagate through the financial system.

Financial institutions started to use stress testing (micro stress testing) in 1990s as an analytical tool to measure potential vulnerability financial institutions had.[1] National authorities and international organizations started to use stress testing as an evaluation tool to assess vulnerability of a country's financial system based on the experience of international financial crises such as Asian crisis. This is the beginning of macro stress testing. Macro stress testing is now actively used by national authorities around the world to evaluate the stability and resilience of the financial system against potential risk factors, given the backdrop of widespread support for a macroprudential perspective since the global financial crisis occurred in the second half of the 2000s.[2]

The Bank of Japan has conducted macro stress testing once every six months and has published the results in the Financial System Report (FSR).[3] Macro stress testing in the FSR has two objectives. First, it reveals the characteristics of potential risk factors faced by Japan's financial institutions and evaluates the extent to which the Japan's financial system as a whole is resilient against these risk factors. Second, the Bank uses it to facilitate communication with relevant domestic and foreign parties in order to secure the stability of the financial system. In this regard, it is important to share the basic macro

---

[1] See Committee on the Global Financial System (CGFS) [2000].

[2] There are various methods for macro stress testing. The authorities could aggregate the results of the micro stress testing for several financial institutions, which are significantly important for a country. Or the authorities could implement macro stress testing by using aggregate data of a country's financial system. When conducting stress testing of individual financial institutions, the authorities could ask financial institutions to implement the test based on the common stress scenarios given by the authorities (bottom up stress testing). Or the authorities could implement the test by themselves (top down stress testing). As described later, the Bank implements top down stress testing and calculate the results of individual financial institutions.

[3] The Bank of Japan started publishing macro stress testing results in the March 2007 issue of the FSR. The first issue of the FSR was published in 2005.

stress testing framework with relevant parties in order to utilize the results effectively. This paper explains the framework of the current macro stress testing program of the Bank of Japan as reported in the April 2014 issue of the FSR.

The macro stress testing framework employed by the Bank has been improved over time in order to capture risk factors relevant to the Japan's financial system in an appropriate manner. There are two significant features of the current macro stress testing framework utilized by the Bank. First, it takes account of the feedback loop between the financial and macroeconomic sectors by using the Financial Macro-econometric Model (FMM), a medium-sized structural model with two sectors: the financial sector and the macroeconomic sector. Second, it is capable of analyzing not only aggregate figures of the financial sector such as capital adequacy ratios and net interest income, but also those for individual financial institutions.

The remainder of this paper is organized as follows. In section 2, we explain the past and current characteristics of the macro stress testing framework employed by the Bank. In section 3, we describe the details of the FMM used for macro stress testing. Section 4 outlines interest rate stress testing. In section 5, we report the macro stress testing methodologies used and results reported in the April 2014 issue of the FSR. In section 6, we describe our conclusions, remarks, and future challenges.

II. Past and Current Characteristics of Macro Stress Testing at the Bank

A. Past and Current Characteristics of the Macro Stress Testing Framework

The macro stress testing framework employed by the Bank has been improved over time in order to capture potential risk factors in the Japan's financial system.

One of the recent improvements made to the framework was to incorporate the feedback mechanism between the financial and macroeconomic sectors. Previously, we first set up scenarios of developments in the real economy and financial markets before calculating the impacts of such developments on the Japan's financial system. This was one-way and no-feedback loop stress testing in which stress testing measured the first round effects of economic developments on the financial system. We now include the feedback mechanism between the financial and macroeconomic sectors in macro stress testing using the FMM, which models the feedback mechanism. Here, we explain the mechanism employed for the economic downturn scenario (Figure 1). Because the creditworthiness of borrowing firms declines when the economy deteriorates, the probability of default increases. This leads to an increase in the credit costs of financial institutions and a decrease in their profits. Stock prices also go down as the economy deteriorates. As a result, the market values of stocks held by financial institutions decline. The capital levels of financial institutions are negatively affected by their decreasing profits and stock values.[4] Credit demand falls as the economy deteriorates, and the amount of lending declines. This is reflected in declining risk-weighted assets among financial institutions. While capital levels and risk-weighted assets change in opposite directions, capital adequacy ratios generally decline under stressful economic conditions.[5] These developments are considered in all macro stress testing models. In the current macro stress testing program at the Bank of Japan, we consider second-round effects, which capture the impacts of declines in the capital adequacy ratios of financial institutions on their lending activities and the economy as a whole. Once the capital adequacy ratios of financial institutions deteriorate, they increase their loan interest rates and reduce their lending. Both the increase in loan interest rates and the decrease in lending depress household and firm expenditure, leading to further deterioration of the economy. This movement again negatively affects the profits of financial institutions and their capital levels as described above.

Another improvement made is that we can analyze not only aggregate data for the financial sector, but also developments among individual financial institutions such as in capital adequacy ratios and net interest income. Initially, we only dealt with aggregate data of the financial system. We then improved the stress testing model in order to include individual financial institutions' activities by using detailed data for individual financial institutions

[4] Unrealized gains/losses on stockholdings are counted in calculating capital levels only for internationally active banks. This treatment is not applied to domestic banks due to domestic regulations.

[5] Capital adequacy ratios are determined due to relative changes in capital levels -- the numerator of such ratios -- and those in risk-weighted asset levels -- the denominator in such ratios. Based on past empirical evidence, the decline in capital levels was much larger than that in risk-weighted asset levels, and therefore capital adequacy ratios generally tended to decline in periods of economic downturn.

such as balance sheet items, profits and losses, and transition matrices of borrower classification. We also expanded the scope of financial institutions. The stress testing model included only banks at the initial stage, but now includes *shinkin* banks, which are small regional financial institutions. We now include 373 financial institutions in macro stress testing.[6]

B. Past Scenarios for Macro Stress Testing

In order to capture the characteristics of potential risk factors for the financial system, it is important to implement macro stress testing by reflecting ongoing developments in financial and economic conditions. In stress testing exercises reported in previous issues of the FSR, we used appropriate scenarios by focusing on the most important risk factors at each point in time and analyzing their impacts on the financial system (Figure 2). For example, in the September 2008 issue of the FSR, we conducted stress testing focusing on credit risk in real estate sector lending when newly established real estate firms actively developed real estate projects in the metropolitan area. In the April 2012 issue of the FSR, we assessed the spillover impacts of the European debt crisis by taking account of co-movements in domestic and international financial markets.

We have used two risk scenarios in recent issues of the FSR. The first is the economic downturn scenario in which the main focus is the change in credit costs. The second is the upward interest rates shift scenario in which we analyze various impacts of rises in interest rates on the financial system. In the latter case, we have investigated conditions in the economy and in the financial system under very severe circumstances in which upward shifts in interest rates coincide with an economic downturn. To do so, we have both improved the structure of the FMM. When interest rates go up, borrowers' burden of interest payments increases and it leads to higher probability of default of borrower. We

---

[6] The 10 major banks comprise Mizuho Bank, The Bank of Tokyo-Mitsubishi UFJ, Sumitomo Mitsui Banking Corporation, Resona Bank, Saitama Resona Bank, Mitsubishi UFJ Trust and Banking Corporation, Mizuho Trust and Banking Company, Sumitomo Mitsui Trust Bank, Shinsei Bank, and Aozora Bank. The 105 regional banks comprise the 64 member banks of the Regional Bank Association of Japan (Regional banks I) and the 41 member banks of the Second Association of Regional Banks (Regional banks II). The 258 *shinkin* banks are the *shinkin* banks that hold current accounts at the Bank of Japan. We adjusted historical data according to current financial institutions in case of mergers previously.

also developed a satellite model for analyzing interest rate movements. We can now analyze not only bond portfolio market values, but also interest income from lending activities and deposit taking in detail.

III. Financial Macro-econometric Model

We give an overview of the Financial Macro-econometric Model (FMM) in this section.[7] The FMM is a medium-sized macro model with two sectors: the financial sector and the macroeconomic sector (Figure 3; the details of equations are shown in Appendix 1). The most notable property of the FMM is the structure of the financial sector in which financial institutions' activities are modeled. For example, changes in credit costs and capital levels affect lending activities among financial institutions. Financial institutions are modeled by using panel data for individual financial institutions. Aggregate figures under stressful scenarios are the sums of the individual institutions' figures.

Note that the specifications of the equations are not induced by specific theoretical models, but are determined by past empirical heuristics and data consistency. These equations are estimated based on data from the 1980s using the least square method with equation-by-equation basis.[8,9] The FMM includes both nominal and real variables and price developments are exogenous.

A. Financial Sector

Individual financial institution variables such as credit costs, net interest income, and capital adequacy ratios are modeled in the financial sector portion of the FMM. As shown below, these individual financial institution variables are affected by macroeconomic variables. In turn, the aggregate financial variables affect macroeconomic variables. Moreover, these

[7] The FMM was developed in 2011 and has been improved overtime. It has been used for various analyses such as about macroprudential policy. See Ishikawa et al. (2011), Kamada and Kurachi (2012), and Kawata et al. (2013).

[8] In some equations, current dependent variables are regressed by current independent variables. Therefore, it is undeniable that the estimated parameters of these equations are subject to simultaneous equation bias. In this respect, the results of the stress testing simulations should be interpreted with some latitude.

[9] The FMM is a model using quarterly data. Therefore, annual and semi-annual data are interpolated using linear or other methods to transform them into quarterly data.

macroeconomic variables cause changes in variables for individual financial institutions. As described above, the feedback loop between the financial and macroeconomic sectors is incorporated into the FMM.

We first explain how net income of financial institutions is calculated in the FMM. The main variables are net interest income and credit costs. We then show how risk-weighted assets and capital adequacy ratios are calculated, and how these variables for individual financial institutions are aggregated.

1. Net income of individual financial institutions

The definition of net income is shown in equation (1). Net interest income is "revenues from lending and securities investments" minus "interest expenses of deposit and market funding." Non-interest income is revenues such as commissions. Other costs include general and administrative expenses, credit costs, and tax payments. Credit costs are outlays for disposing of non-performing assets. Realized gains/losses on stock and bond holdings are gains/losses on purchase/sale activities and charge-offs for stocks and bonds held by financial institutions. Others include extraordinary income/losses. We employ the term "operating profits from core business" for net interest income plus non-interest income minus general and administrative expenses. We use it as a core profitability indicator for financial institutions.

$$
\begin{aligned}
\text{Net income } = \; & \overbrace{\begin{array}{l}\text{net interest income} + \text{non-interest income} \\ - \text{ general and administrative expenses}\end{array}}^{\text{operating profits from core business}} \\
& - \text{credit costs} \\
& + \text{realized gains/losses on stockholdings} \\
& + \text{realized gains/losses on bondholdings} \\
& - \text{tax payments} + \text{others (i.e. extraordinary profits/losses)}
\end{aligned} \tag{1}
$$

Net interest income and credit costs are modeled in detail as follows in the FMM. Other items described above are not modeled, and we assume that the latest values for these items remain constant over time during the simulation period. We calculate tax payments based on the assumption that the effective tax rate for banks is 40 percent, while that for *shinkin* banks is 30 percent.[10]

2. Net interest income of individual financial institutions

The net interest income of individual financial institutions is calculated as shown in equation (2). Net interest income is "revenues from lending and securities investments" minus "interest expenses of deposit taking and market funding."

$$\begin{aligned}\text{Net interest income} &= \text{loan amounts} \times \text{loan interest rates} \\ &\quad - \text{funding amounts} \times \text{funding rates} \\ &\quad + \text{interest and dividends on securities} \\ &\quad + \text{other interest income}\end{aligned} \tag{2}$$

As shown below, changes in macro variables such as expected growth rates and land prices affect the amounts lent by financial institutions and lead to changes in net interest income. Changes in market interest rates are also factors that influence net interest income through loan interest rates, funding rates, and interest income from securities investments. Other interest income is not modeled, and in conducting simulations, we assume that the future value of other interest income is the same as that realized.[11]

Loan amounts and funding amounts

Loan amounts consist of amounts lent to firms, individuals, municipals, and overseas borrowers.

Loans to firms are affected not only by macroeconomic variables such as expected growth rates and land prices, but also by financial variables such as loan interest rates and capital adequacy ratios as shown in equation (3).[12] The specification for *shinkin* banks is described in Appendix 1. If expected growth rates increase, firms are actively engaged in investment activities and borrow more from financial institutions. If land prices go up, the value of collateral -- typically land -- also increases. Against this backdrop, borrowing

---

[10] Based on financial results data from 2000, the actual effective tax rate of banks is about 40 percent, while that of *shinkin* banks is about 30 percent.

[11] Other interest income includes interest income on call loans and deposits with other financial institutions.

[12] Expected growth rates are based on the results of surveys on Japan's real GDP growth rates for the next three years conducted by the Cabinet Office of the Japanese government.

firms find they have easier access to loans and actual loan amounts increase. If loan interest rates decline, funding rates also decline and loan demand among firms increases. If the capital adequacy ratios of financial institutions are high, their risk-taking capacity also increases and financial institutions increase their loan amounts. We use the "capital adequacy ratio gap" as an explanatory variable, which is defined as the difference between actual capital adequacy ratios and their regulatory levels.

$$
\begin{aligned}
&\text{Growth rates in loans bank } i \text{ to firms} \\
&= \text{ fixed effect bank } i \\
&+ 1.546 \times \text{expected growth rates} \\
&- 1.151 \times \text{changes in (loan interest rates of bank } i - \text{inflation rates)} \\
&\qquad\qquad\qquad\qquad\qquad\qquad \text{(one quarter lag, past year average)} \\
&+ 0.172 \times \text{capital adequacy ratio gap of bank } i \text{ (one quarter lag, past year average)} \\
&+ 0.318 \times \text{growth rate in land prices (one quarter lag, past two years average)}
\end{aligned}
\tag{3}
$$

The specification for loans to individuals is the same as that to firms. Overseas loans are modeled for specific financial institutions with large foreign exposures. Overseas loans of those financial institutions are explained by overseas economic developments (nominal GDP of overseas countries) and the capital adequacy ratio gap. The details of the specification are shown in Appendix 1. Overseas loans of other financial institutions are not modeled, and future growth rates in overseas loans are historic average growth rates. Amounts lent to municipals are not modeled, and levels realized in the past are used for simulations.

Growth rates of funding amounts used for simulations are historic average growth rates, and are not modeled and given exogenously.[13]

Funding rates

Funding rates, which are average yields on funds raised, are the weighted average of deposit rates and market funding yields.[14] The specification for funding rates is given in equation (4). Call rates (policy interest rates) and capital adequacy ratio gaps affect funding rates.

---

[13] Funding amounts could be influenced by various factors such as financial and economic conditions, interest rate levels, and the creditworthiness of individual financial institutions. We do not take account of these factors in the FMM.

[14] The weights reflect the funding amounts of each instrument.

$$\begin{aligned}\text{Funding rates } i &= \text{fixed effect } i \\ &+ 0.644 \times \text{call rates (one quarter lag, past year average)} \\ &- 0.043 \times \text{capital adequacy ratio gap } i \text{ (one quarter lag, past year average)}\end{aligned} \tag{4}$$

When we implement stress test simulations, we take account of changes in the yield curve and corresponding changes in deposit rates, in addition to the factors mentioned above. There are certain amounts of deposits with longer-term duration, and their yields will be affected not only by short-term interest rates, but also by the entire yield curve. It is also noted that changes in deposit rates are heterogeneous because individual financial institutions have different balance sheet structures. Therefore, we calculate changes in deposit rates in accordance with changes in the yield curve by using the interest rate model, which will be explained in the next section. The model takes account of different maturity structures among deposits of individual financial institutions. When we conduct simulations under stress scenarios, we calculate deviations of deposit rates under stress scenarios from those under the baseline scenario and use these deviations as exogenous shocks. The underlined term in equation (4)' is an exogenous shock.

$$\begin{aligned}&\text{Funding rates } i \\ &= \text{fixed effect } i \\ &+ 0.644 \times \text{call rates (one quarter lag, past year average)} \\ &- 0.043 \times \text{capital adequacy ratio gap } i \text{ (one quarter lag, past year average)} \\ &+ \underline{\text{changes in deposit rates } i \text{ in accordance with changes in the yield curve}}\end{aligned} \tag{4'}$$

Loan interest rates

In equation (5), loan interest rates are assumed to be affected by funding rates and demand-supply balance in the loan market. The proxy for demand-supply balance in the loan market is the loan amount gap.[15]

[15] The loan amount gap is defined as the deviation of the actual amount lent to firms from the potential loan amount in line with potential GDP. The detailed calculation methodology for the potential loan amount is shown in Appendix 1.

$$\begin{aligned}\text{Loan interest rates } i = {} & \text{fixed effect } i \\ & + 0.992 \times \text{funding rates } i \\ & + 0.029 \times \text{loan amount gap}\end{aligned} \tag{5}$$

When we conduct simulations under stress scenarios, in addition to the above factors, we take account of changes in loan interest rates and changes in the yield curve. Loan interest rates are affected not only by average fund raising rates, but also by changes in the entire yield curve, because financial institutions hold various loan assets with different durations. For example, if short-term interest rates increase and long-term interest rates stay almost constant, the average loan interest rates of certain financial institutions with longer term loans will not increase to the same extent. When we conduct simulations under stress scenarios, we use the deviations of loan interest rates from those under the baseline scenario as exogenous shocks shown in the fourth term underlined in equation (5)'. We calculate these deviations taking account of the heterogeneity of individual financial institutions' balance sheet structures by using the model for interest rate stress testing explained in the next section.

Changes in loan interest rates that occur along with those in the yield curve include changes in deposit rates that occur along with those in the yield curve. On the other hand, changes in funding rates also include those in deposit rates. Therefore, we need to exclude the impacts of changes in deposit rates influenced solely by changes in the yield curve from changes in funding rates, as shown in the second term underlined in equation (5)'. For example, suppose that market interest rates increase by one percentage point and funding costs also increase by the same amount due to changes in the yield curve. If we add up the change in funding rates, which is one percentage point, and that in the yield curve, which is also one percentage point, the total impact of the change in loan interest rates due to changes in the yield curve could be two percentage points. We need to avoid double counting of the impacts of yield curve changes, and therefore exclude the impacts of the change in deposit rates of one percentage point due to changes in the yield curve. In this case, the increase in loan interest rates is one percentage point, and this is exactly the same as the change in the yield curve.

$$
\begin{aligned}
&\text{Loan interest rates } i \\
&\quad = \text{fixed effect } i \\
&\quad + 0.992 \times \begin{pmatrix} \text{funding rates } i \\ -\underline{\text{changes in deposit rates } i \text{ due to changes in the yield curve}} \end{pmatrix} \qquad (5)' \\
&\quad + 0.029 \times \text{loan amount gap} \\
&\quad + \underline{\text{changes in loan interest rates } i \text{ in accordance with changes in the yield curve}}
\end{aligned}
$$

Interest and dividends on securities

Interest and dividends on securities include coupon revenue on bondholdings and dividend payments on stockholdings. We calculate interest income on bondholdings by using the interest rate stress testing model, which will be explained in the next section. The model takes account of bond portfolio maturity structures based on data submitted by financial institutions and of changes in coupon income due to the reinvestment of matured bonds. On the other hand, dividend payments on stockholdings are assumed to be constant over the simulation period at existing levels.

3. Credit costs of individual financial institutions

The definition of credit costs is shown in equation (6).

$$
\text{Credit costs} = \text{net provisions for loan losses} + \text{write-offs} + \text{other credit costs} \qquad (6)
$$

Net provisions for loan losses and write-offs are explicitly modeled. Other credit costs include losses on sales and income from the recovery of bad assets. When we implement simulations, we use the average levels of other credit costs for the past year.

Net provisions for loan losses and write-offs are calculated on the basis of information on rating transition matrices of borrower classification. The Bank of Japan has conducted a survey of rating transition matrices of borrower classification twice a year for banks and once a year for *shinkin* banks. Categorization of the creditworthiness of borrowers is based on rules on the self-assessment of borrowers by banks as stipulated in the Financial Inspection Manual of the Financial Services Agency. There are five categories: normal, need attention excluding special attention, special attention, in danger of bankruptcy, and de facto of bankrupt or bankrupt. The survey data show the extent to which loans move from one category to another in one period. We use ratings of 1 for the best (normal), 2 for the second-best (need attention excluding special attention) and so forth.[16]

Net provisions for loan losses

Net provisions for loan losses are calculated based on equation (7). As shown in the equation, the changes in net provisions for loan losses are caused by three factors. The first factor is the exposures of each of the borrowers' credit rating categories. The second factor is the shares of uncovered portion of loans of each of the borrowers' credit rating categories by collaterals and credit guarantees (uncovered ratios). The third factor is loan loss provision ratios for each of the loan categories. For each of the borrowers' credit rating categories, the second and third factors are more or less constant over time. Therefore, the main cause of the changes in net provisions for loan losses along with the changes in the economy is the first factor. When the loan in one category transits to another category, net provisions will be increased or decreased due to different values of uncovered ratios and loan loss provision ratios for each loan category.

$$
\begin{aligned}
&\text{Net provisions for loan losses } i\\
&\quad = \sum_{n=1}^{4} \begin{aligned}&\text{exposures } i \text{ categorized } n \text{ in the current period}\\ &\times \text{ uncovered ratios } i \text{ categorized } n \text{ in the current period}\\ &\times \text{ loan loss provision ratios } i \text{ categorized } n \text{ in the current period}\end{aligned}\\
&\quad - \sum_{n=1}^{4} \begin{aligned}&\text{exposures } i \text{ categorized } n \text{ in the previous period}\\ &\times \text{ uncovered ratios } i \text{ categorized } n \text{ in the previous period}\\ &\times \text{ loan loss provision ratios } i \text{ categorized } n \text{ in the previous period}\end{aligned}
\end{aligned} \tag{7}
$$

When we conduct macro stress testing simulation, we use equation (7)'. Uncovered ratios and loan loss provision ratios for each of the loan categories are assumed to be constant over the simulation period based on levels from the recent past.[17]

$$
\begin{aligned}
&\text{Net provisions for loan losses } i\\
&\quad = \sum_{n=1}^{4} \begin{aligned}&\text{changes in exposures } i \text{ categorized } n\\ &\times \text{ uncovered ratios } i \text{ categorized } n\\ &\times \text{ loan loss provision ratios } i \text{ categorized } n\end{aligned}
\end{aligned} \tag{7)'}
$$

---

[16] Category 1: normal; category 2: need attention excluding special attention; category 3: special attention; category 4: in danger of bankruptcy; and category 5: de facto of bankrupt or bankrupt.

[17] Due to availability of data, we assume that the uncovered ratios are 100 percent for category 3 or better. The denominators of loan loss provision ratios are total exposures for category 3 or better and the portion of loan exposures not covered by collateral and credit guarantees for category 4.

Write-offs

Write-offs are calculated based on equation (8). Loan amounts categorized in "in danger of bankruptcy" or better will change for one period due to new loans and/or repayments of existing loans. We assume that loan amounts for each category will change with the same growth rate as does that of the total loan amounts. A certain proportion of these exposures will be downgraded to "de facto of bankrupt or bankrupt." Here, we assume that loans newly categorized in "de facto of bankrupt or bankrupt" will be written off immediately during that period.[18]

$$\text{Write-offs } i = \sum_{m=1}^{4} \begin{array}{l} \text{exposures } i \text{ categorized } n \text{ in the previous period} \\ \times \text{ growth rate in loan amounts } i \\ \times \text{ transition probability } i \text{ from category } m \\ \qquad\quad \text{to "de facto of bankrupt or bankrupt"} \end{array} \tag{8}$$

As explained earlier, the Bank has conducted a loan categorization survey twice a year for banks and once a year for *shinkin* banks. Therefore, transition matrix estimations are based on semi-annual data for banks and annual data for *shinkin* banks. However, because the simulations for stress scenarios are calculated on a quarterly basis, we use the estimated parameters for calculation of provisions for loan losses and write-offs on a quarterly basis.

For example, we calculate quarterly credit costs in the October-December quarter of 2013, the first simulation period reported in the April 2014 issue of the FSR, as follows. First, we calculate total exposures at the end of December 2013 by multiplying total exposures at the end of June 2013 by the loan amount growth rate for the next six months.[19] Second, we calculate transition probabilities for the July-December period of 2013, and then multiply them by total exposures and other terms at the end of December 2013 in order to obtain net provisions for loan losses and write-offs for the July-December period of 2013. Total credit costs consist of those calculated and the constant amount of other credit costs

[18] Loan amounts covered by collateral and credit guarantees would be recovered. However, it is difficult to estimate recovery ratios with a high degree of confidence due to data availability. Therefore, we do not take account of recovery ratios, and assume that all loan exposures are written off.

[19] Quarterly realized exposures are calculated by applying the liner interpolation method using semi-annual data series.

explained earlier. We have total credit costs for the July-December period of 2013. Finally, we subtract realized credit costs for the July-September quarter of 2013 from estimated credit costs for the July-December period of 2013 in order to obtain credit costs for the October-December quarter of 2013.[20] As for *shinkin* banks, we first calculate annual credit costs, then subtract realized credit costs for the past three quarters (the period of July 2012 to March 2013) from estimated annual credit costs in order to derive credit costs for the April-June quarter of 2013.[21] We repeat the same calculation and obtain credit costs for the July-September quarter of 2013 and the October-December quarter of 2013.

Loan amounts (exposures) by credit rating category

The specification of total exposures is given in equation (9). Changes in loan exposures of a certain category include transitions between different credit rating categories, new loans, and repayments of existing loans. Transitions between different credit rating categories are described by using the transition matrices of borrowers. Loans are reclassified among categories other than "de facto of bankrupt or bankrupt" because all loan exposures classified in "de facto of bankrupt or bankrupt" are written off immediately and no transitions in these exposures are expected. We assume that the growth rates of loan exposures in each credit rating category are the same for all credit rating categories other than "de facto of bankrupt or bankrupt."

$$\begin{aligned}&\text{Loan exposures } i \text{ categorized } n\\ &\quad = \sum_{m=1}^{4} \begin{array}{l}\text{loan exposures } i \text{ categorized } m \text{ (the previous period)}\\ \times\ \text{growth rate in loan amounts } i\\ \times\ \text{transition probability } i \text{ from category } m \text{ to } n\end{array}\end{aligned} \tag{9}$$

where $n = 1, \cdots, 5$

Borrower classification transition probability

The specification of transition probabilities is shown in equation (10). Probabilities are explained by macroeconomic variables (nominal GDP growth rate) and financial positions

[20] Quarterly realized credit costs are calculated by dividing the total amount of semi-annual credit costs by two.

[21] Quarterly realized credit costs are calculated by dividing the total amount of annual credit costs by four.

of borrowing firms (interest coverage ratios <ICRs>, quick ratios, and debt equity ratios <DE ratios>).[22] Based on the above specification, once macroeconomic conditions deteriorate, the probabilities of downgrades increase in the FMM. At the same time, the financial positions of borrowing firms also worsen as macroeconomic conditions deteriorate, and this also leads to higher probabilities of downgrades. If interest rates go up, the interest payment burdens of firms will increase and ICRs will decline. This also raises the likelihood of downgrades.[23] When macroeconomic conditions deteriorate but firms remain in a strong financial position, downgrades are not so likely.

$$\text{Transition probability } i \text{ from category } m \text{ to } n$$
$$= \frac{1}{1+\exp\left\{-\begin{pmatrix} \text{fixed effect } i^{mn} + \beta^{mn} \times \text{nominal GDP gowth rate} \\ +\gamma^{mn} \times \text{ICRs} + \delta^{mn} \times \text{quick ratios} + \eta^{mn} \times \text{DE ratios} \end{pmatrix}\right\}} \qquad (10)$$
$$\text{where } m = 1, \cdots, 4, \;\; n = 1, \cdots, 5$$

The transition probability equations are estimated based on panel data for banks and *shinkin* banks. For banks, we use transition probabilities based on loan amount data. When using these data, we can estimate parameters taking account of the impacts of previous large defaults during economic downturns. On the other hand, the transition probabilities of *shinkin* banks are based on numbers of borrowers because loan amount figures are not available.

We employ the fixed effects model to estimate transition probabilities. Therefore, differences in transition probabilities among different financial institutions are reflected in the different values of constant terms for the fixed effect. For example, the probability of a bank with a bad quality loan portfolio being downgraded is higher than that for other banks with good quality loan portfolios. This mechanism is captured by the fixed effect terms.

If large negative shocks occur, deterioration in the quality of bank loans tends to be much more severe than that observed in normal economic downturns. In order to take account of such a non-linear impact in the FMM, we use larger downgrade parameters for loans categorized as "normal," "need attention excluding special attention," "special attention,"

[22] We estimate equation (10) by transforming both sides of the equation with the logit function.

[23] ICRs are defined as "operating profits plus interest and dividends received, etc." divided by "interest payments, etc."

and "in danger of bankruptcy" into "de facto of bankrupt or bankrupt." We use the normal parameters for a period in which no stresses are exerted on the economy, which are estimated with a fixed effects model, and use the larger parameters for a period in which large stresses emerge. The larger parameters are estimated using the quantile regression method.[24,25]

The specification of the transition probability equations is given in equation (10), which was used in the April 2014 issue of the FSR. This specification was improved in that issue and its main changes will be explained in Appendix 2.

4. Capital adequacy ratios of individual financial institutions

Changes in net income and loan amounts lead to changes in capital levels (the numerators of capital adequacy ratios) and risk-weighted assets (the denominators of capital adequacy ratios).

Capital adequacy ratios of financial institutions are calculated based on domestic regulations in accordance with the Basel Accord. We have different regulations governing capital adequacy ratios: one set for internationally active banks and another for domestic banks. Therefore, we calculate capital adequacy ratios for each group of banks based on these different regulations for simulation purposes.

---

[24] The quantile regression method is used to estimate parameters in accordance with the distribution of a dependent variable. We could use certain quantile values of these distributions such as the 90th percentile value for a period in which large stresses emerge. We use the normal parameters estimated by the least square method for a period in which no stresses are exerted on the economy. By using different parameters in accordance with different conditions of the financial system, we simulate a non-linear relationship between an explanatory variable and a dependent variable in the FMM.

[25] We use dummy variables for estimation of equations for loan amount to firms, loan amount to individuals, and funding rates during the financial crisis period from late 1990s to early 2000s. Dummy variables push down loan amounts and push up funding rates. These dummy variables capture very cautious activities of financial institutions due to severer capital restrictions during the financial crisis period. We don't use the impacts of the dummy variables for the current stress test simulations because we assume that even under the stress scenarios capital restrictions of financial institutions do not become as severe as those observed during the financial crisis period. It is possible that we could implement stress simulations with non-linear phenomena pushing down the economy very severely by using dummy variables.

There is a phase-in period during which new regulations in accordance with Basel III will be implemented for internationally active banks in March 2013. The Bank's macro stress testing takes account of these phase-in treatments, and capital adequacy ratios are calculated in accordance with regulations including the phase-in treatments. The new regulations for domestic banks were introduced in March 2014. However, we did not have data based on the new regulations for the April 2014 issue of the FSR and used capital adequacy ratios based on the previous regulations.

The calculation methods for capital levels (the numerators) and risk-weighted assets (the denominators) are as follows.

Capital levels

If net income is positive, some of them are distributed as dividends and the remaining profits are saved as retained earnings, and capital levels increase as a result.[26] We assume a dividend payout ratio of 20 percent. If net income is negative, no dividends are paid and retained earnings fall. This leads to lower capital levels.

Capital gains/losses on securities holdings are reflected in capital calculations for internationally active banks.[27] Capital gains/losses on domestic bondholdings are calculated based on the framework of interest rate stress testing discussed later in this paper, based on detailed bondholding data. Capital gains/losses on foreign bondholdings are calculated based on certain assumptions based on changes in interest rates in the United States and Europe.[28] Capital gains/losses on stockholdings are estimated based on the

[26] In macro stress testing in the FSR, we do not take into consideration changes in capital policies of financial institutions such as changes in dividend ratios and stock buybacks.

[27] Capital gains/losses on securities holdings are not reflected in capital levels for domestic banks. However, it is possible to calculate capital gains/losses on securities holdings of domestic banks by applying the same calculation methodology used for internationally active banks. We calculate capital gains/losses on securities holdings of domestic banks and use them to measure the impacts on domestic bank capital adequacy ratios assuming that gains/losses are realized with sales. See, for example, the April 2014 issue of the FSR.

[28] We calculate capital gains/losses on foreign securities holdings on an individual financial institution basis and use the following calculation method. Total capital gains/losses is calculated as foreign bondholdings times share of the U.S. or European bondholdings times changes in interest rates of the U.S. or European bonds times average maturities. Foreign bondholdings of individual financial institutions are estimated by using various statistics since we only have data of foreign

assumption that market beta is one and changes in the values of financial institution stockholdings are the same as those in market capitalization values. We use the same methodology for Japanese, the U.S. and European stocks. Here, we assume that no stock transactions occur during the simulation period and that the book values of stocks remain constant.

Risk-weighted assets

Risk-weighted assets include credit risk assets, market risk assets (banks only), and operational risk assets.

Credit risk assets are the weighted average of assets with different weights for different asset categories such as loans and stocks. We estimate the fixed weights for each asset class in equation (11). Changes in credit risk assets are explained by changes in loans, stockholdings, bondholdings, and other securities holdings (foreign bondholdings, etc.) with estimated parameters serving as fixed weights.[29] We could interpret these fixed weights as average risk weights based on past data.

$$\begin{aligned}\text{Changes in credit risk assets } i &= \text{fixed effect } i \\ &+ 1.981 \times \text{changes in stockholdings } i \\ &+ 0.915 \times \text{changes in loan amounts } i \\ &+ 0.050 \times \text{changes in other securities holdings } i\end{aligned} \tag{11}$$

Market risk assets are explained by interest rate volatility as shown in equation (12). Operational risk assets are explained by gross profits as shown in equation (13).

$$\begin{aligned}\text{Changes in market risk assets } i &= \text{fixed effect } i \\ &+ 0.143 \times \text{changes in interest rate volatility}\end{aligned} \tag{12}$$

securities holdings. Due to data availability, we use the share of the domestic bondholdings to the total domestic securities holdings as a proxy of the foreign share. Share of the U.S. or European bondholdings is calculated as the U.S. or European bondholdings divided by overall bondholdings using Balance of Payments. The average maturities of foreign bonds are assumed to be the same as those of domestic bonds, which are estimated as aggregate figures based on maturity ladder statistics provided by financial institutions.

[29] When conducting stress simulations, we use calculated values of loans but employ the constant levels of other variables.

$$\text{Operational risk assets } i = \text{fixed effect } i + 1.532 \times \text{gross profits } i \text{ (past three years average)} \tag{13}$$

5. Aggregation of financial data of financial institutions

Total loan amounts and aggregate loan interest rates are calculated based on those of individual financial institutions. Total loan amounts are the sums of loans made by individual financial institutions. Aggregate loan interest rates are weighted averages of individual financial institutions' loan interest rates with loan share weights. Aggregate capital adequacy ratios for internationally active banks and domestic banks are calculated; we aggregate numerators and denominators separately before calculating these ratios.

B. Macroeconomic Sector

Aggregate loan amounts and loan interest rates influence household expenditure and firms' investments in the macroeconomic sector. Changes in macroeconomic variables such as nominal GDP including household expenditure and firms' investments lead to changes in variables in the financial sector through net interest income and credit costs of individual financial institutions.

Nominal GDP components such as firms' investments and nominal household expenditure, the expected growth rate, asset prices, and firms' financial variables are modeled as follows.

Nominal GDP components

The nominal firms' capital investments and household expenditure of nominal GDP are modeled in addition to employee compensation. Note that household expenditure is composed of private consumption and housing investment.

Firms' capital investments are explained not only by macroeconomic variables such as expected growth rates and firms' return on assets (ROAs) based on firms' current profits, but also by financial variables such as loan interest rates and loan amounts to firms as shown in equation (14). An increase in the expected growth rates boosts capital investments among firms. An increase in current profit ROAs among firms brings about capital investments among firms through increased retained earnings. Rising loan interest rates suggest that firms' funding costs will increase and that net returns on additional investments will decrease, leading to a decline in capital investments among firms. A rise in loans to firms improves firms' funding conditions, leading to increased capital investments among firms.

$$\begin{aligned}&\text{Growth rates in nominal capital investments}\\&\quad = 6.596 \times \text{changes in current profit ROAs (past two quarters average)}\\&\quad + 0.666 \times \text{expected growth rates}\\&\quad - 1.872 \times \text{changes in (loan interest rates} - \text{inflation rates) (two quarter lags)}\\&\quad + 0.857 \times \text{growth rates in loans to firms}\end{aligned} \tag{14}$$

Household expenditure -- the sum of private consumption and private housing investment -- is determined by employee compensation, stock prices, loan interest rates, and loans to individuals as shown in equation (15). An increase in employee compensation leads to a rise in disposable income, bringing about higher household expenditure. Increasing stock prices cause higher household expenditure through the wealth effect. Increase in loans to individuals facilitates more accommodative financial conditions for households and lead to increased household expenditure. On the other hand, increasing loan interest rates mean higher interest payments, leading to lower household expenditure.

$$\begin{aligned}&\text{Growth rates in nominal household expenditure}\\&\quad = 0.524 \times \text{growth rates in employee compensation}\\&\quad + 0.018 \times \text{growth rates in stock prices}\\&\quad - 0.459 \times \text{changes in loan interest rates (two quarter lags)}\\&\quad + 0.168 \times \text{growth rates in loans to individuals}\end{aligned} \tag{15}$$

Employee compensation is explained by macroeconomic variables such as nominal GDP as shown in equation (16). When economic conditions are good, nominal GDP growth is high and firms become more economically active. Under such conditions, labor hours and the number of employees also increase, and employee compensation also rises. Firms' decision-making on labor share influences the total amount of employee compensation. An increase in the inflation rates exerts upward pressure on nominal wages, leading to higher employee compensation.

Growth rates in employee compensation

$$= 0.591 \times \text{nominal GDP growth rate} + 0.376 \times \text{changes in labor share (one quarter lag)} + 1.023 \times \text{inflation rates} \tag{16}$$

Expected growth rates and asset prices

The expected growth rates are influenced by potential GDP growth rates and are gradually adjusted by actual changes in real GDP growth rates as shown in equation (17).[30,31]

Expected growth rates

$$= 0.776 \times \text{potential GDP growth rate (past three years average)} + 0.099 \times \text{real GDP growth rate} \tag{17}$$

Stock prices are influenced by current profit ROAs, the expected growth rates, and the U.S. stock prices as shown in equation (18). If current profit ROAs, which are proxies for corporate profits, improve, stock prices also increase. An increase in the expected growth rates brings about higher medium- to long-term growth rates, leading to higher stock prices. The U.S. stock prices are proxies for overseas economic conditions and investment attitudes of global investors.

Growth rates in stock prices

$$= 13.882 \times \text{changes in current profit ROAs} + 1.882 \times \text{expected growth rates} + 0.285 \times \text{growth rates in the U.S. stock prices} \tag{18}$$

Land prices are influenced by nominal GDP, inflation rates, and loan amounts as shown in equation (19). An increase in nominal GDP provides a higher rate of return in land investments, leading to higher land prices. An increase in loan amounts stimulates real estate investments among firms and households, which also leads to higher land prices. Inflation rates also contribute to higher land prices.

[30] The Bank of Japan estimates potential GDP growth rates. The details of the estimation method are explained by Hara et al. (2006).

[31] While we use nominal GDP as a proxy for economic activity in the FMM, expected growth rates are real variables. This is because limited data availability of nominal potential GDP growth rate.

$$\begin{aligned}&\text{Growth rates in land prices}\\&\quad = -3.962 + 0.294 \times \text{nominal GDP growth rate (past year average)}\\&\quad + 0.931 \times \text{growth rate in loan amounts (one quarter lag, past year average)}\\&\quad + 0.447 \times \text{changes in inflation rates}\end{aligned} \tag{19}$$

Financial indicators of firms

In equation (10), we showed that financial indicators of firms (interest coverage ratios <ICRs>, quick ratios, and debt equity ratios <DE ratios>) are explanatory variables for transition matrices of borrower classification. These three ratios and current profit ROAs of firms are explained below.

ICRs are defined as operating profits plus interest and dividends received, etc., divided by interest payments, etc. The numerator reflects the extent to which firms can meet interest payments, and the denominator is a measure of the interest payment burden. If ICRs are high, firms have sufficient capacity to make interest payments.

The ICRs numerator -- operating profits plus interest and dividends received, etc. -- is divided by nominal GDP, and the ratio is expected to be affected by current profit ROAs of firms as shown in equation (20). If firm profitability improves along with better economic conditions, the ICRs numerator -- operating profits and interest income, etc. -- will also increase.

$$\begin{aligned}&(\text{Operating profits} + \text{interest and dividends received, etc.})/\text{nominal GDP}\\&= 0.006 + 0.550 \times \text{current profit ROAs (past two quarters average)}\end{aligned} \tag{20}$$

The ICRs denominator -- interest payments, etc. -- is divided by loans to firms, and the ratios are explained by loan interest rates as shown in equation (21). If loan interest rates go up against the backdrop of higher market interest rates, firms' interest payment burden will increase and the ICRs denominator will rise, resulting in falling ICRs.

$$\begin{aligned}&\text{Interest payments, etc.}/\text{loans to firms}\\&\quad = 0.001 + 1.044 \times \text{loan interest rates (past two quarters average)}\end{aligned} \tag{21}$$

Quick ratios are affected by current profit ROAs of firms and the output gap of the macro economy as shown in equation (22).[32] Therefore, if firm profitability improves along with an economic recovery, the output gap will go up and quick ratios will increase.

$$\begin{aligned}\text{Quick ratios} = {} & 0.168 \\ & + 0.015 \times \text{current profit ROAs (past two quarters average)} \\ & + 0.601 \times \text{output gap}\end{aligned} \tag{22}$$

DE ratios are explained by their own lag and loan amounts to firms divided by nominal GDP, as shown in equation (23)[33]. If firms increase their loan amounts relative to nominal GDP, DE ratios will go up.

$$\begin{aligned}\text{DE ratios} = {} & -0.148 \\ & + 0.955 \times \text{DE ratios (one quarter lag)} \\ & + 0.145 \times \text{loans to firms}/\text{nominal GDP}\end{aligned} \tag{23}$$

Current profit ROAs depend not only on macro variables such as the output gap and the labor share, but also on loan interest rates as shown in equation (24). The output gap is a proxy for macroeconomic activity, and an improvement in the output gap leads to higher current profit ROAs supported by increased sales and margins. If the labor share increases, personnel expense payments relative to firms' profits become higher, leading to lower current profit ROAs. Increased loan interest rates push down current profit ROAs by raising firms' funding costs and reducing profits.

$$\begin{aligned}\text{Changes in current profit ROAs} = {} & 26.802 \times \text{changes in output gap} \\ & - 0.420 \times \text{changes in loan interest rate} \\ & - 19.448 \times \text{changes in labor share}\end{aligned} \tag{24}$$

C. Feedback Loop between the Financial and Real Economic Sectors

The macro stress testing framework employed by the Bank of Japan includes not only the first round effect -- reflecting the impact of the real economy on the financial sector -- but also the second round effect -- indicating the influence of changes in financial variables such as loan amounts and loan interest rates on the real economy. Therefore, we can

[32] Quick ratios are defined as quick assets (cash, deposits, bills and accounts receivable, and securities) divided by liquid liabilities.

[33] DE ratios are defined as liabilities divided by capital in financial statements.

depict the feedback loop between the financial and real economic sectors. For example, if nominal GDP changes, the credit costs and capital adequacy ratios of financial institutions are affected, and loan amounts and loan interest rates change. Changes in loan amounts and loan interest rates affect investments among firms and households, causing changes in nominal GDP. Changes in the economy feed back into the financial sector again.

In order to measure the impact of the feedback loop, we show the extent to which nominal GDP with the feedback loop will differ from that without the feedback loop (the details of this simulation are explained in Appendix 3).[34] The simulation results show that the first year's nominal GDP growth rate deviates from the baseline case by about one percentage point without the feedback loop, whereas it deviates by about two percentage points with the feedback loop (Figure 4). In the case of the feedback loop, loan amounts decline along with deterioration in nominal GDP, leading to a downturn in nominal expenditure among households and in nominal investments among firms. This is one route via which the feedback loop operates through lending activities. A decline in loan amounts brings down net interest income among financial institutions, leading to lower operating profits from core business for financial institutions. Worsening conditions in the real economy will bring about an increase in bankruptcies among borrowing firms through the deterioration of firms' financial variables and higher credit costs. As a result, the capital adequacy ratios of financial institutions deteriorate to a much greater extent with the feedback loop than without. For internationally active banks, unrealized losses on stockholdings along with declining stock prices caused by a deteriorating economy contribute to lower capital adequacy ratios.

IV. Framework for Interest Rate Stress Testing

Fluctuations in market interest rates affect the periodic income of financial institutions by causing changes in their loan interest rates, deposit rates, and coupon income on bonds in their portfolios. In addition, they change the market values of their bonds (Figure 5). To quantify these effects, we need to utilize detailed data on the asset and liability structure of financial institutions. When conducting interest rate stress testing, we complement the

[34] The quantitative evaluation of the feedback loop here is based on certain assumptions and some elements are omitted. Therefore, the results should be interpreted with some latitude.

FMM simulation with analysis using more granular data on loan interest rates, deposit rates, and asset and liability items on the balance sheets of financial institutions.

In this section, we explain how we quantitatively assess the effects of fluctuations in market interest rates on an individual financial institution's loan interest rates, deposit rates, coupon income from bonds, and market values of bonds in its portfolio.

A. Loan and Deposit Rates

Fluctuations in market interest rates lead to changes in loan and deposit rates among financial institutions. However, the sensitivity of loan and deposit rates to changes in market interest rates varies across types of loan or deposit. In addition, the speed of changes in loan and deposit rates in response to fluctuations in market interest rates varies across types of loan and deposit. The FMM cannot capture such differences in sensitivities and in the speed of changes in loan and deposit rates. Therefore, these are taken into account by using a separate model.

More specifically, we conduct simulations on loan and deposit rates by using a satellite model for interest rate stress testing, which takes account of differences in sensitivities and in the speed of changes in interest rates by type and maturity of loans and deposits (see Appendix 4 for details of the satellite model). There are two types of loan interest rates: long-term and short-term.[35] For each type, equations capturing the dynamics of loan interest rates are estimated using panel data consisting of observations for individual financial institutions. In estimating sensitivities to changes in market interest rates, we control for some factors other than market interest rates that can affect loan interest rates. These factors include macroeconomic variables such as output gaps and balance sheet items of individual financial institutions (Figure 6). Regarding time deposit rates, for each deposit term we have equations to capture the dynamics of deposit rates. Each equation is estimated using panel data consisting of observations for individual financial institutions. As was the case for loan interest rates, we control for macroeconomic factors and balance sheet items of individual financial institutions in estimating sensitivities of deposit rates to changes in market interest rates. Regarding ordinary deposits, equations to capture their dynamics are estimated using aggregate data by type of banks (major banks, regional banks,

[35] Short-term loans include discount bills and overdrafts.

and *shinkin* banks). The reason for not using panel data, consisting of observations for individual financial institutions, is that fluctuation patterns for ordinary deposit rates are very similar within each type.

The pass-through rate measures the extent to which loan or deposit rates change in response to fluctuations in market interest rates. According to estimation results obtained using historical data, pass-through rates for loan interest rates rise to about 90 percent and those for deposit rates go up to about 60 percent three years later after an increase in market rates (Figure 7).[36] The pass-through rates for deposit rates are slower than those for loan interest rates because the pass-through rates for ordinary deposit rates are very low.

When conducting interest rate stress testing, we occasionally use pass-through rates that differ from the estimates obtained by the process described above. For example, in the April 2014 issue of the FSR, we conducted a stress test which assumed that economic conditions were severe and that the profitability of financial institutions was low. When market interest rates rose under the stress scenario, financial institutions were assumed to be unable to increase their loan interest rates as much as they could in a normal situation, while they were assumed to be forced to raise funding rates to a greater extent than they would under normal circumstances. In implementing this approach, for both internationally active banks and domestic banks, we assume that the pass-through of loan interest rates would be smaller, while the pass-through of funding interest rates would be larger, than the estimation results based on past data. The extent of downward and upward deviations is calculated by adjusting the estimated coefficients of each pass-through rate by about two standard errors (Figure 7).

B. Coupon income from bonds and market value of bonds[37]

A change in market interest rates leads to (1) a fluctuation in coupon income from bonds caused by a change in coupon rates; and (2) a change in the market value of bonds.

---

[36] We estimate pass-through rates of loan and deposit rates based on the assumption that they converge to 100 percent in the long run. For ordinary deposit rates of *shinkin* banks, estimation under this assumption did not yield a statistically significant result. Thus, we estimated pass-through rated for this case without making this assumption. Hence, pass-through rates for the ordinary deposit rates of *shinkin* banks do not converge to 100 percent in the long run.

[37] For more details on how we compute these items in simulations, see Appendix 5.

First, coupon income from fixed rate bonds is computed as follows. We assume that the coupon rate on a fixed rate bond is set to the market interest rate prevailing when it is issued. As for existing fixed rate bonds, its coupon rate does not change even if market rates increase. We also assume that when a bond matures during the simulation period, the redemption funds will be reinvested in bonds so that the maturity structure of the bond portfolio will remain unchanged from what it was at the beginning of the simulation period. For instance, suppose that there are 10-year fixed rate bonds with a total face value of one trillion yen and that their remaining maturity is three months. In this case, after three months elapse and the bonds mature, the one trillion yen will be invested in newly issued 10-year fixed rate bonds. When market interest rates are rising, coupon rates on such newly issued bonds will also increase hand-in-hand with market interest rates. Therefore, coupon income from newly issued bonds purchased using redemption funds will increase as market interest rates rise.

For floating rate bonds, coupon rates on such bonds are continually reset to the prevailing market interest rates. Thus, when market interest rates rise, coupon income from such bonds also increases.

Next, the market value of a fixed rate bond is computed using the yield for the corresponding maturity as the discount rate. For instance, the market value of the principal of a fixed rate bond with a remaining maturity of five years is computed using the 5-year yield as the discount rate.[38]

Finally, when computing the market value of a 15-year floating rate bond, we take account of its distinct patterns of coupon rate and market value changes. Coupon rates for this type of floating rate bond are affected by market interest rates for maturities

[38] Attention should be paid to the difference between capital losses on bondholdings calculated in our macro stress testing and 100 basis point value -- capital losses on bondholdings under the parallel shift scenario in which interest rates at all maturities instantly rise by 1 percentage point at the same time. The effect of time elapsed after the rise in interest rates is taken into account in calculating capital losses in macro stress testing, while it is not in calculating 100 basis point value. That is, with an upward yield curve shift, discount rates fall and the market value of bonds increases as the remaining maturities of bonds shorten with the passage of time. This is termed the "roll-down effect." Due to this effect, in macro stress testing, capital losses on bondholdings decrease below 100 basis point value as time passes, even if the same 1 percentage point parallel shift scenario is assumed.

longer than that of the discount rate used to calculate the market value of the bond. More specifically, the coupon rate of a 15-year floating rate bond is reset semi-annually at the 10-year bond rate (the compound yield of the average accepted bid in the 10-year JGB auction held six months before the coupon payment month) less a fixed number of basis points. Therefore, under a yield curve steepening scenario in which longer term market interest rates increase by a large amount, the rising coupon rate effect (which increases the market value) exceeds the rising discount rate effect (which decreases the market value), and unrealized gains increase. In contrast, under a yield curve flattening scenario in which shorter term market interest rates increase by a large amount, the rising discount rate effect (which decreases the market value) exceeds the rising coupon rate effect (which increases the market value), and unrealized losses increase.

Among securities held by financial institutions, held-to-maturity securities are reported in the balance sheet at their amortized cost under the current accounting rule unless their market value declines considerably. Meanwhile, in the macro stress testing reported in the FSR, all fixed-income securities held by financial institutions are valued at market value. This means that the testing evaluates their changes in economic value rather than their changes in accounting value.

V. Implementation of Macro Stress Testing

In this section, we explain how we conduct macro stress testing in the FSR using the framework described above.

A. Stress Scenarios

We have one baseline scenario and two stress scenarios for macro stress testing in the latest issue of the FSR.[39] One stress scenario assumes that severe stresses equivalent to the Lehman shock in 2008 occur in overseas economies and global financial markets (an economic downturn scenario). The other stress scenario assumes that the yield curve

[39] It should be noted that the scenarios assumed in macro stress testing are not used to present the most likely projection for Japan's economy and asset prices. Rather, they are aimed at clarifying the characteristics of risks financial institutions face and assessing the resilience of the financial system.

steepens with a rise of about two percentage points in long-term interest rates in Japan (an upward interest rate shift scenario). The magnitude of stresses under each scenario is assessed by comparing them with the baseline scenario.

The simulation period for macro stress testing is about three years. In the latest issue of the FSR (April 2014), we assume that stresses occur from the April-June quarter of 2014, and changes through until the end of fiscal 2016 (the end of March 2017) are calculated. Therefore, the simulation period is exactly three years.[40]

Under extremely stressful conditions in the financial system, credit costs tend to increase in a non-linear way, to a much larger extent than the deterioration of macroeconomic conditions. Therefore, as mentioned above, we use the "stress" parameters for equation (10) when we conduct stress scenario simulations. We estimate the "stress" parameters of the transition probability functions using the quantile regression method. We first calculate the difference between the current and previous nominal GDP growth rates and draw the distribution. We then identify the lower 30th and 10th percentile point values of the distribution. If nominal GDP growth rates deteriorate by more than the below values under the stress scenarios, we use the "stress" parameters of the 70th or 90th percentile points for transition probability functions. We use the normal parameters estimated by the fixed effect panel model for the period outside the stressful periods.

1. Baseline scenario

Assumptions made for the baseline scenario are as follows (Figure 8). The overseas real GDP growth rate rises moderately from 2.5-3.0 percent in 2013 to about 4.0 percent through 2016. We use annual forecast data from the International Monetary Fund (IMF) to create quarterly series with the spline function. The nominal GDP growth rate rises from minus 0.2 percent in fiscal 2012 to 2.3 percent in fiscal 2013 and hovers at 2.0-2.5 percent through fiscal 2016. This assumption is based on the ESP forecasts provided by the Japan Center for Economic Research (JCER) from fiscal 2014 to fiscal 2015. We assume the same

[40] Financial results are available for banks and *shinkin* banks until the end of September 2013 and the end of March 2013, respectively. In this analysis, financial results are estimated until the end of March 2014 using the FMM. Macro stress testing is conducted starting from the end of March 2014.

growth rate for fiscal 2016 as that for fiscal 2015.[41] Stock prices (TOPIX) and 10-year JGB yields remain unchanged from the levels observed at the end of September 2013.[42]

2. Economic downturn scenario

Assumptions made for the economic downturn scenario are as follows (Figure 9). Stresses equivalent to the Lehman shock in 2008 arise in overseas economies and global financial markets in the first half of fiscal 2014. Specifically, we assume that a large exogenous negative shock causes large downward revisions of real GDP growth rates in overseas economies, a situation comparable with the downward revision of actual GDP growth rates for 2008-2010 from the forecasts made in April 2008 and published in IMF World Economic Outlook. We also assume that the declines in the U.S. and European stock market prices are equivalent to those seen from the pre-Lehman shock peak to the subsequent trough.[43]

Based on the above-mentioned assumptions, the overseas economic growth rate plunges to 0.5 percent in 2014 from 2.5-3.0 percent in 2013 and returns to around the baseline scenario level in 2016. Stock prices (TOPIX) fall by 55 percent between the end of March 2014 and the end of March 2015,[44] and 10-year JGB yields decline by about 0.3 percentage points during the same period. Thereafter, stock prices and 10-year JGB yields remain more or less unchanged.

3. Upward interest rate shift scenarios

Macro stress testing assumes the following two rising interest rate cases: a case in which interest rates rise in line with economic improvement; and a case in which interest rates rise with an economic downturn. Both cases assume a steepening scenario under which

---

[41] The future paths of nominal GDP components are set by using forecasts of private sector research institutions.

[42] Specifically, stock prices (TOPIX) are 1,194 points and the 10-year JGB yield is 0.69 percent.

[43] We calculate the paths of long-term interest rates in the U.S. and European markets by using a vector auto regression (VAR) model with four variables (overseas economic growth rate; and long-term interest rates in Japan, the U.S., and Europe). Changes in long-term interest rates are extrapolated using VAR, with the overseas economic growth rate serving as an exogenous variable.

[44] We assume that the decline in Japan's stock prices is equivalent to that realized from the pre-Lehman shock peak to the post-Lehman shock trough.

market interest rates for instruments with longer maturities rise by two percentage points, while those for instruments with shorter maturities do not rise significantly. We set the same assumptions for overseas economies as those employed in the baseline scenario.

A rise in interest rates in line with economic improvement

The first case assumes that the yield curve steepens gradually as demand for funds increases in line with the economic improvement and a rise in stock prices. The assumptions are explained in more detail as follows (Figure 10).

Market interest rates for instruments with a 10-year maturity rise from the baseline scenario level by two percentage points for one year from the end of March 2014 and remain unchanged through the end of fiscal 2016. Interest rates for instruments with shorter maturities remain more or less unchanged. The nominal GDP growth rate increases from the baseline scenario level by about two percentage points in fiscal 2014. The upward shift of the nominal GDP growth rate is calculated based on the correlation between changes in long-term interest rates and the nominal GDP growth rate, and we use the maximum elasticity of their positive correlation since early 1990 when the Heisei bubble collapsed. Stock prices are endogenous variables in this simulation and rise gradually in line with the economic improvement, rising from the baseline scenario level by about 25 percent in fiscal 2016.

A rise in interest rates with an economic downturn

The second case assumes that a decline in stock prices and an economic downturn in tandem with a sharp rise in interest rates hinder an improvement in financial institutions' interest rate spreads on loans. The assumptions are outlined in more detail as follows (Figure 10).

The interest rate yield curve steepens immediately after the start of the estimation period. Specifically, 10-year rates rise by two percentage points from the baseline scenario level at the beginning of the April-June quarter of 2014 and remain at the same level through the end of fiscal 2016. Stock prices fall by 34 percent during the quarter, with a simultaneous rise in interest rates. Changes in stock prices are calculated based on the correlation between stock prices and long-term interest rates, and we use the maximum negative elasticity of the correlation since 1990 recorded in the April-October period of 1991. After declining for one year along with the economic downturn, stock prices are endogenously determined and drop 45 percent below the baseline scenario level. Stock prices stay at the same level after fiscal 2015. With respect to the economy, the nominal GDP growth rate deviates from the baseline scenario level immediately after the start of the estimation period, sitting at around minus 1.5 percent in fiscal 2014.

Furthermore, we assume a situation in which the deterioration in economic conditions and rises in market interest rates make it difficult for financial institutions to set their loan interest rates and funding rates on favorable terms. First, we assume that it is more difficult for financial institutions to raise their loan interest rates than in normal times amid weakening demand for funds. Second, we assume that as market interest rates rise, the correlation between financial institutions' deposit interest rates and market interest rates becomes stronger than when interest rates are stable at low levels. When market interest rates go up, yields on certain financial products highly correlated with market interest rates increase. Under these circumstances, financial institutions need to raise their deposit rates in order to maintain their deposit bases. Specifically, we assume lower pass-through rates for loan interest rates (changes in loan interest rates relative to those in market interest rates) and conduct simulations of periods when financial institutions find it difficult to raise their loan interest rates. We also assume higher pass-through rates for funding rates, and financial institutions need to increase their funding and deposit rates to a much greater extent than they do when interest rates are stable at low levels. We use different parameters for the pass-through rates: the elasticity of loan interest rates to market interest rates is about two standard errors lower, while that of funding rates is higher by the same magnitude (Figure 7).

B. Results of Macro Stress Testing

1. Baseline scenario

The simulation results for the baseline scenario are as follows (Figure 8). Given that Japan's economy would continue to exhibit relatively high growth from the beginning of the estimation period, firms' financial conditions would continue to improve, which in turn would keep their quick ratios and ICRs at levels slightly above those in fiscal 2012. As a result, credit cost ratios would remain at low levels, while CET I capital ratios and Tier I capital ratios would rise moderately through fiscal 2016.[45]

2. Economic downturn scenario

The simulation results for financial institutions' balance sheets and profits are as follows (Figure 9). The nominal GDP growth rate would drop to minus 3.5-4.0 percent in fiscal 2014 due to large drops in fixed investments and exports owing to the deterioration in overseas economies, before returning to around the baseline scenario level in fiscal 2016.[46] As corporate profits declined significantly owing to the economic downturn, firms' financial indicators such as quick ratios and ICRs would deteriorate in fiscal 2014. Thereafter, although firms' profits would pick up and their financial indicators would improve in line with the recovery in the domestic economic growth rate, firms' profits and financial indicators would deviate from the baseline scenario levels throughout the estimation period. As a result, credit cost ratios would increase considerably in fiscal 2014. Despite a subsequent decline, credit cost ratios would continue to stay above the baseline scenario level throughout the estimation period. In addition, financial institutions would incur unrealized losses on stockholdings due to the decline in stock prices.

Consequently, although capital adequacy ratios would fall significantly from their baseline scenario levels from fiscal 2014, these ratios would on average continue to exceed regulatory levels. The CET I capital ratio for internationally active banks would be 9.7 percent in fiscal 2016, falling by 2.2 percentage points from the baseline scenario level of

[45] As pointed out in the April 2014 issue of the FSR, financial institutions' credit cost ratios have been low in recent times. This is because (1) financial institutions' asset quality continued to improve; and (2) financial institutions' support for firms with sluggish business performance restricted the occurrence of default. We assume in the baseline scenario that this trend will continue in future, and that credit cost ratios for internationally active banks from fiscal 2013 are slightly negative while those for domestic banks are near zero. A large number of borrowing firms' credit ratings would be upgraded because the domestic economic growth rate would remain high during the beginning of the estimation period. On the other hand, based on the assumption that financial institutions continue supporting firms with sluggish business performance, the number of downgraded borrowing firms would be limited. As a result, from fiscal 2013, banks' credit cost ratios would remain at low levels and the ratios of internationally active banks would be negative, as reversals of provisions for loan losses were recorded.

[46] Such developments in the domestic economic growth rate reflect external shocks including a downturn in overseas economies and the simulation results of the effects of an adverse feedback loop between the financial system and the real economy.

11.9 percent. The CET I capital ratio at internationally active banks would be under downward pressure caused by unrealized losses on securities holdings resulting from falling stock prices and increased credit costs due to the economic downturn (Figure 11). On the other hand, the Tier I capital ratio for domestic banks would be 9.1 percent at the end of fiscal 2016, falling by 2.0 percentage points from the baseline scenario level of 11.1 percent. The decline in the Tier I capital ratio for domestic banks would be caused mainly by the occurrence of credit costs due to the economic downturn.[47]

The above results are aggregate numbers. Because we model balance sheets of individual financial institutions in the FMM, we can trace the development of financial numbers for individual financial institutions. For example, the distribution of Tier I capital ratios for individual financial institutions shows that some domestic banks' Tier I capital ratios decline relatively quickly (Figure 12(1)). This indicates that the extent of the capital impact of an increase in credit costs due to an economic downturn differs among individual banks. Particular attention should be paid to the fact that the rates of decline in Tier I capital ratios would be substantial for financial institutions with low loan quality (Figure 12(2)).

3. Upward interest rate shift scenarios

A rise in interest rates in line with economic improvement

The simulation results for financial institutions' balance sheets and profits are as follows (Figure 10). The nominal GDP growth rate would deviate upward from the baseline level by about two percentage points before returning to around the baseline scenario level in fiscal 2016.[48] Financial institutions would incur unrealized capital losses on bondholdings as market interest rates rose. However, they would also face unrealized gains on stockholdings due to the rise in stock prices. As economic activity grew from the baseline scenario level, the outstanding amount of loans would rise from the baseline scenario level and interest rate spreads on loans would improve. Therefore, core profits (operating profits from core business) would also exceed the baseline scenario level. Firms' quick

[47] In calculating capital adequacy ratios, domestic banks' capital does not reflect unrealized losses on securities holdings. Thus, unlike in the case of internationally active banks, unrealized losses on securities holdings caused by a decline in stock prices do not reduce domestic banks' capital.

[48] Similar to the economic downturn scenario results, developments in the domestic economic growth rate reflect the simulation results of the effects of an adverse feedback loop between the financial system and the real economy.

ratios would also improve from the baseline scenario level owing to the improvement in business conditions. Their ICRs would remain at around the baseline scenario level despite the downward pressure from increased interest payments caused by the rise in interest rates because firm profits are higher than those of the baseline scenario. As a result, credit cost ratios would fall slightly from baseline scenario levels.

In these circumstances, CET I capital ratio would exceed baseline scenario levels at internationally active banks. This is because increases in core profits and unrealized gains on stockholdings would exceed increases in unrealized capital losses on bondholdings due to the rise in interest rates (Figure 13(1)). At domestic banks, whose unrealized gains/losses on securities holdings are not taken into account in calculating Tier I capital ratio, this ratio would remain at around baseline scenario levels through fiscal 2015 because the sharp increase in lending would raise the amount of risk-weighted assets they held, despite an improvement in core profits. However, interest rate spreads on loans would improve over time, and operating profits from core business would accumulate further. As a result, domestic banks' Tier I capital ratio would also rise slightly from baseline scenario levels in fiscal 2016.

As shown above, an increase in interest rates with an improvement in the economy has positive impacts on the capital adequacy ratios of financial institutions, as basic profits increase from baseline levels and credit costs fall from baseline levels regardless of capital losses on bondholdings.

A rise in interest rates with an economic downturn

The simulation results for financial institutions' balance sheets and profits are as follows (Figure 10). The nominal GDP growth rate would drop to around minus 1.5 percent in fiscal 2014 before recovering gradually but remaining about one percentage point lower than the baseline scenario level in fiscal 2016.[49] A rise in market interest rates combined with a simultaneous decline in stock prices would cause unrealized losses on both stock and bond holdings at financial institutions. At the same time, the rise in loan interest rates -- reflecting higher market interest rates -- and the economic downturn would make growth in

[49] Similar to the economic downturn scenario results, developments in the domestic economic growth rate reflect the simulation results of the effects of an adverse feedback loop between the financial system and the real economy.

loans outstanding fall sharply from the baseline scenario rate. In a situation in which interest rate spreads on loans do not improve at the pace seen in normal times, the drop in loans outstanding from the baseline scenario level would exert downward pressure on financial institutions' core profits. Moreover, a sharp deterioration in profits and an increase in interest payments among borrowing firms would worsen firms' financial conditions (as measured by quick ratios and ICRs). As a result, credit cost ratios would rise to levels substantially above those in the baseline scenario.

In these circumstances, CET I capital ratio for internationally active banks would fall significantly from baseline scenario levels because of the emergence of unrealized losses on securities holdings and credit costs. The average ratio would stand at 9.5 percent at the end of fiscal 2016, falling by 2.4 percentage points from the baseline scenario level of 11.9 percent (Figure 13(2)). Tier I capital ratio for domestic banks would drop significantly from baseline scenario levels due to the emergence of credit costs, although the capital of this group of banks does not reflect unrealized losses on securities holdings. The average ratio would stand at 9.5 percent at the end of fiscal 2016, falling by 1.6 percentage points from the baseline scenario level of 11.1 percent.

As described above, a rise in interest rates combined with an economic downturn has a major impact on financial institutions' capital because it causes the emergence of unrealized losses on bondholdings and stockholdings, as well as increased credit costs and lower core profits. Nevertheless, CET I capital ratios and Tier I capital ratios would remain above regulatory levels on average. Assuming that unrealized losses on securities holdings would become realized losses due to sales of bonds and stocks, the overall Tier I capital ratio for domestic banks would be 8.9 percent, falling more significantly from the baseline scenario level of 11.1 percent (Figure 14(1)).

As in the economic downturn scenario, the extent of the impact of a rise in interest rates on credit costs would differ among individual financial institutions. The impact of such a rise on core profits (net interest income) would also differ among individual institutions due to differences in their balance sheet structures and interest rate setting behavior. The distribution of Tier I capital ratios by individual financial institution shows that some banks would face relatively high rates of decline in their Tier I capital ratios, and this point warrants attention (Figure 14(2)).

VI. Conclusion, Remarks, and Future Challenges

A. Conclusion

This paper explains the framework of macro stress testing reported in the Financial System Report published by the Bank of Japan. The framework has been improved over time to ensure it appropriately analyzes risk factors in Japan's financial system. Current notable features of the Bank's macro stress testing are as follows. First, it includes a mechanism reflecting the feedback loop between the financial and economic sectors by using the FMM, a medium-sized structural macro model comprising two sectors: financial and macroeconomic. Second, it can analyze not only aggregate figures such as capital adequacy ratios and net interest income, but also those for individual financial institutions.

In the FSR, which is published twice a year, we conduct macro stress testing to evaluate the resilience of Japan's financial system by examining two scenarios: an economic downturn and an upward interest rate shift. We conduct simulations for major financial indicators such as capital adequacy ratios not only based on aggregate figures, but also by examining figures for individual financial institutions in order to analyze resilience to shocks.

B. Remarks

We make the following remarks regarding the current macro stress testing framework.

First, the current macro stress testing framework is based on a model abstracted from the complex financial system and real economy. All macro models are at best approximations of the actual financial system and economy that focus on particular aspects and do not perfectly capture the entire structure. Therefore, we need to interpret macro stress testing results with some latitude because they are based on calculations made under certain assumptions and some factors are not considered.

Second, we need to examine appropriate stress scenarios in order to measure the resilience of the financial system. It is important to evaluate the resilience of the financial system and of individual financial institutions by assuming the occurrence of shocks, which are rare but cause large negative impacts. In this respect, we assume the occurrence of large shocks by historical standards when conducting macro stress testing at the Bank. The economic downturn scenario assumes that negative shocks comparable with those that transpired during the Lehman crisis occur in overseas economies and global financial markets. The upward interest rate shift scenario assumes a two percentage points' increase in long-term interest rates.[50] It is important to conduct quantitative evaluations by assuming the occurrence of sufficiently large shocks when evaluating potential risks in future.

C. Future Challenges

Macro stress testing of the Bank has been improved over time as available data have been expanded and analytical tools have been upgraded. However, we have future challenges for macro stress testing since there are various risk factors and transmission mechanisms to be analyzed.

First, we could include more financial variables of financial institutions as endogenous variables in the model. For example, net non-interest income and realized gains/losses on stockholdings are not modeled, and values from the recent past are applied to these variables for simulation purposes. Furthermore, outstanding amounts of securities holdings are assumed to remain constant over the simulation period at recent levels and do not move in tandem with economic conditions. Funding amounts such as deposit amounts are also exogenously derived for the simulation period. Differences in risk weights among various assets are not considered when calculating the total amount of credit risk assets for the simulation period. Nor are credit risk assets associated with changes in stockholdings when market values of stocks change. We estimate unrealized gains/losses on bondholdings among individual financial institutions based on aggregate data rather than using data for individual financial institutions. Regarding credit costs, we could set up more detailed mechanisms for households (consumer credits and housing loans) and overseas.

Second, we could elaborate the macroeconomic sector. We set up the macroeconomic sector of the FMM as a set of reaction functions to the financial sector and those reaction functions are consistent with data.[51] However, the set-up is rather ad hoc and is not

[50] A two percentage points' increase in long-term interest rates is a large shock in historical perspective. In 1999, long-term interest rates went up by 1.7 percentage point in about four months. In 2003, long-term interest rates went up by 1.2 percentage point in about three months.

[51] FMM could be interpreted as a structural vector auto-regression model (SVAR) with an

necessarily theoretically consistent. We are still on the developing stage for establishing macro models with financial sector and it is important to make use of the recent outcomes of academic studies regarding financial-macro linkage.

Third, it is important to include important transmission mechanisms as many as possible. For example, we could set up a model to analyze interdependence among financial institutions. Based on the model, we could analyze how a trouble of one financial institution with large losses propagates to other financial institutions through fund transactions. It might be more important to consider the above-mentioned mechanism not only for domestic transactions but also international transactions. Related to this, it is also important to consider the relationship between liquidity risk and credit risk. Although a trigger for a financial crisis is occurrence of large credit costs, changes in liquidity in the financial system such as "run" play an important role in the propagation process of the crisis. We saw the same mechanism in the recent global financial crisis. We know how difficult it is to model the above-mentioned mechanisms in stress test framework. However, it is important to include the mechanisms as many as possible in the FMM or to develop different models to be combined with the FMM in order to upgrade our analytical tools to capture factors quantitatively.

We are not able to model some factors mentioned above due to the limited availability of data we collect. It is important to improve the macro stress testing framework by expanding the range of data available and taking account of macro stress testing methodologies used overseas.[52]

---

elaborated financial sector.

[52] For example, the ECB has used this model to determine the sizes of balance sheet items taking account of risks and returns on each item for financial institutions when conducting macro stress testing reported in the Financial Stability Review (European Central Bank, 2013; Halaj, 2013).

Appendix 1. Financial Macro-econometric Model (FMM) Equations

This appendix details the equations employed in the Financial Macro-econometric Model (FMM). Definitions of variables are shown in the final section.[53]

[53] "HY" is the year-on-year growth rate, i.e. $HYGDPOR_t = GDPOR_t/GDPOR_{t-4} - 1$. "HQ" is the quarter-on-quarter growth rate, i.e. $HQGDPOR_t = GDPOR_t/GDPOR_{t-1} - 1$. "***" indicates that the estimated coefficient is at the 1 percent significance level, "**" at the 5 percent, and "*" at the 10 percent. In the financial sector, "α_i" is the deviation of a financial institution *i*'s fixed effect from the mean value.

A. Financial Sector (Common for Internationally Active Banks and Domestic Banks)

A.1. Loan amount

$$LENDV_{i,t} = LENDVCORP_{i,t} + LENDVIDV_{i,t} + LENDVGOV_{i,t} + LENDVOS_{i,t}$$

A.2. Loan amount to firms

$$\begin{aligned}
&HYLENDVCORP_{i,t} \cdot 100 = -1.276^{***} + \alpha_i \\
&+ \left(1.546^{***} - 0.434^{***} \cdot SBDUM_{i,t}\right) \cdot EXGROR_t \\
&+ \left(-1.151^{***} + 0.641^{***} \cdot SBDUM_{i,t}\right) \cdot 1/4 \\
&\cdot \textstyle\sum_{s=0}^{3} \{LENDR_{i,t-1-s} - (IFRROR_{t-1-s} - VATIFRROR_{t-1-s})\} \\
&\qquad\qquad - \{LENDR_{i,t-5-s} - (IFRROR_{t-5-s} - VATIFRROR_{t-5-s})\} \\
&+ 0.318^{***} \cdot 1/8 \cdot \textstyle\sum_{s=0}^{7} HYLANDPOR_{t-1-s} \cdot 100 \\
&+ \{0.172^{***} \cdot \left(1 - SBDUM_{i,t}\right) + 0.138^{***} \cdot DUM981994_t\} \\
&\qquad\qquad \cdot 1/4 \cdot \textstyle\sum_{s=0}^{3} \left(CPTLX_{i,t-1-s}/RISKAS_{i,t-1-s} \cdot 100 - BASEL_{i,t-1-s}\right) \\
&+ 1.920^{***} \cdot SBDUM_{i,t} \cdot 1/8 \cdot \textstyle\sum_{s=0}^{7} HYPOPOR_{t-1-s} \cdot 100 \\
&- 1.279^{***} \cdot DUMOFFBS_t - 0.748^{***} \cdot DUMKSP_t + 1.388^{***} \cdot DUMZT_t \\
&+ 73.722^{***} \cdot DUMMER_{i,t} - 65.981^{***} \cdot DUMMER_{i,t} + 136.234^{***} \cdot DUMMER_{i,t} \\
&+ 93.577^{***} \cdot DUMMER_{i,t} + 111.111^{***} \cdot DUMMER_{i,t}
\end{aligned}$$

Sample period: 1989Q1-2013Q1, Adjusted R-squared: 0.426

A.3. Loan amount to individuals

$$\begin{aligned}
& HYLENDVIDV_{i,t} \cdot 100 = -3.205^{***} + \alpha_i \\
& + \left(1.655^{***} - 0.273^{**} \cdot SBDUM_{i,t}\right) \cdot EXGROR_t \\
& - 0.757^{***} \cdot 1/4 \cdot \textstyle\sum_{s=0}^{3} \left\{ LENDR_{i,t-1-s} - (IFRROR_{t-1-s} - VATIFRROR_{t-1-s}) \right\} \\
& \qquad\qquad - \left\{ LENDR_{i,t-5-s} - (IFRROR_{t-5-s} - VATIFRROR_{t-5-s}) \right\} \\
& + 0.124^{***} \cdot 1/8 \cdot \textstyle\sum_{s=0}^{7} HYLANDPOR_{t-1-s} \cdot 100 \\
& + \left\{ 0.047^{**} \cdot \left(1 - SBDUM_{i,t}\right) + 0.041^{**} \cdot DUM981014_t \right\} \\
& \qquad\qquad \cdot 1/4 \cdot \textstyle\sum_{s=0}^{3} \left(CPTLX_{i,t-1-s} / RISKAS_{i,t-1-s} \cdot 100 - BASEL_{i,t-1-s} \right) \\
& + 7.961^{***} \cdot SBDUM_{i,t} \cdot 1/8 \cdot \textstyle\sum_{s=0}^{7} HYPOPOR_{t-1-s} \cdot 100 \\
& + 3.154^{***} \cdot DUMCT97L_t + 2.350^{***} \cdot DUMLSJS_t + 2.862^{***} \cdot DUMJKK_t \\
& + 120.760^{***} \cdot DUMMER_{i,t} + 68.272^{***} \cdot DUMMER_{i,t} - 37.917^{***} \cdot DUMMER_{i,t} \\
& + 195.125^{***} \cdot DUMMER_{i,t} + 119.684^{***} \cdot DUMMER_{i,t} + 157.781^{***} \cdot DUMMER_{i,t}
\end{aligned}$$

Sample period: 1989Q3-2013Q1, Adjusted R-squared: 0.392

A.4. Loan amount to municipals

$$LENDVGOV_{i,t} = LENDVGOV_{i,t-1}$$

A.5. Overseas loans (only for banks with large exposures)

$$\begin{aligned}
HQLENDVOS_{i,t} \cdot 100 = & -3.748^{***} + \alpha_i \\
& + 0.261^{***} \cdot HQLENDVOS_{i,t-1} \cdot 100 \\
& + 1.124^{***} \cdot HYFNGDPOR_t \cdot 100/4 \\
& + 0.562^{***} \cdot \left(CPTL_{i,t-1} / RISKAS_{i,t-1} \cdot 100 - BASEL_{i,t-1} \right)
\end{aligned}$$

Sample period: 1989Q1-2013Q3, Adjusted R-squared: 0.134

A.6. Loan interest rate

$$\begin{aligned}
LENDR_{i,t} = & \ 3.715^{***} + \alpha_i \\
& + 0.992^{***} \cdot FUNDR_{i,t} \\
& + 0.029^{***} \cdot (LENDVCORPOR_t / PLENDVCORPOR_t - 1) \cdot 100
\end{aligned}$$

Sample period: 1988Q1-2013Q3, Adjusted R-squared: 0.974

A.7. Funding rate

$$
\begin{aligned}
FUNDR_{i,t} = {} & 0.544^{***} + \alpha_i \\
& + 0.644^{***} \cdot 1/4 \cdot \textstyle\sum_{s=0}^{3} CALL_{t-1-s} \\
& + (-0.043^{***} - 0.011^{***} \cdot DUM981984_t) \\
& \quad \cdot 1/4 \cdot \textstyle\sum_{s=0}^{3} \left(CPTL_{i,t-1-s} / RISKAS_{i,t-1-s} \cdot 100 - BASEL_{i,t-1-s} \right)
\end{aligned}
$$

Sample period: 1989Q3-2013Q3, Adjusted R-squared: 0.952

A.8. Shareholder's equity

$$
\begin{aligned}
& \left(PCRE_{i,t} - CAP_{i,t}\right) - \left(PCRE_{i,t-4} - CAP_{i,t-4}\right) \\
& = \textstyle\sum_{s=0}^{3} NPR_{i,t-s} - \max\left[\sum_{s=0}^{3} NPR_{i,t-s} \quad ,0\right] \cdot CTAX_{i,t} \\
& - \max\left[\textstyle\sum_{s=0}^{3} NPR_{i,t-s} - \max\left[\sum_{s=0}^{3} NPR_{i,t-s} \quad ,0\right] \cdot CTAX_{i,t} \quad ,0\right] \cdot 0.2
\end{aligned}
$$

A.9. Net income before tax

$$NPR_{i,t} = CBIC_{i,t} - CC_{i,t} + ORLB_{i,t} + RGLS_{i,t}$$

A.10. Operating profits from core business

$$CBIC_{i,t} = IIC_{i,t} + NIIC_{i,t} - EX_{i,t}$$

A.11. Net interest income

$$IIC_{i,t} = IICLV_{i,t} + DIS_{i,t} + IICX_{i,t}$$

A.12. Net interest income from lending

$$IICLV_{i,t} = LENDV_{i,t} \cdot LENDR_{i,t}/400 - FUNDA_{i,t} \cdot FUNDR_{i,t}/400$$

A.13. Unrealized gains/losses on stockholdings compared to the base period

$$STKUPL_{i,t} = (STKPOR_t / STKPOR\_BV_t - 1) \cdot IVSTK\_BV_{i,t}$$

A.14. Valuation difference on available-for-sale securities

$$RRS_{i,t} = RRS\_BV_{i,t} + \left(1 - CTAX_{i,t}\right) \cdot STKUPL_{i,t}$$

B. Financial Sector (Internationally Active Banks: Based on the Basel III Requirements)

B.1. Total capital

$$CPTL_{i,t} = CPTLT1_{i,t} + CPTLT2_{i,t}$$

B.2. Total capital excluding public injection

$$CPTLX_{i,t} = CPTL_{i,t} - CPTLT1IJT_{i,t} - CPTLT2IJT_{i,t}$$

B.3. Tier I capital

$$CPTLT1_{i,t} = CET1_{i,t} + AT1_{i,t}$$

B.4. Common equity Tier I capital

$$\begin{aligned} CET1_{i,t} = {} & CET1AOCI_{i,t} + CET1MI_{i,t} + CET1OT_{i,t} - CET1TAOT_{i,t} \\ & - \left(CET1OTFI10_{i,t} + CET1MSR10_{i,t} + CET1DTA10_{i,t}\right) \cdot B3KEIKA_t \\ & - \left(CET1OTFI15_{i,t} + CET1MSR15_{i,t} + CET1DTA15_{i,t}\right) \cdot B3KEIKA_t \\ & - AT1SHORT_{i,t} \end{aligned}$$

B.5. Additional Tier I capital

$$AT1_{i,t} = \max\begin{bmatrix} AT1ET1_{i,t} + AT1AOCI_{i,t} + AT1OT_{i,t} & \\ -AT1TA_{i,t} - AT1RAADJ_{i,t} - T2SHORT_{i,t} & ,0 \end{bmatrix}$$

B.6. Shortfall of additional Tier I capital

$$AT1SHORT_{i,t} = \max\begin{bmatrix} AT1TA_{i,t} + AT1RAADJ_{i,t} + T2SHORT_{i,t} & \\ -AT1ET1_{i,t} - AT1AOCI_{i,t} - AT1OT_{i,t} & ,0 \end{bmatrix}$$

B.7. Accumulated other comprehensive income, etc.

$$CET1AOCI_{i,t} = \left(RRS_{i,t} + CET1AOCIOT_{i,t}\right) \cdot B3KEIKA_t$$

B.8. Phase-in arrangement for accumulated other comprehensive income (additional Tier I capital)

$$AT1AOCI_{i,t} = \left(AT1AOCIOT_{i,t} + \min[RRS_{i,t} \quad ,0]\right) \cdot (1 - B3KEIKA_t)$$

B.9. Tier II capital

$$CPTL2_{i,t} = \max\begin{bmatrix} T2AOCI_{i,t} + T2GR_{i,t} + T2ET2_{i,t} + T2OT_{i,t} & \\ -T2TA_{i,t} - T2RAADJ_{i,t} & ,0 \end{bmatrix}$$

B.10. Phase-in arrangement for accumulated other comprehensive income (Tier II capital)

$$T2AOCI_{i,t} = T2AOCIOT_{i,t} + \max\left[0.45 \cdot RRS_{i,t}/\left(1 - CTAX_{i,t}\right) \quad ,0\right] \cdot (1 - B3KEIKA_t)$$

B.11. Shortfall of Tier II capital

$$T2SHORT_{i,t} = \max\begin{bmatrix} T2TA_{i,t} + T2RAADJ_{i,t} & \\ -T2AOCI_{i,t} - T2GR_{i,t} - T2ET2_{i,t} - T2OT_{i,t} & ,0 \end{bmatrix}$$

B.12. Other common equity Tier I capital

$$CET1OT_{i,t} - CET1OT_{i,t-4} = PCRE_{i,t} - PCRE_{i,t-4}$$

B.13. General loan loss provisions

$$T2GLLP_{i,t} = T2GLLP\_BV_{i,t} \cdot LENDV_{i,t}/LENDV\_BV_{i,t}$$

B.14. General reserve for possible loan losses

$$T2GR_{i,t} = \begin{cases} CRISKAS_{i,t} \cdot 1.25/100, & T2GLLP_{i,t} > CRISKAS_{i,t} \cdot 1.25/100 \\ T2GLLP_{i,t}, & T2GLLP_{i,t} \leq CRISKAS_{i,t} \cdot 1.25/100 \end{cases}$$

B.15. Deferred tax assets arising from temporary differences

$$CET1DTAOR_{i,t} = -RRS_{i,t}/\left(1 - CTAX_{i,t}\right) \cdot CTAX_{i,t} + CET1DTAOT_{i,t}$$

B.16. The 10 percent threshold on specified items

$$CET1THH_{i,t} = CET1OT_{i,t} + \left(RRS_{i,t} + CET1AOCIOT_{i,t}\right) - CET1GFOT_{i,t}$$

B.17. Amount exceeding the 10 percent threshold on specified items (Other Financial Institutions)

$$CET1OTFI10_{i,t} = \max[CET1OTFIOR_{i,t} - CET1THH_{i,t} \cdot 0.1 \quad ,0]$$

B.18. Amount exceeding the 10 percent threshold on specified items (mortgage servicing rights)

$$CET1MSR10_{i,t} = \max[CET1MSROR_{i,t} - CET1THH_{i,t} \cdot 0.1 \quad, 0]$$

B.19. Amount exceeding the 10 percent threshold on specified items (deferred tax assets arising from temporary differences)

$$CET1DTA10_{i,t} = \max[CET1DTAOR_{i,t} - CET1THH_{i,t} \cdot 0.1 \quad, 0]$$

B.20. Amount below the 10 percent threshold on specified items

$$\begin{aligned} CET1RES10_{i,t} &= \left(CET1OTFIOR_{i,t} + CETMSROR_{i,t} + CET1DTAOR_{i,t}\right) \\ &\quad - \left(CET1OTFI10_{i,t} + CET1MSR10_{i,t} + CET1DTA10_{i,t}\right) \end{aligned}$$

B.21. Amount exceeding the 15 percent threshold on specified items (Other Financial Institutions)

$$\begin{aligned} CET1OTFI15_{i,t} &= \max[CET1RES10_{i,t} - CET1THH_{i,t} \cdot 0.15 \quad, 0] \\ &\quad \cdot \left(CET1OTFIOR_{i,t} - CET1OTFI10_{i,t}\right)/CET1RES10_{i,t} \end{aligned}$$

B.22. Amount exceeding the 15 percent threshold on specified items (mortgage servicing rights)

$$\begin{aligned} CET1MSR15_{i,t} &= \max[CET1RES10_{i,t} - CET1THH_{i,t} \cdot 0.15 \quad, 0] \\ &\quad \cdot \left(CET1MSROR_{i,t} - CET1MSR10_{i,t}\right)/CET1RES10_{i,t} \end{aligned}$$

B.23. Amount exceeding the 15 percent threshold on specified items (deferred tax assets arising from temporary differences)

$$\begin{aligned} CET1DTA15_{i,t} &= \max[CET1RES10_{i,t} - CET1THH_{i,t} \cdot 0.15 \quad, 0] \\ &\quad \cdot \left(CET1DTAOR_{i,t} - CET1DTA10_{i,t}\right)/CET1RES10_{i,t} \end{aligned}$$

B.24. Amount below the thresholds for deduction on specified items (Other Financial Institutions, after 250 percent risk weighting)

$$RAOTFIU10_{i,t} = \max[CET1OTFIOR_{i,t} - CET1OTFI10_{i,t} - CET1OTFI15_{i,t} \quad, 0] \cdot 2.5$$

B.25. Amount below the thresholds for deduction on specified items (mortgage servicing rights, after 250 percent risk weighting)

$$RAMSRU10_{i,t} = \max[CET1MSROR_{i,t} - CET1MSR10_{i,t} - CET1MSR15_{i,t} \quad , 0] \cdot 2.5$$

B.26. Amount below the thresholds for deduction on specified items (deferred tax assets arising from temporary differences, after 250 percent risk weighting)

$$RADTAU10_{i,t} = \max[CET1DTAOR_{i,t} - CET1DTA10_{i,t} - CET1DTA15_{i,t} \quad , 0] \cdot 2.5$$

B.27. Risk-weighted assets

$$\begin{aligned} RISKAS_{i,t} &= CRISKAS_{i,t} + MRISKAS_{i,t} + ORISKAS_{i,t} + EXRISKAS_{i,t} \\ &\quad + RAOTFIU10_{i,t} + RAMSRU10_{i,t} + RADTAU10_{i,t} + RAADJ_{i,t} \end{aligned}$$

B.28. Credit risk assets

$$\begin{aligned} & CRISKAS_{i,t} - CRISKAS_{i,t-4} = -3.205 + \alpha_i \\ & + 1.981^{***} \cdot \left(IVSTK_{i,t} - IVSTK_{i,t-4}\right) \\ & + 0.915^{***} \cdot \left\{\left(LENDVCORP_{i,t} + LENDVIDV_{i,t} + LENDVOS_{i,t}\right)\right. \\ & \qquad \left. - \left(LENDVCORP_{i,t-4} + LENDVIDV_{i,t-4} + LENDVOS_{i,t-4}\right)\right\} \\ & + 0.050^{**} \cdot \left\{\left(IVCB_{i,t} + EXIV_{i,t}\right) - \left(IVCB_{i,t-4} + EXIV_{i,t-4}\right)\right\} \\ & - 121.670^{***} \cdot DUMBII_t - 3981.059^{***} \cdot DUMAIRB_t \cdot MBDUM_t \\ & + \left(RACVA_{i,t} - RACVA_{i,t-4}\right) + \left(RACCP_{i,t} - RACCP_{i,t-4}\right) \end{aligned}$$

Sample period: 2000Q1-2013Q3, Adjusted R-squared: 0.543

B.29. Market risk assets

$$\begin{aligned} MRISKAS_{i,t} - MRISKAS_{i,t-4} &= 1.455 + \alpha_i \\ &\quad + 0.143^{**} \cdot (LTRV30OR_t - LTRV30OR_{t-4}) \\ &\quad + 30.409^{***} \cdot DUMBII_t \end{aligned}$$

Sample period: 1999Q1-2013Q3, Adjusted R-squared: 0.010

B.30. Operational risk assets

$$ORISKAS_{i,t} = 18.532^{***} + \alpha_i + 1.532^{***} \cdot 1/3 \cdot \sum_{s=0}^{11} \left(CBIC_{i,t-4-s} + EX_{i,t-4-s} + ORLB_{i,t-4-s} \right)$$

Sample period: 2007Q1-2013Q3, Adjusted R-squared: 0.984

B.31. Total capital adequacy ratio

$$CPTLRT_{i,t} = CPTL_{i,t} / RISKAS_{i,t} \cdot 100$$

B.32. Tier I capital adequacy ratio

$$CPTLT1RT_{i,t} = CPTLT1_{i,t} / RISKAS_{i,t} \cdot 100$$

B.33. Common equity Tier I capital ratio (CET I capital ratio)

$$CET1RT_{i,t} = CET1_{i,t} / RISKAS_{i,t} \cdot 100$$

C. Financial Sector (Domestic Banks: Based on the Basel II Requirements)

C.1. Capital

$$CPTL_{i,t} = CPTLT1_{i,t} + CPTLT2_{i,t} + CPTLEX_{i,t}$$

C.2. Capital excluding public injection

$$CPTLX_{i,t} = \begin{cases} CPTL_{i,t} - CPTLT1IJT_{i,t} - CPTLT2IJT_{i,t}, & i\text{: banks} \\ CPTL_{i,t}, & i\text{: } \textit{shinkin} \text{ banks} \end{cases}$$

C.3. Tier I capital

$$CPTLT1_{i,t} = PCRE_{i,t} + CPTLT1EX_{i,t}$$

C.4. Tier II capital

$$CPTLT2_{i,t} = CPTLT2_{i,t-1}$$

C.5. Tier I capital considering unrealized losses on securities holdings

$$CPTLT1ALT_{i,t} = PCRE_{i,t} + CPTLT1EX_{i,t} + \min[RRS_{i,t}, 0]$$

C.6. Risk-weighted assets

$$RISKAS_{i,t} = \begin{cases} CRISKAS_{i,t} + MRISKAS_{i,t} + ORISKAS_{i,t} + EXRISKAS_{i,t}, & i\text{: banks} \\ CRISKAS_{i,t} + ORISKAS_{i,t}, & i\text{: } \textit{shinkin} \text{ banks} \end{cases}$$

C.7. Credit risk assets

$$\begin{aligned} CRISKAS_{i,t} - CRISKAS_{i,t-4} &= -3.205 + \alpha_i \\ &+ 1.981^{***} \cdot \left(IVSTK_{i,t} - IVSTK_{i,t-4}\right) \\ &+ 0.915^{***} \cdot \{\left(LENDVCORP_{i,t} + LENDVIDV_{i,t} + LENDVOS_{i,t}\right) \\ &\qquad - \left(LENDVCORP_{i,t-4} + LENDVIDV_{i,t-4} + LENDVOS_{i,t-4}\right)\} \\ &+ 0.050^{**} \cdot \{\left(IVCB_{i,t} + EXIV_{i,t}\right) - \left(IVCB_{i,t-4} + EXIV_{i,t-4}\right)\} \\ &- 121.670^{***} \cdot DUMBII_t \end{aligned}$$

Sample period: 2000Q1-2013Q3, Adjusted R-squared: 0.543

C.8. Market risk assets (only for banks)

$$\begin{aligned} MRISKAS_{i,t} - MRISKAS_{i,t-4} &= 1.455 + \alpha_i \\ &+ 0.143^{**} \cdot (LTRV30OR_t - LTRV30OR_{t-4}) \\ &+ 30.409^{***} \cdot DUMBII_t \end{aligned}$$

Sample period: 1999Q1-2013Q3, Adjusted R-squared: 0.010

C.9. Operational risk assets

$$\begin{aligned} ORISKAS_{i,t} &= 18.532^{***} + \alpha_i \\ &+ 1.532^{***} \cdot 1/3 \cdot \textstyle\sum_{s=0}^{11}\left(CBIC_{i,t-4-s} + EX_{i,t-4-s} + ORLB_{i,t-4-s}\right) \end{aligned}$$

Sample period: 2007Q1-2013Q3, Adjusted R-squared: 0.984

C.10. Capital adequacy ratio

$$CPTLRT_{i,t} = CPTL_{i,t}/RISKAS_{i,t} \cdot 100$$

C.11. Tier I capital adequacy ratio

$$CPTLT1RT_{i,t} = CPTLT1_{i,t}/RISKAS_{i,t} \cdot 100$$

D. Financial Sector (Credit Costs)

1. Banks

D.1-1. Credit costs

$$
\begin{aligned}
CC_{i,t} + CC_{i,t-1} = \big(&EXPO_{i,t}^{1} \cdot PR_{i,t}^{1} + EXPO_{i,t}^{2} \cdot PR_{i,t}^{2} + EXPO_{i,t}^{3} \cdot PR_{i,t}^{3} \\
&+ EXPO_{i,t}^{4} \cdot PR_{i,t}^{4} \cdot UR_{i,t}^{4} + EXPO_{i,t}^{5} \cdot PR_{i,t}^{5}\big) \\
&- \big(EXPO_{i,t-2}^{1} \cdot PR_{i,t-2}^{1} + EXPO_{i,t-2}^{2} \cdot PR_{i,t-2}^{2} + EXPO_{i,t-2}^{3} \cdot PR_{i,t-2}^{3} \\
&+ EXPO_{i,t-2}^{4} \cdot PR_{i,t-2}^{4} \cdot UR_{i,t-2}^{4}\big)
\end{aligned}
$$

D.1-2. Credit cost ratio (annualized)

$$CCRT_{i,t} = \left(\textstyle\sum_{s=0}^{3} CC_{i,t-s} / LENDV_{i,t}\right) \cdot 100$$

D.1-3. Transition probability from "normal" to "normal"

$$PT_{i,t}^{11} = 1 - \left(PT_{i,t}^{12} + PT_{i,t}^{13} + PT_{i,t}^{14} + PT_{i,t}^{15}\right)$$

D.1-4. Transition probability from "need attention excluding special attention" to "need attention excluding special attention"

$$PT_{i,t}^{22} = 1 - \left(PT_{i,t}^{21} + PT_{i,t}^{23} + PT_{i,t}^{24} + PT_{i,t}^{25}\right)$$

D.1-5. Transition probability from "special attention" to "special attention"

$$PT_{i,t}^{33} = 1 - \left(PT_{i,t}^{31} + PT_{i,t}^{32} + PT_{i,t}^{34} + PT_{i,t}^{35}\right)$$

D.1-6. Transition probability from "in danger of bankruptcy" to "in danger of bankruptcy"

$$PT_{i,t}^{44} = 1 - \left(PT_{i,t}^{41} + PT_{i,t}^{42} + PT_{i,t}^{43} + PT_{i,t}^{45}\right)$$

D.1-7. Loan exposures categorized *n*

$$EXPO_{i,t}^{n} = \left(\textstyle\sum_{m=1}^{4} EXPO_{i,t-2}^{m} \cdot PT_{i,t}^{mn}\right) \cdot \left(LENDV_{i,t} / LENDV_{i,t-2}\right)$$

where $n = 1, \cdots, 5$

D.1-8. Transition probability from m to n $(m \neq n)$

$$\ln\left(\frac{PT_{i,t}^{mn}}{1-PT_{i,t}^{mn}}\right) = \overline{\alpha^{mn}} + \alpha_i^{mn} + \beta^{mn} \cdot \text{nominal GDP growth rate}_t + \gamma^{mn} \cdot \text{ICR}_t + \delta^{mn} \cdot \text{quick ratio}_t + \eta^{mn} \cdot \text{DE ratio}_t$$

$PT_{i,t}^{mn}$ is transition probability of bank i from category m to n.

$\overline{\alpha^{mn}}$ is the mean value of bank i's fixed effect ($\overline{\alpha^{mn}} + \alpha_i^{mn}$).

m \ n		1	2	3	4	5
1	β		—	—	-3.96*	-9.25***
	γ		-0.07*** L: -0.06***	—	-0.14***	-0.16***
	δ		-2.68***	-8.06*** L: -9.05***	-7.88***	-20.12***
	η		—	—	—	—
2	β	—		—	—	—
	γ	0.08***		—	-0.03***	-0.18***
	δ	—		-6.40*** L: -4.43**	—	-10.27***
	η	—		—	—	—
3	β	—	—		—	—
	γ	MA2: 0.10**	—		O: -0.20**	O: -0.19* R, MA2: -0.18***
	δ	—	MA4: 2.28*		—	—
	η	—	—		—	—
4	β		—	—		—
	γ		—	MA2: 0.10**		-0.07***
	δ		3.27***	—		-9.19***
	η		—	—		—

Notes: 1. Category 1: normal; category 2: need attention excluding special attention; category 3: special attention; category 4: in danger of bankruptcy; category 5: de facto of bankrupt or bankrupt.

2. The sample period is from the first half of fiscal 2005 to the first half of fiscal 2013.

3. L represents a one period lag and MAn is the moving average of n period lags. O is the parameter for major banks and R is the parameter for regional banks.

4. In the shaded area, no statistically significant parameter is estimated and the transition probability is treated as an exogenous variable.

2. *Shinkin* banks

D.2-1. Credit costs

$$
\begin{aligned}
&CC_{i,t} + CC_{i,t-1} + CC_{i,t-2} + CC_{i,t-3} \\
&\quad = \left(EXPO^1_{i,t} \cdot PR^1_{i,t} + EXPO^2_{i,t} \cdot PR^2_{i,t} + EXPO^3_{i,t} \cdot PR^3_{i,t}\right. \\
&\qquad \left. + EXPO^4_{i,t} \cdot PR^4_{i,t} \cdot UR^4_{i,t} + EXPO^5_{i,t} \cdot PR^5_{i,t}\right) \\
&\quad - \left(EXPO^1_{i,t-4} \cdot PR^1_{i,t-4} + EXPO^2_{i,t-4} \cdot PR^2_{i,t-4} + EXPO^3_{i,t-4} \cdot PR^3_{i,t-4}\right. \\
&\qquad \left. + EXPO^4_{i,t-4} \cdot PR^4_{i,t-4} \cdot UR^4_{i,t-4}\right)
\end{aligned}
$$

D.2-2. Credit cost ratio (annualized)

$$CCRT_{i,t} = \left(\sum_{s=0}^{3} CC_{i,t-s} / LENDV_{i,t}\right) \cdot 100$$

D.2-3. Transition probability from "normal" to "normal"

$$PT^{11}_{i,t} = 1 - \left(PT^{12}_{i,t} + PT^{13}_{i,t} + PT^{14}_{i,t} + PT^{15}_{i,t}\right)$$

D.2-4. Transition probability from "need attention excluding special attention" to "need attention excluding special attention"

$$PT^{22}_{i,t} = 1 - \left(PT^{21}_{i,t} + PT^{23}_{i,t} + PT^{24}_{i,t} + PT^{25}_{i,t}\right)$$

D.2-5. Transition probability from "special attention" to "special attention"

$$PT^{33}_{i,t} = 1 - \left(PT^{31}_{i,t} + PT^{32}_{i,t} + PT^{34}_{i,t} + PT^{35}_{i,t}\right)$$

D.2-6. Transition probability from "in danger of bankruptcy" to "in danger of bankruptcy"

$$PT^{44}_{i,t} = 1 - \left(PT^{41}_{i,t} + PT^{42}_{i,t} + PT^{43}_{i,t} + PT^{45}_{i,t}\right)$$

D.2-7. Loan exposures categorized *n*

$$EXPO^n_{i,t} = \left(\sum_{m=1}^{4} EXPO^m_{i,t-4} \cdot PT^{mn}_{i,t}\right) \cdot \left(LENDV_{i,t} / LENDV_{i,t-4}\right)$$

where $n = 1, \cdots, 5$

D.2-8.　Transition probability from m to n $(m \neq n)$

$$\ln\left(\frac{PT_{i,t}^{mn}}{1-PT_{i,t}^{mn}}\right) = \overline{\alpha^{mn}} + \alpha_i^{mn} + \beta^{mn} \cdot \text{nominal GDP growth rate}_t + \gamma^{mn} \cdot \text{ICR}_t + \delta^{mn} \cdot \text{quick ratio}_t + \eta^{mn} \cdot \text{DE ratio}_t$$

$PT_{i,t}^{mn}$ is transition probability of *shinkin* bank i from category m to n.

$\overline{\alpha^{mn}}$ is the mean value of *shinkin* bank *i*'s fixed effect ($\overline{\alpha^{mn}} + \alpha_i^{mn}$).

m \ n		1	2	3	4	5
1	β		—	—	—	—
	γ		-0.07*** L: -0.10***	—	-0.06***	-0.09***
	δ		—	-2.66** L: -2.13*	—	-7.25***
	η		—	—	—	—
2	β	—		—	—	—
	γ	0.02**		—	—	-0.09***
	δ	—		-3.10*** L: -4.63***	D: -0.09**	-4.74***
	η	—		—	—	—
3	β	—	—		—	—
	γ	—	—		—	-0.15***
	δ	—	D: 0.24***		D: -0.69***	—
	η	-1.24**	—		—	—
4	β	—	—	5.93***		—
	γ	D: 0.04***	—	—		-0.03***
	δ	—	D: 0.27***	—		-5.86***
	η	—	—	—		—

Notes: 1. Category 1: normal; category 2: need attention excluding special attention; category 3: special attention; category 4: in danger of bankruptcy; category 5: de facto of bankrupt or bankrupt.

2. The sample period is from fiscal 2005 to fiscal 2012.

3. L represents a one period lag and D represents a dummy variable which takes the value of 1 from fiscal 2005 to fiscal 2008.

3. Quantile regression estimation results

$$\ln\left(\frac{PT_{i,t}^{mn}}{1-PT_{i,t}^{mn}}\right) - \alpha_i^{mn} = \mu^{mn} + \beta^{mn}\cdot \text{nominal GDP growth rate}_t + \gamma^{mn}\cdot \text{ICR}_t + \delta^{mn}\cdot \text{quick ratio}_t + \eta^{mn}\cdot \text{DE ratio}_t$$

α_i^{mn} is the same value of fixed effect model.[54]

D.3-1 Banks

m	n	de facto of bankrupt or bankrupt	
		70th percentile	90th percentile
1	β	-11.03***	-19.97***
	γ	-0.11***	-0.09*
	δ	-20.15***	-15.04***
	η	—	—
2	β	—	—
	γ	-0.17***	-0.19***
	δ	-9.78***	-8.94***
	η	—	—
3	β	—	—
	γ	O: -0.22*** R, MA: -0.16***	O: -0.23*** R, MA: -0.07
	δ	—	—
	η	—	—
4	β	—	—
	γ	-0.01	-0.03
	δ	-9.87***	-11.22***
	η	—	—

D.3-2 *Shinkin* banks

m	n	de facto of bankrupt or bankrupt	
		70th percentile	90th percentile
1	β	—	—
	γ	-0.08***	-0.06***
	δ	-6.94***	-9.78***
	η	—	—
2	β	—	—
	γ	-0.07***	-0.04***
	δ	-4.49***	-4.17***
	η	—	—
3	β	—	—
	γ	-0.15***	-0.19***
	δ	—	—
	η	—	—
4	β	—	—
	γ	-0.04***	-0.02
	δ	-5.23***	-5.15***
	η	—	—

Notes: 1. Category 1: normal; category 2: need attention excluding special attention; category 3: special attention; category 4: in danger of bankruptcy.

2. For banks, the sample period is from the first half of fiscal 2005 to the first half of fiscal 2013. For *shinkin* banks, the sample period is from fiscal 2005 to fiscal 2012.

3. MA is the moving average of two period lags. O is the parameter for major banks and R is the parameter for regional banks.

[54] Canay (2011) shows that the estimated parameters obtained from quantile regression with this method are the consistent estimators.

E. Financial Sector (Aggregate)

E.1. Loan amount

$$LENDVOR_t = \sum_i LENDV_{i,t}$$

E.2. Loan amount to firms

$$LENDVCORPOR_t = \sum_i LENDVCORP_{i,t}$$

E.3. Potential loan amount to firms

$$PLENDVCORPOR_t = PLENDVCORPOR_{t-4} \cdot (1 + HYPGDPOR_t/100)$$

E.4. Loan amount to individuals

$$LENDVIDVOR_t = \sum_i LENDVIDV_{i,t}$$

E.5. Loan interest rate

$$LENDROR_t = \sum_i LENDR_{i,t} \cdot \frac{LENDV_{i,t}}{LENDVOR_t}$$

E.6. Tier I capital

$$CPTLT1OR_t = \sum_i CPTLT1_{i,t}$$

E.7. Risk-weighted assets

$$RISKASOR_t = \sum_i RISKAS_{i,t}$$

E.8. Credit costs

$$CCOR_t = \sum_i CC_{i,t}$$

F. Macroeconomic Sector

F.1. Nominal GDP

$$NGDPOR_t = NPREXPOR_t + NINVOR_t + NIIVOR_t + NGOVOR_t + NEXPTOR_t - NIMPTOR_t$$

F.2. Real GDP

$$GDPOR_t = NGDPOR_t / GDPDEFOR_t \cdot 100$$

F.3. Nominal GDP (seasonally adjusted)

$$NGDP_t = NGDPOR_t \cdot 4 / SANGDP_t$$

F.4. Nominal GDP (seasonal factor)

$$SANGDP_t = SANGDP_{t-4} + (SANGDP_{t-4} - SANGDP_{t-8})/2$$

F.5. Nominal household expenditure

$$\begin{aligned} HYNPREXPOR_t \cdot 100 = {} & 0.524^{***} \cdot HYYWAGEOR_t \cdot 100 \\ & + 0.018^{***} \cdot HYSTKPOR_t \cdot 100 \\ & + 0.168^{***} \cdot HYLENDVIDVOR_t \cdot 100 \\ & - 0.459^{*} \quad \cdot (LENDROR_{t-2} - LENDROR_{t-6}) \\ & + 3.966^{***} \cdot (DUMCT97_t - DUMCT97_{t-4}) \end{aligned}$$

Sample period: 1984Q1-2013Q3, Adjusted R-squared: 0.789

F.6. Nominal capital investment

$$\begin{aligned} & HYNINVOR_t \cdot 100 \\ & = 6.596^{***} \cdot 1/2 \cdot \textstyle\sum_{s=0}^{1} (ROACORPOR_{t-s} - ROACORPOR_{t-4-s}) \\ & + 0.666^{**} \quad \cdot EXGROR_t \\ & - 1.872^{***} \cdot \{(LENDROR_{t-2} - IFRROR_{t-2}) - (LENDROR_{t-6} - IFRROR_{t-6})\} \\ & + 0.857^{***} \cdot HYLENDVCORPOR_t \cdot 100 \end{aligned}$$

Sample period: 1984Q1-2013Q1, Adjusted R-squared: 0.495

F.7. Nominal exports

$$\begin{aligned} HYNEXPTOR_t \cdot 100 = {} & 0.198^{***} \cdot HYFNGDPOR_t \cdot 100 \\ & - 0.355^{***} \cdot HYREER_t \cdot 100 \\ & + 0.602^{***} \cdot HYNEXPTOR_{t-1} \cdot 100 \end{aligned}$$

Sample period: 1982Q1-2012Q4, Adjusted R-squared: 0.674

F.8. Nominal imports

$$\begin{aligned} HYNIMPTOR_t \cdot 100 = {} & 0.264^{***} \cdot 1/8 \cdot \textstyle\sum_{s=0}^{7} HYREER_{t-s} \cdot 100 \\ & + 0.275^{***} \cdot HYPIMPT_t \cdot 100 \\ & + 0.509^{***} \cdot HYNEXPTOR_t \cdot 100 \\ & + 0.524^{***} \cdot HYNIMPTOR_{t-1} \cdot 100 \end{aligned}$$

Sample period: 1981Q2-2013Q3, Adjusted R-squared: 0.879

F.9. Potential real GDP

$$PGDPOR_t = PGDPOR_{t-4} \cdot (1 + HYPGDPOR_t/100)$$

F.10. Real expected growth rate

$$\begin{aligned} EXGROR_t = {} & 0.776^{***} \cdot 1/12 \cdot \textstyle\sum_{s=0}^{11} HYPGDPOR_{t-s} \cdot 100 \\ & + 0.099^{***} \cdot HYGDPOR_t \cdot 100 \end{aligned}$$

Sample period: 1983Q4-2013Q1, Adjusted R-squared: 0.617

F.11. Nominal employee compensation

$$\begin{aligned} HYYWAGEOR_t \cdot 100 = {} & 0.591^{***} \cdot HYNGDPOR_t \cdot 100 \\ & + 0.376^{***} \cdot \left(\frac{YWAGEOR_{t-1}}{NGDPOR_{t-1}} - \frac{YWAGEOR_{t-5}}{NGDPOR_{t-5}} \right) \cdot 100 \\ & + 1.023^{***} \cdot (IFRROR_t - VATIFRROR_t) \end{aligned}$$

Sample period: 1981Q2-2013Q3, Adjusted R-squared: 0.852

F.12. Interest coverage ratios (ICRs)

$$ICR_t = OPIR_t/EXIR_t$$

F.13. Operating profits plus interest and dividends received, etc.

$$OPIR_t/NGDP_t = 0.006^{***} + 0.550^{***} \cdot 1/2 \cdot \sum_{s=0}^{1} ROACORPOR_{t-s}/100$$

Sample period: 1994Q1-2013Q3, Adjusted R-squared: 0.886

F.14. Interest payments, etc.

$$EXIR_t/LENDVCORPOR_t = 0.001^{***} + 1.044^{***} \cdot 1/2 \cdot \sum_{s=0}^{1} LENDROR_{t-s}/400$$

Sample period: 1994Q1-2013Q1, Adjusted R-squared: 0.951

F.15. Quick ratio

$$\begin{aligned} QR_t = {} & 0.080 + 0.088^{***} \cdot DUM091Z_t \\ & + 0.015^{***} \cdot 1/2 \cdot \sum_{s=0}^{1} ROACORPOR_{t-s} \\ & + 0.601^{***} \cdot GDPOR_t/PGDPOR_t \end{aligned}$$

Sample period: 1985Q1-2013Q3, Adjusted R-squared: 0.767

F.16. Debt equity ratio (DE ratio)

$$\begin{aligned} \log(DERT_t) = {} & -0.148^{***} \\ & + 0.145^{***} \cdot \log(LENDVCORPOR_t/NGDPOR_t) \\ & + 0.955^{***} \cdot \log(DERT_{t-1}) \end{aligned}$$

Sample period: 1985Q1-2013Q3, Adjusted R-squared: 0.995

F.17. Return on assets (current profit ROA)

$$\begin{aligned} ROACORPOR_t - ROACORPOR_{t-4} = {} & 26.802^{***} \cdot \left(\frac{GDPOR_t}{PGDPOR_t} - \frac{GDPOR_{t-4}}{PGDPOR_{t-4}}\right) \\ & - 0.420^{***} \cdot (LENDROR_t - LENDROR_{t-4}) \\ & - 19.448^{***} \cdot \left(\frac{YWAGEOR_t}{NGDPOR_t} - \frac{YWAGEOR_{t-4}}{NGDPOR_{t-4}}\right) \end{aligned}$$

Sample period: 1983Q3-2013Q1, Adjusted R-squared: 0.691

F.18. CPI, general excluding fresh foods

$$CPICOR_t = CPICOR_{t-4} \cdot (1 + IFRROR_t/100)$$

F.19. Stock prices

$$
\begin{aligned}
HYSTKPOR_t \cdot 100 = {} & 13.882^{***} \cdot (ROACORPOR_t - ROACORPOR_{t-4}) \\
& + \ 1.882^{***} \ \cdot EXGROR_t \\
& + \ 0.285^{***} \ \cdot HYNYDSTKPOR_t \cdot 100 \\
& - 22.247^{**} \ \cdot DUMPER_t
\end{aligned}
$$

Sample period: 1980Q1-2013Q1, Adjusted R-squared: 0.388

F.20. Land prices

$$
\begin{aligned}
& HYLANDPOR_t \cdot 100 = -3.962^{***} \\
& + 0.294^{***} \cdot 1/4 \cdot \textstyle\sum_{s=0}^{3} HYNGDPOR_{t-s} \cdot 100 \\
& + 0.931^{***} \cdot 1/4 \cdot \textstyle\sum_{s=0}^{3} HYLENDVOR_{t-1-s} \cdot 100 \\
& + 0.447^{**} \cdot \{(IFRROR_t - VATIFRROR_t) - (IFRROR_{t-4} - VATIFRROR_{t-4})\}
\end{aligned}
$$

Sample period: 1985Q3-2013Q3, Adjusted R-squared: 0.861

Definitions of Variables (Shaded variables are data of individual financial institutions)

Variables		Unit	Source
AT1	Additional Tier I capital (Basel III)	Billion yen	BOJ
AT1AOCI	Accumulated other comprehensive income (included in Additional Tier I capital)	Billion yen	BOJ
AT1AOCIOT	Accumulated other comprehensive income (included in Additional Tier I capital) excluding valuation difference on available-for-sale securities	Billion yen	BOJ
AT1ET1	Eligible Tier I capital instruments subject to phase-in arrangements (included in additional Tier I capital: instruments)	Billion yen	BOJ
AT1OT	Additional Tier I capital: instruments excluding accumulated other comprehensive income and eligible Tier I capital instruments subject to phase-in arrangements	Billion yen	BOJ
AT1RAADJ	Total of items included in Additional Tier I capital: regulatory adjustments subject to phase-in arrangements	Billion yen	BOJ
AT1SHORT	Regulatory adjustments applied to Common Equity Tier I due to insufficient Additional Tier I and Tier II to cover deductions	Billion yen	BOJ
AT1TA	Additional Tier I capital: regulatory adjustments excluding total of items included in Additional Tier I capital: regulatory adjustments subject to phase-in arrangements and regulatory adjustments applied to Additional Tier I due to insufficient Tier II to cover deductions	Billion yen	BOJ
BASEL	regulatory minimum capital requirements for (total) capital adequacy ratio	%	Internationally active banks: 8, domestic banks: 4
B3KEIKA	Phase-in deductions	—	13CY: 0, 14CY: 0.2, 15CY: 0.4, 16CY: 0.6, 17CY: 0.8, after 18CY: 1
CALL	Uncollateralized overnight call rate	% per annum	BOJ
CAP	Capital (capital stock, capital reserves, and other capital surpluses)	Billion yen	BOJ
CBIC	Operating profits from core business	Billion yen	BOJ
CC	Credit costs	Billion yen	BOJ
CCOR	Credit costs (aggregate)	Billion yen	BOJ
CCRT	Credit cost ratio	% per annum	BOJ
CET1	Common Equity Tier I capital	Billion yen	BOJ
CET1AOCI	Accumulated other comprehensive income and other disclosed reserves	Billion yen	BOJ

CET1AOCIOT	Amount not included as accumulated other comprehensive income and other disclosed reserves due to phase-in arrangements excluding valuation difference on available-for-sale securities	Billion yen	BOJ
CET1DTA10	Amount exceeding the 10% threshold on specified items of which: deferred tax assets arising from temporary differences	Billion yen	BOJ
CET1DTA15	Amount exceeding the 15% threshold on specified items of which: deferred tax assets arising from temporary differences	Billion yen	BOJ
CET1DTAOR	Deferred tax assets arising from temporary differences	Billion yen	BOJ
CET1DTAOT	Deferred tax assets arising from temporary differences excluding valuation difference on available-for-sale securities	Billion yen	BOJ
CET1GFOT	Amount not included as Common Equity Tier I capital: regulatory adjustments due to phase-in arrangements excluding amount exceeding the thresholds on specified items and regulatory adjustments applied to Common Equity Tier I due to insufficient Additional Tier I and Tier II to cover deductions	Billion yen	BOJ
CET1MI	Minority interests, etc. included under phase-in arrangements	Billion yen	BOJ
CET1MSR10	Amount exceeding the 10% threshold on specified items of which: mortgage servicing rights	Billion yen	BOJ
CET1MSR15	Amount exceeding the 15% threshold on specified items of which: mortgage servicing rights	Billion yen	BOJ
CET1MSROR	Mortgage servicing rights	Billion yen	BOJ
CET1OT	Common Equity Tier I capital: Instruments and reserves excluding accumulated other comprehensive income and minority interests, etc. included under phase-in arrangements	Billion yen	BOJ
CET1OTFI10	Amount exceeding the 10% threshold on specified items of which: significant investments in the common stock of Other Financial Institutions, net of eligible short positions	Billion yen	BOJ
CET1OTFI15	Amount exceeding the 15% threshold on specified items of which: significant investments in the common stock of Other Financial Institutions, net of eligible short positions	Billion yen	BOJ

CET1OTFIOR	Significant investments in the common stock of Other Financial Institutions, net of eligible short positions	Billion yen	BOJ
CET1RES10	Amount included and not included as amount within the 10% threshold on specified items due to phase-in arrangements	Billion yen	BOJ
CET1RT	Common Equity Tier I capital ratio	%	BOJ
CET1TAOT	Common Equity Tier I capital: regulatory adjustments due to phase-in arrangements excluding amount exceeding the thresholds on specified items and regulatory adjustments applied to Common Equity Tier I due to insufficient Additional Tier I and Tier II to cover deductions	Billion yen	BOJ
CET1THH	The 10% threshold on specified items	Billion yen	BOJ
CPICOR	Consumer price index (general excluding fresh food)	CY2010 average = 100	Ministry of Internal Affairs and Communications, "Consumer Price Index"
CPTL	(Total) capital	Billion yen	BOJ
CPTLEX	Tier III capital including deductions from total qualifying capital	Billion yen	BOJ
CPTLRT	(Total) capital adequacy ratio	%	BOJ
CPTLT1	Tier I capital	Billion yen	BOJ
CPTLT1ALT	Tier I capital considering unrealized losses on securities holdings for domestic banks	Billion yen	BOJ
CPTLT1EX	Other Tier I capital (Basel II)	Billion yen	BOJ
CPTLT1IJT	Public injection for Tier I capital	Billion yen	BOJ
CPTLT1RT	Tier I capital adequacy ratio	%	BOJ
CPTLT2	Tier II capital	Billion yen	BOJ
CPTLT2IJT	Public injection for Tier II capital	Billion yen	BOJ
CPTLX	Capital excluding public injection	Billion yen	BOJ
CRISKAS	Credit risk assets	Billion yen	BOJ
CTAX	Effective tax rate	—	Banks: 0.4, *Shinkin* banks: 0.3
DERT	Debt equity ratios	—	Ministry of Finance, "Financial statements statistics of corporations by industry"
DIS	Interest and dividends on securities	Billion yen	BOJ
DUMAIRB	Introduction of Advanced Internal Rating-Based (AIRB) risk analysis dummy	—	2008Q4-2009Q3 = 1
DUMBII	Introduction of Basel II dummy	—	2006Q4-2007Q3 = 1
DUMCT97	Consumption tax dummy (CY1997)	—	1997Q1-1997Q1 = 1

DUMCT97L	Consumption tax dummy (CY1997)	—	1996Q1-1996Q3 = 1
DUMJKK	Government Housing Loan Corporation's reduced business dummy	—	2002Q2-2005Q1 = 1
DUMKSP	Financial Revitalization Program dummy	—	2002Q4-2005Q1 = 1
DUMLSJS	Transition from housing loan company dummy	—	1995Q3-1996Q2 = 1
DUMMER	Adjustment of merger dummy	—	BOJ
DUMOFFBS	Off-balance-sheet dummy	—	2002Q2-2004Q1 = 1
DUMPER	PER convergence dummy	—	2002Q3-2003Q2 = 1
DUMZT	Independent administrative institution dummy	—	2005Q4-2006Q3 = 1
DUM*yyqhhk*	Dummy variable for temporary level shift	—	*yy*Q*q*-*hh*Q*k* = 1
DUM*yyqZ*	Dummy variable for permanent level shift	—	after *yy*Q*q* = 1
EXIV	Amount outstanding of other securities holdings	Billion yen	BOJ
EX	General and administrative expenses	Billion yen	BOJ
EXGROR	Real expected growth rate	%	Cabinet Office, "Annual Survey of Corporate Behavior"
EXIR	Interest payments, etc.	Billion yen	Ministry of Finance, "Financial statements statistics of corporations by industry"
$EXPO^{m}$	Loan exposures categorized *m*	Billion yen	BOJ
EXRISKAS	Other risk-weighted assets	Billion yen	BOJ
FNGDPOR	Nominal GDP of overseas countries	Billion dollar	IMF, "World Economic Outlook"
FUNDA	Funding amounts	Billion yen	BOJ
FUNDR	Funding rate	% per annum	BOJ
GDPDEFOR	GDP deflator	CY2005 average = 100	Cabinet Office, "National Accounts"
GDPOR	Real GDP	Billion yen	Cabinet Office, "National Accounts"
ICR	Interest coverage ratios	Times	Ministry of Finance, "Financial statements statistics of corporations by industry"
IFRROR	Inflation rate of CPI general excluding fresh food	%	Ministry of Internal Affairs and Communications, "Consumer Price Index"
IIC	Net interest income	Billion yen	BOJ
IICLV	Net interest income from lending	Billion yen	BOJ

IICX	Other interest income	Billion yen	BOJ
IVCB	Amount outstanding of corporate bond holdings	Billion yen	BOJ
IVSTK	Amount outstanding of stockholdings	Billion yen	BOJ
IVSTK_BV	Based value of amount outstanding of stockholdings excluding stocks of subsidiary corporations	Billion yen	BOJ
LANDPOR	Land prices	End of March 2000 = 100	Japan Real Estate Institute, "Urban Land Price Index"
LENDR	Loan interest rate	% per annum	BOJ
LENDROR	Loan interest rate (aggregate)	% per annum	BOJ
LENDV	Loan amounts	Billion yen	BOJ
LENDVCORP	Loan amount to firms	Billion yen	BOJ
LENDVCORPOR	Loan amount to firms(aggregate)	Billion yen	BOJ
LENDVGOV	Loan amount to municipals	Billion yen	BOJ
LENDVIDV	Loan amount to individuals	Billion yen	BOJ
LENDVIDVOR	Loan amount to individuals (aggregate)	Billion yen	BOJ
LENDVOR	Loan amounts (aggregate)	Billion yen	BOJ
LENDVOS	Overseas loans	Billion yen	BOJ
LENDV_BV	Based value of loan amounts	Billion yen	Latest value of LENDV
LTRV30OR	10-year JGB interest rate volatility	%	Bloomberg
MBDUM	Major banks dummy	—	Major banks: 1, Regional banks and *shinkin* banks: 0
MRISKAS	Market risk assets	Billion yen	BOJ
NEXPTOR	Nominal exports	Billion yen	Cabinet Office, "National Accounts"
NGDP	Nominal GDP (seasonally adjusted)	Billion yen, per annum	Cabinet Office, "National Accounts"
NGDPOR	Nominal GDP	Billion yen	Cabinet Office, "National Accounts"
NGOVOR	Nominal government expenditure	Billion yen	Cabinet Office, "National Accounts"
NIIC	Non-interest income	Billion yen	BOJ
NIIVOR	Nominal private inventory	Billion yen	Cabinet Office, "National Accounts"
NIMPTOR	Nominal imports	Billion yen	Cabinet Office, "National Accounts"
NINVOR	Nominal capital investment	Billion yen	Cabinet Office, "National Accounts"
NPR	Net income before tax	Billion yen	BOJ
NPREXPOR	Nominal household expenditure	Billion yen	Cabinet Office, "National Accounts"

NYDSTKPOR	U.S. stock prices (Dow Jones Industrial Average)	dollar	Bloomberg
OPIR	Operating profits plus interest and dividends received, etc.	Billion yen	Ministry of Finance, "Financial statements statistics of corporations by industry"
ORISKAS	Operational risk assets	Billion yen	BOJ
ORLB	Realized gains/losses on bondholdings	Billion yen	BOJ
PCRE	Shareholder's equity	Billion yen	BOJ
PGDPOR	Potential real GDP	Billion yen	BOJ
PIMPT	Import price index (all commodities, contact currency basis)	CY2010 average = 100	BOJ
PLENDVCORPOR	Potential amount loans to firms	Billion yen	BOJ[55]
POPOR	Population of 15 years old or more	10,000 persons	Ministry of Internal Affairs and Communications, "Labour Force Survey"
PR^m	Loan loss provision rate of category *m*	—	BOJ
PT^{mn}	Transition probability of category *m* to *n*	—	BOJ
QR	Quick ratios	—	Ministry of Finance, "Financial statements statistics of corporations by industry"
RAADJ	Amount included in risk-weighted assets under phase-in arrangements	Billion yen	BOJ

[55] We define as the level of long-term equilibrium the potential amount loans to firms that matches the potential nominal GDP. We estimate the potential real GDP using the method of Hara et al. (2006) and calculate the potential nominal GDP using a GDP deflator. Then, we calculate the potential amount loans to firms for each lending purpose (business fixed investments and working). First, we assume that firms potentially need capital to maintain or renew their capital stock, and define this capital as the potential amount loans to firms for business fixed investments. We calculate it by multiplying the figure for nominal net capital stock by the potential amount loans to firms for business fixed investment multiplier (which is the average of the loan amounts for business fixed investment / nominal capital stock). Second, to calculate the potential loan amounts to firms for working, we assume that firms potentially need capital to pay wages, etc. in an amount equal to the labor input (which is labor input time wages), and define this capital as the potential amount loans to firms for working. We reach our estimate by multiplying potential labor input by the average wage by the potential loan amounts for working multiplier (which is the average loan amounts for working / amount of labor input). Here, the average wage represents the average total cash earnings per worker per hour; potential labor input represents the labor input that is used to estimate the potential real GDP based on the production function approach.

RACCP	Credit risk associated with exposures to Central CounterParties (CCPs)	Billion yen	BOJ
RACVA	Credit value adjustment (CVA) risk equivalent / 8 percent	Billion yen	BOJ
RADTAU10	Amount below the thresholds for deduction on specified items (deferred tax assets arising from temporary differences, after 250 percent risk weighting)	Billion yen	BOJ
RAMSRU10	Amount below the thresholds for deduction on specified items (mortgage servicing rights, after 250 percent risk weighting)	Billion yen	BOJ
RAOTFIU10	Amount below the thresholds for deduction on specified items (significant investments in the common stock of Other Financial Institutions, net of eligible short positions, after 250 percent risk weighting)	Billion yen	BOJ
REER	Real effective exchange rate	CY2010 average = 100	BIS, "Effective Exchange Rate"
RGLS	Realized gains/losses on stockholdings	Billion yen	BOJ
RISKAS	Risk-weighted assets	Billion yen	BOJ
RISKASOR	Risk-weighted assets (aggregate)	Billion yen	BOJ
ROACORPOR	Return on assets (current profit ROAs)	%	Ministry of Finance, "Financial statements statistics of corporations by industry"
RRS	Valuation difference on available-for-sale securities	Billion yen	BOJ
RRS_BV	Based value of valuation difference on available-for-sale securities	Billion yen	Latest value of RRS
SANGDP	Seasonal factor of nominal GDP	—	Cabinet Office, "National Accounts"
SBDUM	*Shinkin* banks dummy	—	Banks: 0, *Shinkin* banks: 1
STKPOR	Stock prices (TOPIX)	Points	Bloomberg
STKPOR_BV	Based value of stock prices	Points	Latest value of STKPOR
STKUPL	Unrealized gains/losses on stockholdings compared to the base period	Billion yen	BOJ
T2AOCI	Accumulated other comprehensive income (included in Tier II capital)	Billion yen	BOJ
T2AOCIOT	Accumulated other comprehensive income (included in Tier II capital) excluding valuation difference on available-for-sale securities	Billion yen	BOJ
T2ET2	Eligible Tier II capital instruments	Billion yen	BOJ
T2GLLP	General loan loss provision	Billion yen	BOJ

T2GLLP_BV	Based value of general loan loss provisions	Billion yen	Latest value of T2GLLP
T2GR	General reserve for possible loan losses	Billion yen	BOJ
T2OT	Tier II capital: instruments and provisions excluding eligible Tier II capital instruments, accumulated other comprehensive income included in Tier II capital, and general reserve for possible loan losses	Billion yen	BOJ
T2RAADJ	Total of items included in Tier II capital: regulatory adjustments subject to phase-in arrangements	Billion yen	BOJ
T2SHORT	Regulatory adjustments applied to Additional Tier I due to insufficient Tier II to cover deductions	Billion yen	BOJ
T2TA	Tier II capital: regulatory adjustments excluding total of items included in Tier II capital: regulatory adjustments subject to phase-in arrangements	Billion yen	BOJ
UR4	Uncovered ratio of exposures categorized "in danger of bankruptcy"	—	BOJ
VATIFRROR	Consumption tax contribution in the inflation rates	%	Japan Center for Economic Research, "ESP forecasts"
YWAGEOR	Nominal employee compensation	Billion yen	Cabinet Office, "National Accounts"

Appendix 2. Refinement of the Credit Cost-Related Equations

A rise in market interest rates reduces the market value of bonds held by financial institutions. At the same time, it affects the net interest income of financial institutions through various factors including their loan interest rates and funding rates and loan amounts.

Furthermore, a rise in market interest rates can increase the debt repayment burden on firms by causing a rise in borrowing rates, and in turn, this can lead to an increase in firm defaults and financial institutions' credit costs. In fact, as for loans to firms, it has been observed that default rates are related to interest coverage ratios (ICRs; defined as [operating profits plus interest and dividends received, etc.] / interest payments, etc.), which indicate a firm's interest payment burden. Specifically, default rates start to increase rapidly as ICRs fall below a certain threshold (Appendix Figure 2-1).[56]

The previous version of the FMM did not necessarily fully capture such a mechanism, in which an increase in borrowers' interest payment burden caused by higher borrowing rates raises default rates and financial institutions' credit costs.[57] In order to better incorporate this mechanism into the framework, we refined the credit cost-related equations. This refinement made it possible for our testing framework to more comprehensively capture the impacts of a rise in interest rates. Specifically, the refinements made involved the following two aspects.

First, we refined the credit cost-related equations so that default rates among borrowing firms are affected not only by changes in the macroeconomic environment (i.e., nominal GDP growth rate), but also more directly by changes in firms' financial positions. More specifically, in the previous specification of the functions of credit rating category transition probabilities, which is shown as Equation (A1) below, indicators of firms' financial positions were entered as explanatory variables in a multiplicative form using the nominal GDP growth rate. This was done to allow for the possibility that the sensitivity of

[56] In Appendix Figure 2-1, due to the limited availablility of data, the relationship between borrowing firms' ICRs and default rates is not shown for loans to overall firms, but is shown for loans to small and medium-sized firms only.

[57] This issue was raised in the October 2013 issue of the FSR.

transition probabilities to changes in macroeconomic conditions (represented by the nominal GDP growth rate) depends on the firms' financial positions. However, this specification did not fit the data very well. Therefore, we refined the specification so that indicators of firms' financial positions are entered in an additive form. In addition, we adopted the DE ratios as an additional indicator of firms' financial positions. Default risk among borrowing firms is thought to increase when the DE ratios rise, i.e., when borrowing firms are more leveraged.

Transition probability *i* from category *m* to *n*

$$= \frac{1}{1 + \exp\left\{ - \begin{pmatrix} \text{fixed effect } i^{mn} + \beta^{mn} \times \text{nominal GDP gowth rate} \\ +\gamma^{mn} \times \text{nominal GDP gowth rate} \times \text{ICRs} \\ +\delta^{mn} \times \text{nominal GDP gowth rate} \times \text{quick ratios} \end{pmatrix} \right\}} \quad \text{(A1)}$$

where $m = 1, \cdots, 4, \;\; n = 1, \cdots, 5$

As a result of this refinement, the transition probability functions now fit the data significantly much better than they did previously (Appendix Figure 2-2). Under the previous specification, for some credit rating category transition patterns, the transition probability functions could not even be estimated because they fit the data too poorly.[58] Thanks to this refinement, more credit rating category transition patterns are now explained by changes in the macroeconomic environment or firms' financial positions. As a result, transitions between credit rating categories and credit cost fluctuations caused by such transitions have generally become more responsive to changes in the macroeconomic environment and firms' financial positions.

Second, we modified the equation used for determining the level of firms' financial position indicator so that changes in firms' interest payment burden are directly reflected in changes in this indicator. Under the previous version of the equation, which is shown as Equation (A2) below, firms' financial indicators changed in accordance with changes in nominal GDP, and these indicators were not directly affected by changes in the level of interest rates. In this refinement, we modified the equation employed for determining interest payments, etc. -- the ICRs denominator -- so that interest payments, etc., directly respond to changes in the

[58] For such patterns, we had to assume that transition probabilities would remain constant at the most recent observations throughout the simulation period in macro stress testing.

level of interest rates (see Equations (20) and (21) in the main text).

$$\text{ICRs} = \alpha + \beta_1 \times \text{nominal GDP growth rate} \\ + \beta_2 \times \text{nominal GDP growth rate (one quarter lag)} \tag{A2}$$

As a result refining the two aspects of the FMM mentioned above, the estimated magnitude of increases in credit cost ratios under upward interest rate shift scenarios has become larger than it was in the previous framework (Appendix Figure 2-3).

Before concluding this appendix, it is worth making a few comments on the data used in the credit cost-related equations. First, we previously constructed a firms' financial position indicator for each financial institution and used it as a financial institution-specific explanatory variable in the transition probability functions. It was constructed by taking the weighted average of a financial position indicator across industries and size categories, using as a weight the loan amounts held by the financial institution to firms in a particular industry and in a particular size category. However, analyses have revealed that financial position indicators aggregated at the macro level sufficiently capture fluctuations in transition probabilities. Thus, we have instead started using the macro-level financial position indicators (namely, ICRs, the quick ratios, and the DE ratios). Second, in the transition probability function of the FMM, we use only firms' financial position indicators as explanatory variables, and omit household financial position indicators. Nevertheless, the functions sufficiently fit the data because lending to firms accounts for a fairly large share of total lending in Japan.

Appendix 3. Simulation of the Feedback Loop between the Financial and Economic Sectors

The FMM features a feedback loop mechanism between the financial and economic sectors. As explained in the main text, the credit costs, net interest income, and capital adequacy ratios of individual financial institutions are determined in the financial sector. The aggregates of these variables affect macroeconomic variables, which then feedback into the financial sector again.

In the main text, we report simulation results on the size of the impacts of the feedback mechanism. In this appendix, we explain the simulation procedure. Specifically, we examine a shock in which the nominal GDP growth rate declines by one percentage point in the first year of the simulation and observe how nominal GDP and other variables vary with/without the feedback mechanism. The quantitative evaluation of the feedback loop here is based on certain assumptions and some elements are omitted. Therefore, the results should be interpreted with some latitude.

A. Simulation without the Feedback Mechanism

The simulation procedure without the feedback mechanism is the same as macro stress testing used by financial institutions and foreign authorities, in that we first decide the future paths of macroeconomic variables such as nominal GDP before calculating financial variables such as credit costs and net interest income. This is "one way" stress testing from the macroeconomy to the financial sector. The details of the simulation procedure are as follows.

1. Future paths of the macroeconomic sector

We construct a model in which macroeconomic variables are endogenous and financial variables such as loan amounts and loan interest rates are exogenous (the macroeconomic sector model).[59] This model uses the same equations and parameters as those employed in the FMM, but disconnects the feedback loop between the financial and macroeconomic

[59] This model includes nominal GDP, real GDP, nominal household expenditure, nominal investments, nominal exports, nominal imports, potential growth rates, expected growth rates, employee compensation, return on assets, stock prices, land prices, inflation rates, nominal effective exchange rates, real effective exchange rates, quick ratios, ICRs, and DE ratios.

sectors. We use the same values for financial variables as those employed in the baseline scenario and apply the macroeconomic sector shocks mentioned above, then calculate the future paths of various indicators.

2. Impact analysis of the financial sector

Next, we construct a model in which macroeconomic variables are exogenous and financial variables are endogenous (the financial sector model). This model also uses the same equations and parameters as those employed in the FMM, but disconnects the feedback loop between the financial and macroeconomic sectors. We use the simulation results of the macroeconomic model described above as exogenous variables and enter them into the financial sector model in order to determine the future paths of financial variables.

B. Simulation with the Feedback Mechanism

The results of the simulation conducted with the feedback mechanism are the outcomes of the FMM simulation given the aforementioned exogenous macro shocks in nominal GDP.

Appendix 4. Interest Rate Model

We need to estimate the pass-through rates of loan and deposit rates to market rate fluctuations in order to calculate interest income under the upward interest rates shift scenario.

The sample period for the pass-through rate estimation is from 2003, and the parameters are estimated using the dynamic panel model. The dependent variables are long-term loan interest rates, short-term loan interest rates, one-month time deposit rates, three-month time deposit rates, six-month time deposit rates, one-year time deposit rates, two-year time deposit rates, three-year time deposit rates, and five-year time deposit rates. The independent variables are (1) financial variables for individual financial institutions (total asset size, liquid asset ratios, capital adequacy ratios, loans to small and medium-sized firms-to-total loan ratios, and deposits-to-total liability ratios); (2) market interest rates (Libor and swap rates); (3) macroeconomic variables (economic growth rates, market volatility index, etc.).[60] When we estimate pass-through rates of ordinary deposits, we use aggregate data for each type of financial institutions (major banks, regional banks, and *shinkin* banks) as dependent variables and employ market interest rates and macroeconomic variables only as independent variables, applying the least square estimation method. This is because differences in individual financial institutions' ordinary deposit rates are small within each type of financial institutions.

The specifications of loan and deposit rates are shown below in equations (A3) and (A4) based on Gambacorta (2008).

[60] Loan interest rates are stock data, whereas time deposit rates are flow data. When we conduct simulations of net interest income, we assume that new time deposits are made in line with past developments and calculate the future paths of time deposit interest payments for stock data by using the estimated pass-through rates of time deposit rates for flow data.

$$\begin{aligned}\Delta i_{L_\tau k,t} &= \mu_{L_\tau k} + \sum_{j=1}^{2} \kappa_{L_\tau j} \Delta i_{L_\tau k,t-j} + \sum_{j=0}^{\Lambda_{L_\tau}} \left(\beta_{L_\tau j} + \sum_{m=1}^{6} \beta_{L_\tau mj} X_{Lm,k,t-1} \right) \Delta i_{M_\tau,t-j} \\ &\quad + \left(\alpha_{L_\tau} + \sum_{m=1}^{6} \alpha_{L_\tau m} X_{Lm,k,t-1} \right) \left(i_{L_\tau k,t-1} - i_{M_\tau,t-1} \right) \\ &\quad + \sum_{m=1}^{6} \lambda_{L_\tau m} X_{Lm,k,t-1} + \phi_{L_\tau} \overline{Z}_{L_\tau,t} + \Gamma_{L_\tau} \overline{\Phi}_{L_\tau,t} + \varepsilon_{L_\tau k,t}\end{aligned} \tag{A3}$$

$$\begin{aligned}\Delta i_{D_\tau k,t} &= \mu_{D_\tau k} + \sum_{j=1}^{2} \kappa_{D_\tau j} \Delta i_{D_\tau k,t-j} + \sum_{j=0}^{\Lambda_{D_\tau}} \left(\beta_{D_\tau j} + \sum_{m=1}^{5} \beta_{D_\tau mj} X_{Dm,k,t-1} \right) \Delta i_{M_\tau,t-j} \\ &\quad + \left(\alpha_{D_\tau} + \sum_{m=1}^{5} \alpha_{D_\tau m} X_{Dm,k,t-1} \right) \left(i_{D_\tau k,t-1} - i_{M_\tau,t-1} \right) \\ &\quad + \sum_{m=1}^{5} \lambda_{D_\tau m} X_{Dm,k,t-1} + \phi_{D_\tau} \overline{Z}_{D_\tau,t} + \Gamma_{D_\tau} \overline{\Phi}_{D_\tau,t} + \varepsilon_{D_\tau k,t}\end{aligned} \tag{A4}$$

where $i_{L_\tau k,t}$ is financial institution *k*'s loan interest rate at time *t* with duration τ, $i_{D_\tau k,t}$ is financial institution *k*'s deposit rate at time *t* with duration τ, $i_{M_\tau,t}$ is the market interest rate at time *t* with duration τ, $X_{Lm,k,t}$ and $X_{Dm,k,t}$ are financial institution *k*'s vectors of balance sheet items at time *t*, $\overline{Z}_{L_\tau,t}$ and $\overline{Z}_{D_\tau,t}$ are controlled variables at time *t*, $\overline{\Phi}_{L_\tau,t}$ and $\overline{\Phi}_{D_\tau,t}$ are seasonal dummy variables at time *t*, $\mu_{L_\tau k}$ and $\mu_{D_\tau k}$ are constant terms for fixed effects for financial institution *k*, and Δ is the first difference.[61]

The loan interest rate control variable vector, $\overline{Z}_{L_\tau,t}$, includes potential growth rates, difference in output gaps between the previous and current periods, market volatilities, and differences in non-performing asset ratios. The balance sheet item vector, $X_{Lm,k,t}$, includes liquid asset ratios, capital adequacy ratio gaps, small and medium-sized firms' share of loan amounts, market conditions (the Herfindahl index),[62] unemployment rates,

[61] The instantaneous pass-through rate just after an increase in the market interest rate is $\beta_0 + \sum_m \beta_{m0} X_{m,t-1}$. Subsequent pass-through rates would increase over time and in the long-run converge to 100 percent. This is because changes in market interest rates would gradually be charged to loan and deposit rates through their own lags, market interest rate lags, and error correction terms.

[62] Earlier empirical studies on pass-through rates show that market conditions surrounding financial institutions have influenced pass-through rates. See, for example, Leuvensteijn et al. (2013). Various proxies for market conditions have been used in these studies. We use the Herfindahl index

and total asset sizes. The deposit rate control variable vector, $\overline{Z}_{D_{\tau},t}$, includes potential growth rates, output gap difference between the previous and current periods, and market volatilities. The balance sheet item vector, $X_{Dm,k,t}$, includes capital adequacy ratio gaps, market conditions (the Herfindahl index), total asset sizes, the deposit ratios, and unemployment rates.

We use control variables in order to separate various factors other than changes in market interest rates from loan and deposit rate fluctuations. For example, changes in loan demand, market uncertainty, and deterioration of loan portfolio quality put upward pressure on loan interest rates without any changes in market interest rates. Removing these factors allows us to appropriately capture the degree of pass-through from market interest rate fluctuations to loan interest rates.

We calculate the future paths of loan and deposit rates by using the estimated equations shown above and applying market interest rate assumptions. We then calculate the differences between the values obtained under the baseline and stress scenarios. We use these differences as exogenous shocks in FMM simulations and proceed to conduct macro stress testing.

---

as a proxy variable for market conditions, which is the sum of the squares of loan or deposit amounts of individual financial institutions divided by the squares of the average level of loan or deposit amounts.

Appendix 5. Calculation Methodologies for Interest Income and Capital Gains/Losses on Bondholdings

This appendix details the calculation methodologies we employ for interest income and capital gains/losses on bondholdings.

Changes in interest income on bondholdings occur due to (1) the cessation of coupon income when existing bonds are redeemed; and (2) additional coupon income from newly invested bonds. The former is influenced by the extent to which financial institutions have bonds to be redeemed at each point in time. The latter depends on the duration of newly invested bonds and market interest rates (the shape of the yield curve) when bonds are acquired.

The market value of a bond is the discounted present value of future cash flows from the bond. These cash flows include not only the principal to be redeemed, but also coupon income.

Therefore, we need detailed bond portfolio information in order to calculate coupon income and the market values of bonds. For example, what is the duration of the bond when it is initially issued? What is the remaining maturity of the bond? More specifically, it is necessary to have information such as the fact that a 2-year bond has one year remaining to maturity, or that a 10-year bond has three years remaining to maturity. In the following section, we explain how bond balances with different initial and remaining maturities are estimated, then show how coupon income and market values of bonds are calculated.

A. Estimation of Bond Balances by Initial and Remaining Maturity

The Bank of Japan conducts a quarterly survey of bondholdings (the maturity ladder table of bonds), which shows bond balances by remaining maturity. This enables us to capture the remaining maturities of bonds held by financial institutions. However, because we do not have initial maturity information on bonds held by each financial institution, we need to estimate the initial and remaining maturities of bonds by assuming certain conditions (Appendix Figure 5-1).

In order to estimate the initial and remaining maturities of bonds, we make two assumptions. First, we assume that there are eight types of bonds: 3-month, 6-month, 1-year, 3-year, 5-year, 7-year, 10-year, and 14-year. Some of them are hypothetical and do not exist in the actual bond market. Second, we assume that financial institutions have held the same amount of every type of bond in the past. Based on this assumption, the same amount of a certain type of bond exists for any remaining maturity period, and the same amount will be redeemed in every period. For example, we assume that the amount of 10-year bonds is one trillion yen in each quarter.

Based on the above assumptions, we create matrices of the initial and remaining maturities of bonds, which are aggregate data for each type of financial institutions. First, we estimate the quarterly share of 14-year bonds. We know that there are only 14-year bonds with more than 10 years to maturity and assume that those with maturities of above 10 years are all 14-year bonds. In this case, we need to calculate the quarterly share of 14-year bonds with remaining maturities beyond 10 years, namely, the quarterly share of bonds with remaining maturities from 11 years to 14 years. The total number of quarters is 4 years * 4 quarters = 16 quarters. The total share of 14-year bonds with remaining maturities beyond 10 years is 1.6 percent, so the quarterly share is 1.6 percent/16 quarters = 0.1 percent. We assume that the quarterly share of 14-year bonds due to mature within 10 years is the same as that beyond 10 years. There are 14 years * 4 quarters = 56 quarters, and the quarterly share is 0.1 percent. The total share of 14-year bonds with a remaining maturity of 14 years is 0.1 percent * 56 quarters = 5.6 percent. Next, we estimate the quarterly share of 10-year bonds. Based on the maturity ladder table, the share of bonds with an initial maturity of 7 to 10 years (29 to 40 quarters, 12 quarter periods) is 13.2 percent. Here, we have a 1.2 percent share of 14-year bonds and a 12 percent share of 10-year bonds (13.2 - 1.2 = 12 percent). Therefore, the quarterly share of 10-year bonds with a remaining maturity from 7 to 10 years is 12/12 quarters = 1 percent. The total share of 10-year bonds is 10 years*4 quarters*1 percent = 40 percent. As we iterate these calculations, we obtain complete matrices, which include all the shares of the initial and remaining maturities of bonds. Then, we calculate the matrices of bond amounts (aggregate matrix data) for each type of financial institutions by using the shares calculated above.

The above calculations are performed for each type of financial institutions (major banks, regional banks, and *shinkin* banks). There are many cases in which no realistic numbers are obtained for certain bond types and maturities if we use bond data for individual financial institutions. Once we obtain the aggregate matrix data, we use the bond shares of individual financial institutions to total bond amounts for each type of financial institutions to derive estimated bond matrices for individual financial institutions.

B. Calculation of Coupon Income

We assume that coupon rates on newly issued bonds are the same as prevailing market interest rates. Based on this assumption, we can estimate coupon income at any time by using the abovementioned bond balances by type and remaining maturity and past market interest rates.

During the simulation period, we assume that bonds redeemed are reinvested in the same types of bonds. The coupon rates on reinvested bonds would be the prevailing market interest rates.[63] Therefore, if market interest rates are higher than the original coupon rates, the coupon rates on the reinvested bonds would also be higher.

Based on the above assumptions, we can calculate quarterly coupon income on bonds as shown in equation (A5) because we have information on estimated bond balances by type and remaining maturity and past market interest rates.

$$\text{Coupon income } i = \sum_{m}\sum_{n=1}^{56}\left(\begin{array}{r}\text{bond balances } i \text{ with remaining maturity of } n \text{ quarters} \\ \text{and original maturity of } m \text{ years} \\ \times \dfrac{\text{market interest rates on } m \text{ year maturity } (4m-n) \text{ quarters ago}}{4}\end{array}\right) \quad \text{(A5)}$$

We calculate semi-annual coupon income on floating rate bonds based on equation (A6). We use the total balance of bonds, balances for each type, spreads on each type, and past market interest rates.[64]

[63] A bond with a remaining maturity of *n* quarters and an original maturity of *m* years was invested (4*m* - *n*) quarters ago. The annualized coupon rate on the bond corresponds to the market interest rate with an original maturity of *m* years (4*m* - *n*) quarters ago.

[64] Quarterly coupon income is 50 percent of semi-annual coupon income.

$$\text{Coupon income on floating rate bonds } i$$
$$= \text{balance of floating rate bond } i \text{ with original maturity of 15 years}$$
$$\times \sum_{s} \left\{ \begin{array}{l} \text{share of balance of the bond issued at time } s \\ \times \dfrac{\text{market rate on 10-year maturity bond half a year ago} - \text{spread at time } s}{2} \end{array} \right\} \quad \text{(A6)}$$

C. Calculation of Capital Gains/Losses on Bonds

We calculate the market values of fixed income bonds based on equations (A7) and (A8) using data on bond balances by type and remaining maturity and past market interest rates.

$$\text{Market Value of fixed income bonds}$$
$$= \sum_{m} \sum_{n=1}^{56} \left(\begin{array}{l} \text{bond balances with remaining maturity of } n \text{ quarters} \\ \qquad \text{and original maturity of } m \text{ years} \\ \times \text{ market value of one unit of a bond with remaining maturity of} \\ \qquad n \text{ quarters and original maturity of } m \text{ years} \end{array} \right) \quad \text{(A7)}$$

$$\begin{aligned} &\text{Market Value of one unit of a bond with remaining maturity of n quarters} \\ &\qquad \text{and original maturity of m years} \\ &= \text{discounted present value of principal} + \text{discounted present value of coupons} \\ &= 1/\{1 + (n/4) \text{ year market interest rate}/4\}^{n} \\ &+ \sum_{k=1}^{n} \frac{m \text{ year market interest rate } (4m - n)\text{quarters ago}/4}{\{1 + (k/4) \text{ year market interest rate}/4\}^{k}} \end{aligned} \quad \text{(A8)}$$

The market values of floating rate bonds held by individual financial institutions are calculated as shown in equations (A9) and (A10) using information on the total balance, share of each type of bonds, spreads on each type of bonds, and past market interest rates.

$$\text{Market Value of floating rate bond } i$$
$$= \text{balance of floating rate bond } i \text{ with 15 year maturity}$$
$$\times \sum_{s} \left(\begin{array}{l} \text{total share of floating rate bond issued in period } s \\ \text{with original maturity of 15 years to total amount of floating rate bond} \\ \times \text{ market value of one unit of floating rate bond issued in period } s \\ \quad \text{with original maturity of 15 years} \end{array} \right) \quad \text{(A9)}$$

$$
\begin{aligned}
&\text{Market Value of one unit of a floating rate bond issued in period s} \\
&\qquad\qquad\qquad\qquad\qquad\qquad\text{with original maturity of 15 years} \\
&= \text{discounted present value of principal} + \text{discounted present value of coupons} \\
&= 1/\{1 + (\tau^s/2)\text{ year market interest rate}/2\}^{\tau^s} \\
&+ \sum_{t=1}^{\tau^s} \frac{\{\text{market interest rate of } (t\text{-}1) \text{ semi-annual period later} - \text{spread in period } s\}/2}{\{1 + (t/2)\text{ year market interest rate}/2\}^t}
\end{aligned}
\tag{A10}
$$

where τ_s is the remaining maturity of the bond issued in period *s*.

Capital gains/losses on bonds during simulation periods are calculated by inserting market interest rates into the above equations. It is possible for reinvestment activities among financial institutions to vary depending on changes in the shape of the yield curve. However, we assume that the structure of bond portfolios remains constant over time.

References

Canay, I. A., "A simple approach to quantile regression for panel data," *Econometrics Journal*, 14, pp. 368-386, 2011.

Committee on the Global Financial System (CGFS), "Stress testing by large financial institutions: current practice and aggregation issues," *CGFS Publications*, No.14, April 2000.

European Central Bank, "A macro stress-testing framework for bank solvency analysis," *ECB Monthly Bulletin*, pp.93-109, August 2013.

Gambacorta, L., "How do banks set interest rates?" *European Economic Review*, 52, pp.792-819, 2008.

Halaj, G., "Optimal asset structure of a bank --- bank reactions to stressful market conditions," *ECB Working Paper Series*, No.1533, April 2013.

Hara, Naoko, Naohisa Hirakata, Yusuke Inomata, Satoshi Ito, Takuji Kawamoto, Takushi Kurozumi, Makoto Minegishi and Izumi Takagawa, "The New Estimates of Output Gap and Potential Growth Rate," *Bank of Japan Review*, 2006-E-3, May 2006.

Ishikawa, Atsushi, Koichiro Kamada, Yoshiyuki Kurachi, Kentaro Nasu, and Yuki Teranishi, "Introduction to the Financial Macro-econometric Model," *Bank of Japan Working Paper Series*, No.12-E-1, January 2012.

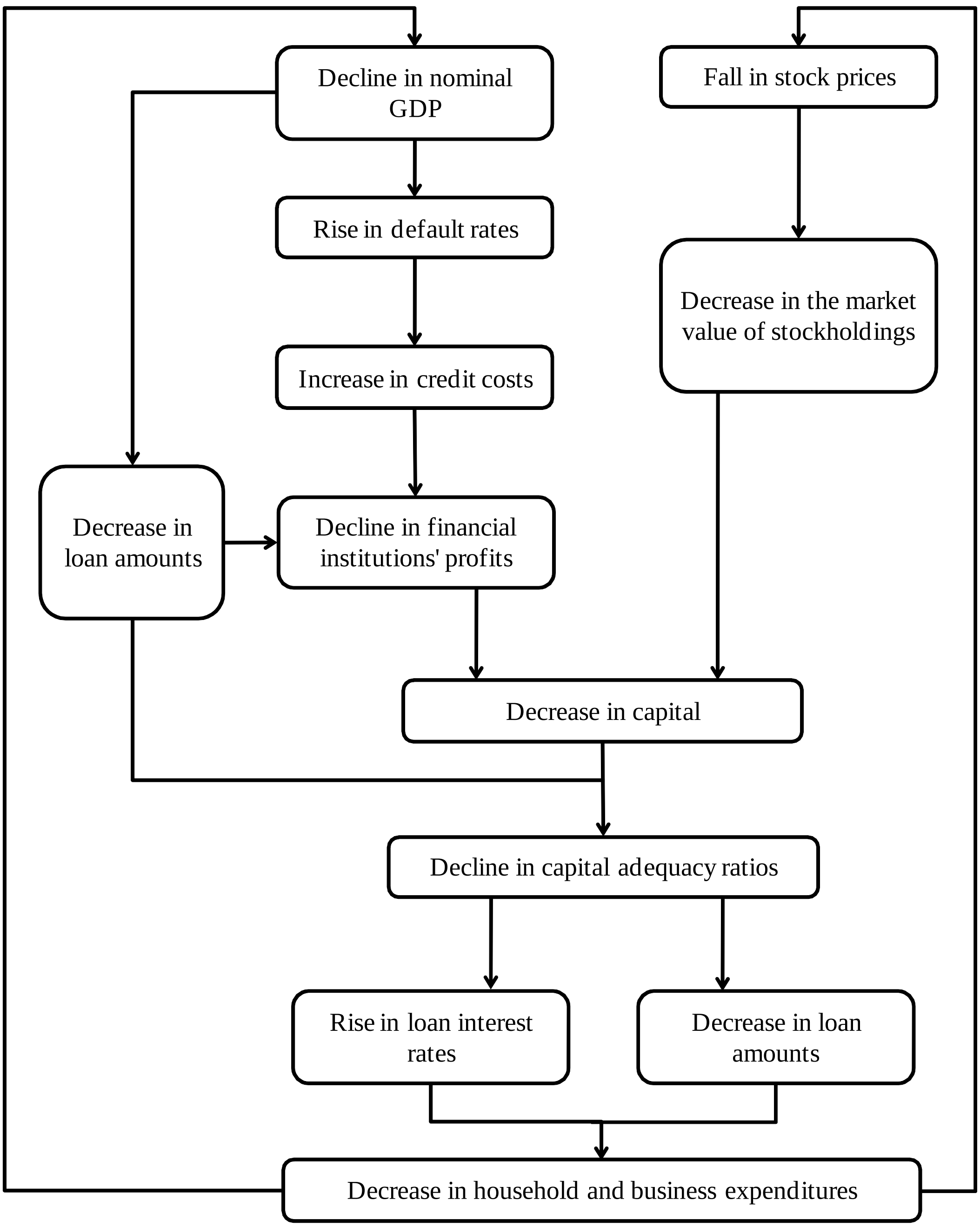
Kamada, Koichiro, and Yoshiyuki Kurachi, "The Impact of Changes in JGB Yields on the Japanese Financial Institutions and the Real Economy: Simulation analysis using the Financial Macro-econometric Model," *RIETI Discussion Paper Series*, 12-J-021, July 2012 (available in Japanese).

Kawata, Hiroshi, Yoshiyuki Kurachi, Koji Nakamura, and Yuki Teranishi, "Impact of Macroprudential Policy Measures on Economic Dynamics: Simulation Using a Financial Macro-econometric Model," *Bank of Japan Working Paper Series*, No.13-E-3, February 2013.

Leuvensteijn, M. V., Kok Sorensen, C., Bikker, J. A. and Rixtel, A. A. R. J. M., "Impact of bank competition on the interest rate pass-through in the euro area," *Applied Economics*, 45, pp.1359-1380, 2013.

(Figure 1)

Feedback Loop between Financial Sector and Macroeconomic Sector



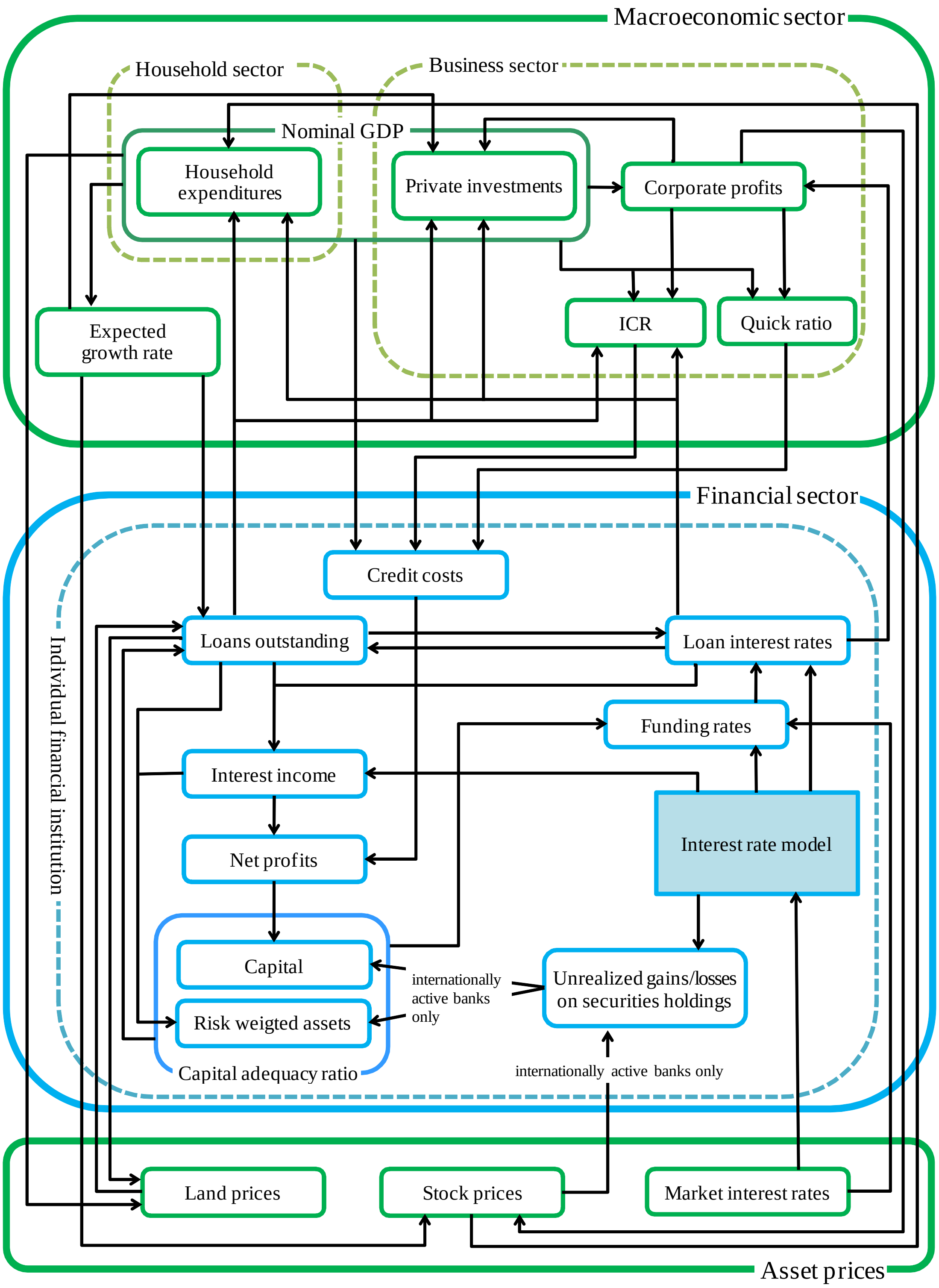
(Figure 2)

Past Stress Scenario of Macro Stress Testing

FSR publication	Stress Scenarios of Macro Stress Testing
March 2007	1. Economic downturn 2. Upward interest rate shift
Septermber 2007	1. Economic downturn 2. Upward interest rate shift
March 2008	1. Economic downturn 2. Upward interest rate shift
Septermber 2008	1. Economic downturn 2. Credit risk for the real estate-related loan portfolio 3. Upward interest rate shift
March 2009	1. Economic downturn 2. Upward interest rate shift
September 2009	1. Economic downturn 2. Upward interest rate shift
March 2010	1. Economic downturn 2. Upward interest rate shift
September 2010	1. Economic downturn 2. Upward interest rate shift
October 2011	1. Economic downturn 2. Protracted stagnation 3. Upward interest rate shift 4. Increasing correlation between domestic and overseas financial market
April 2012	1. Economic downturn 2. Protracted stagnation 3. Upward interest rate shift 4. Increasing correlation between domestic and overseas financial market
October 2012	1. Economic downturn 2. Upward interest rate shift
April 2013	1. Economic downturn 2. Upward interest rate shift
October 2013	1. Economic downturn 2. Upward interest rate shift
April 2014	1. Economic downturn 2. Upward interest rate shift

(Figure 3)

Framework of Financial Macro-econometric Model

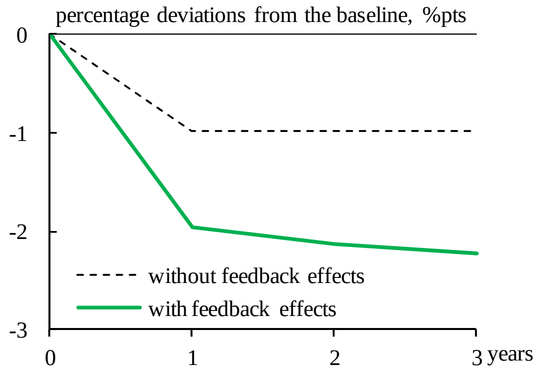


(Figure 4)

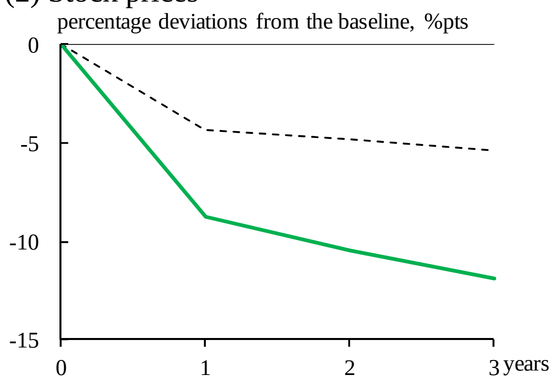
Feedback Effects between Financial Sector and Macroeconomic Sector

Assumption: Nominal GDP growth rates deviate by one percentage point from the baseline for the first year.

(1) Nominal GDP

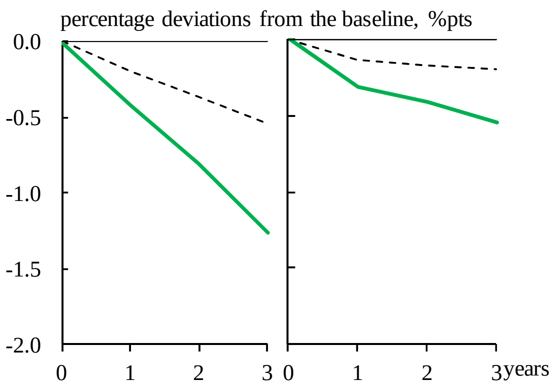


(2) Stock prices



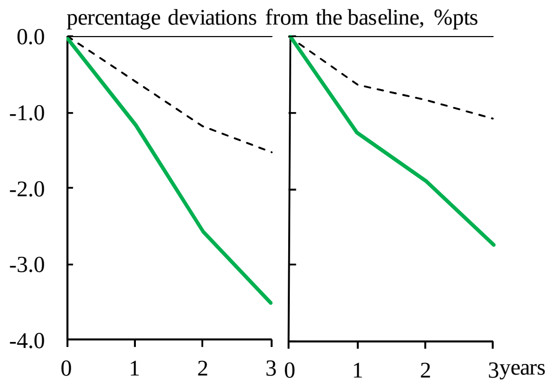
(3) Loan amounts

Internationally active banks Domestic banks



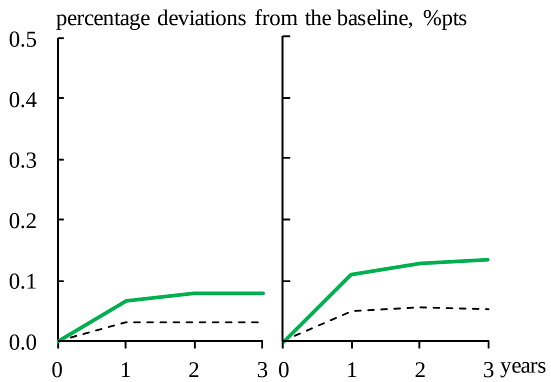
(4) Operating profits from core business

Internationally active banks Domestic banks



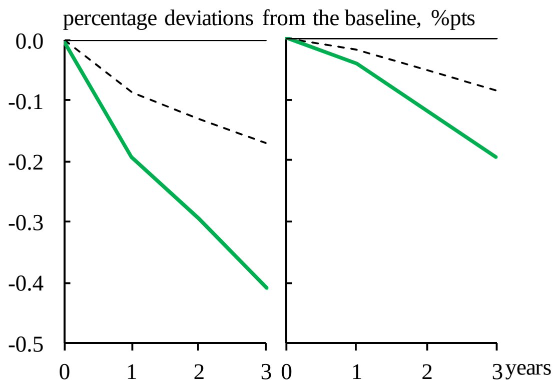
(5) Credit cost ratios

Internationally active banks Domestic banks



(6) Capital adequacy ratios

Internationally active banks Domestic banks

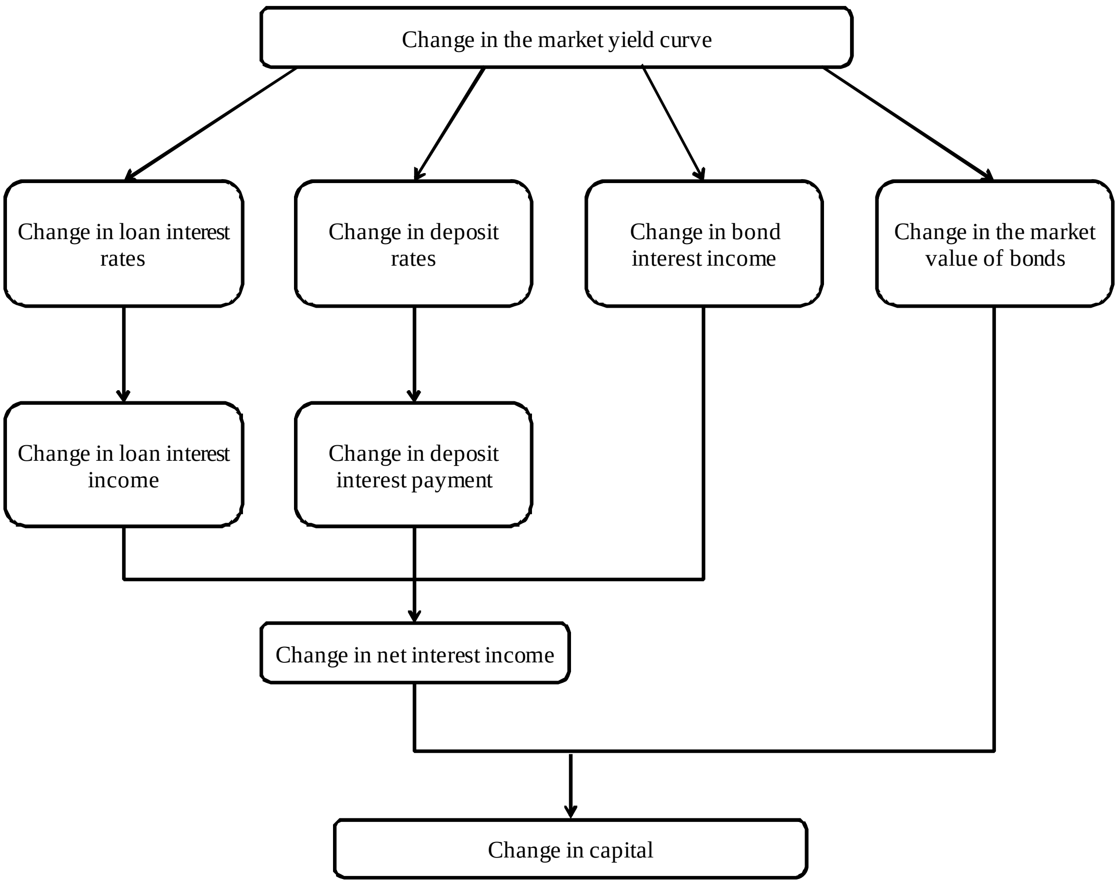


Notes: 1. Banks and *shinkin* banks are counted.

2. The left-hand chart of (6) shows the CET I capital ratio of internationally active banks. The right-hand chart of (6) shows Tier I capital ratio of domestic banks. The CET I capital ratio of internationally active banks is based on the Basel III requirements (taking the phase-in arrangements into consideration).

(Figure 5)

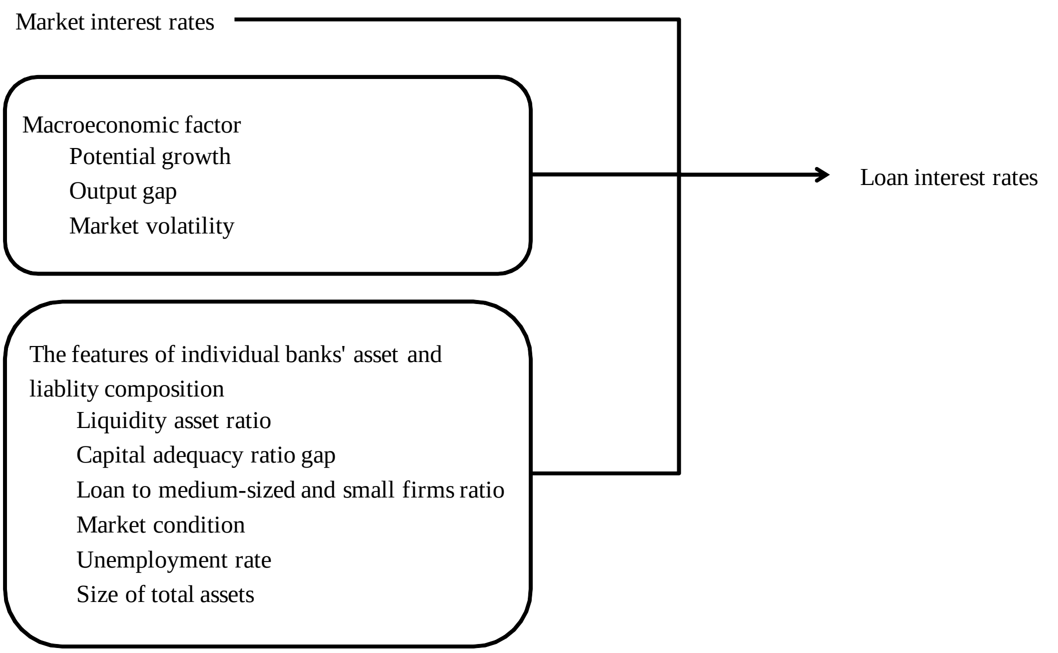
Framework of Interest Rate Stress Testing



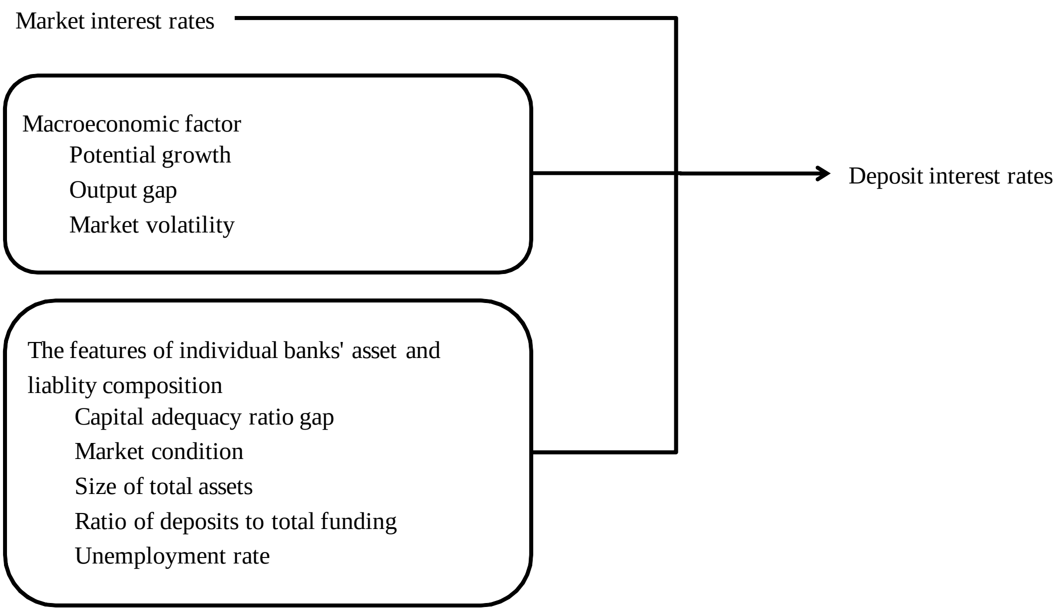
(Figure 6)

Estimation of Pass-Through Rates

(1) Estimation of loan interest rates

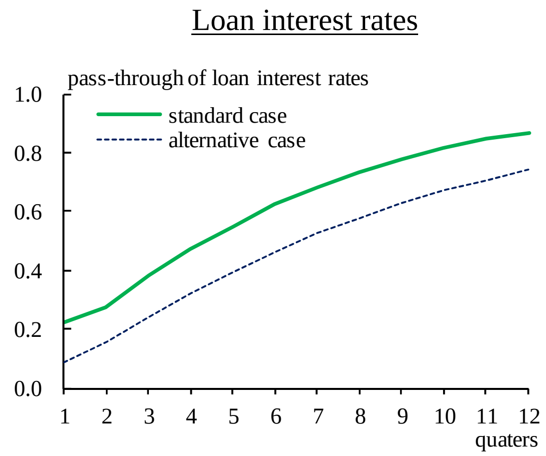


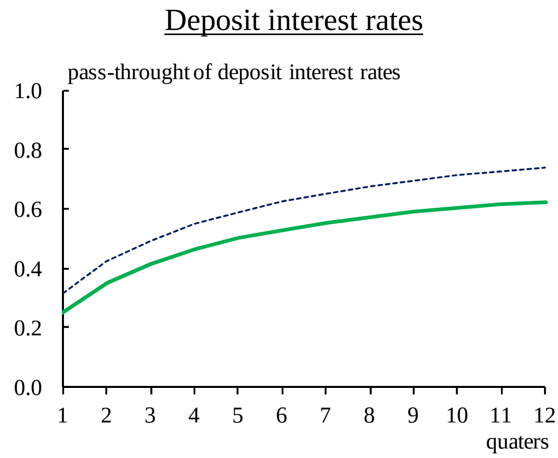
(2) Estimation of deposit interest rates



(Figure 7)

Pass-Through Rates of Loan and Deposit Interest Rates





Notes: 1. Banks and *shinkin* banks are counted.

2. Pass-through of loan interest rates is the weighted average of loans. Pass-through of deposit interest rates is the weighted average of deposits.

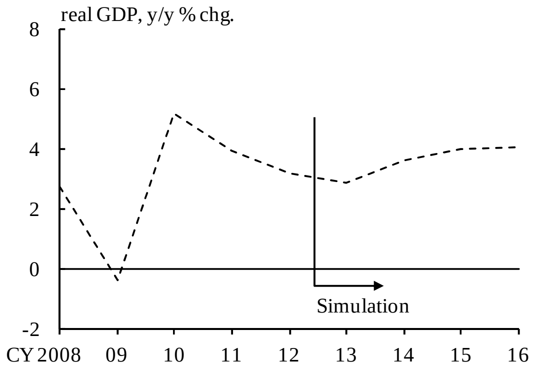
3. Standard case is calculated by the estimated coefficients of pass-through rates.

4. Alternative case is calculated by adjusting the estimated coefficients of pass-through rates by about two standard errors.

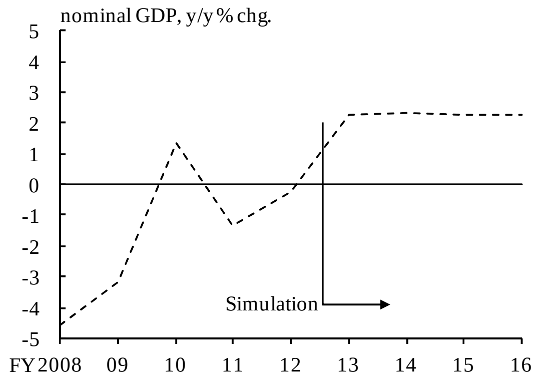
(Figure 8)

Indicators of the Baseline Scenario

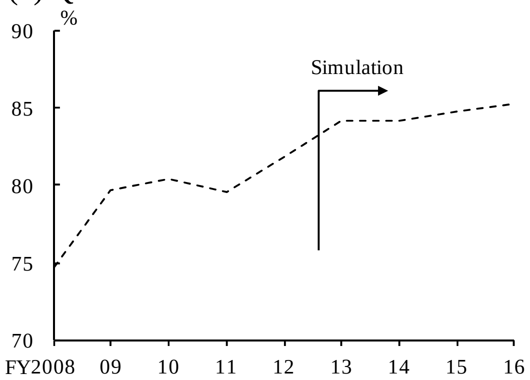
(1) Overseas economies



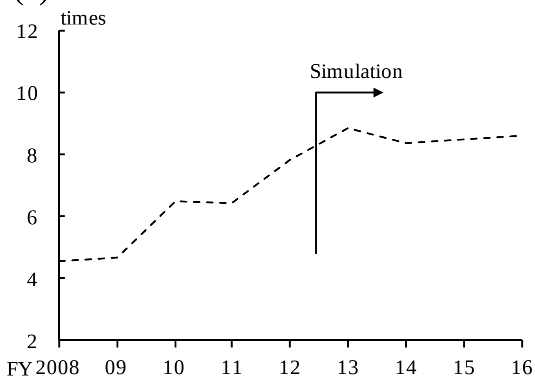
(2) Domestic economy



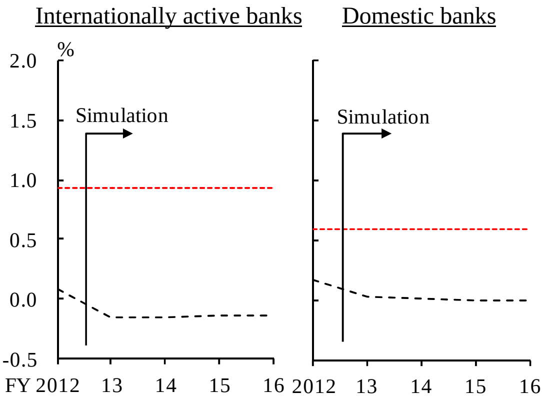
(3) Quick ratio



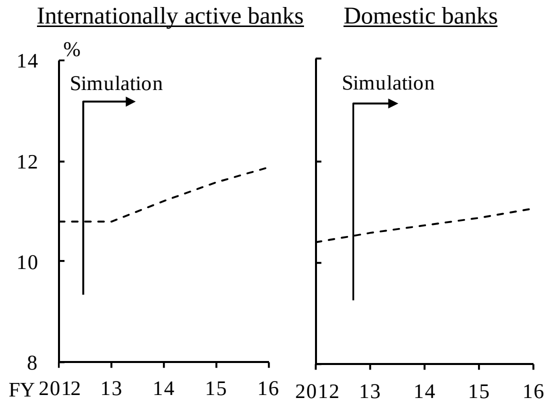
(4) ICR



(5) Credit cost ratios



(6) Capital adequacy ratios



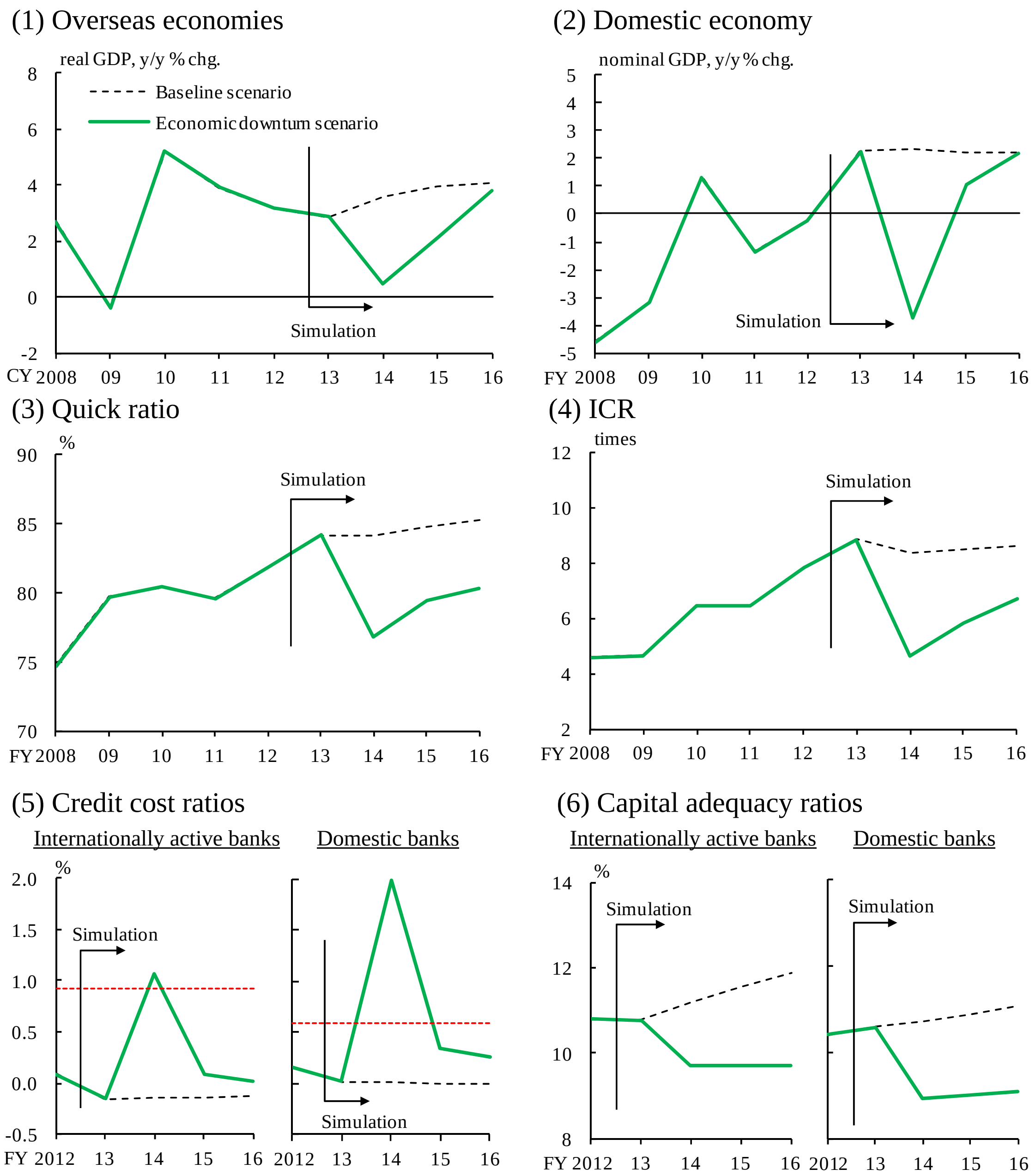
Notes: 1. Banks and *shinkin* banks are counted.

2. The horizontal dashed lines of (5) indicate the break-even points in the first half of fiscal 2013.

3. The left-hand chart of (6) shows the CET I capital ratio of internationally active banks. The right-hand chart of (6) shows the Tier I capital ratio of domestic banks. The CET I capital ratio of internationally active banks is based on the Basel III requirements (taking the phase-in arrangements into consideration).

(Figure 9)

Indicators of Economic Downturn Scenario



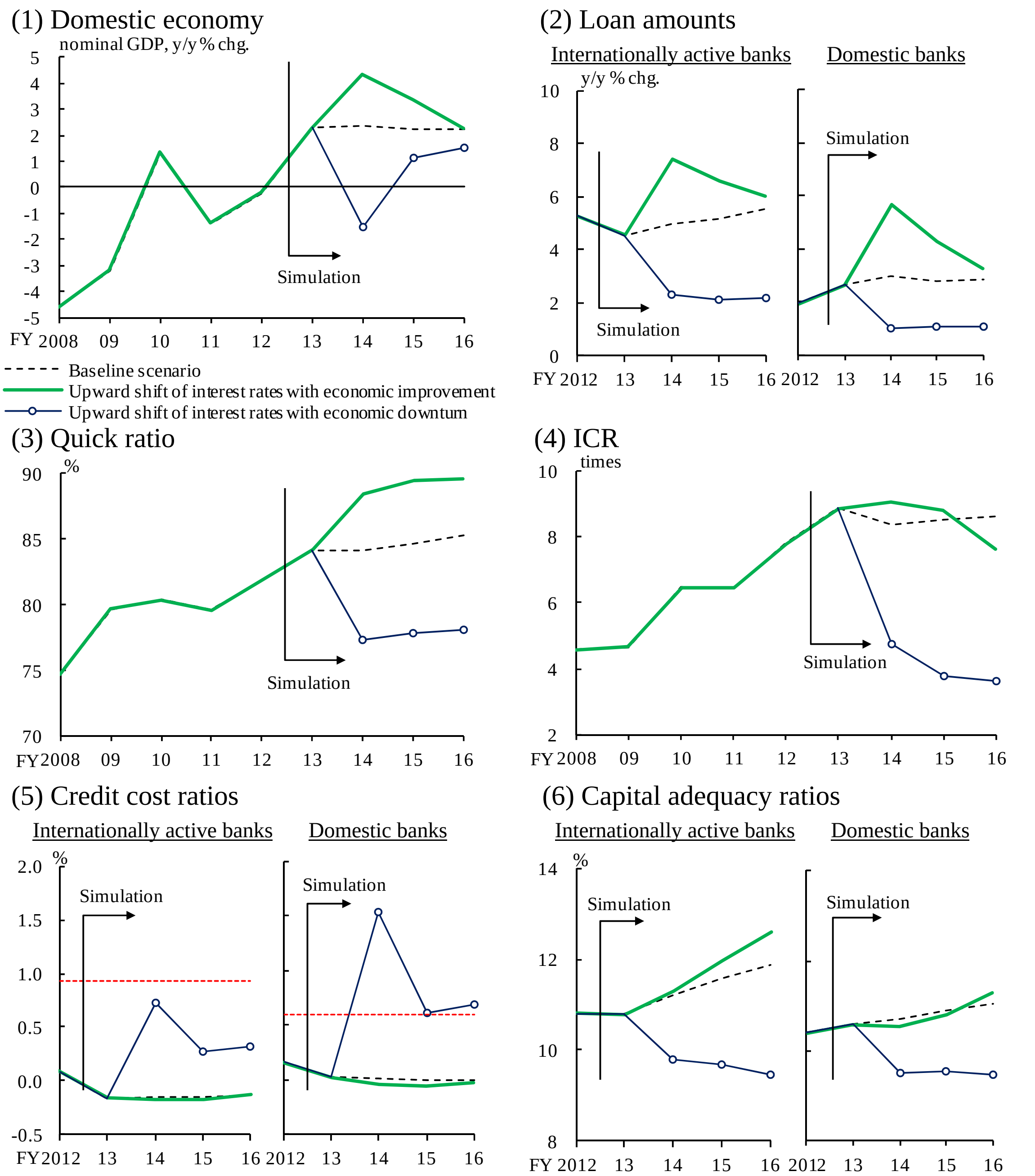
Notes: 1. Banks and *shinkin* banks are counted.

2. The horizontal dashed lines of (5) indicate the break-even points in the first half of fiscal 2013.

3. The left-hand chart of (6) shows the CET I capital ratio of internationally active banks. The right-hand chart of (6) shows the Tier I capital ratio of domestic banks. The CET I capital ratio of internationally active banks is based on the Basel III requirements (taking the phase-in arrangements into consideration).

(Figure 10)

Indicators of upward shift of interest rates scenario



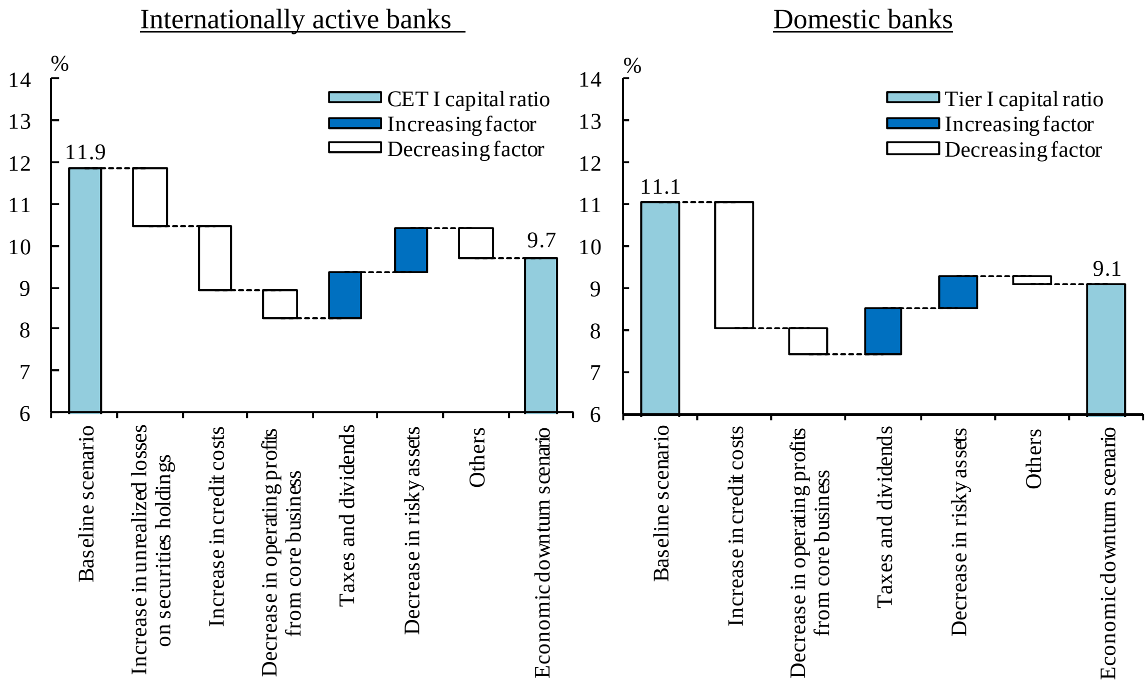
Notes: 1. Banks and *shinkin* banks are counted.

2. The horizontal dashed lines of (5) indicate the break-even points in the first half of fiscal 2013.

3. The left-hand chart of (6) shows the CET I capital ratio of internationally active banks. The right-hand chart of (6) shows the Tier I capital ratio of domestic banks. The CET I capital ratio of internationally active banks is based on the Basel III requirements (taking the phase-in arrangements into consideration).

(Figure 11)

Determinants of the CET I Capital Ratio and the Tier I Capital Ratio (Economic Downturn Scenario)



Notes: 1. Banks and *shinkin* banks are counted.

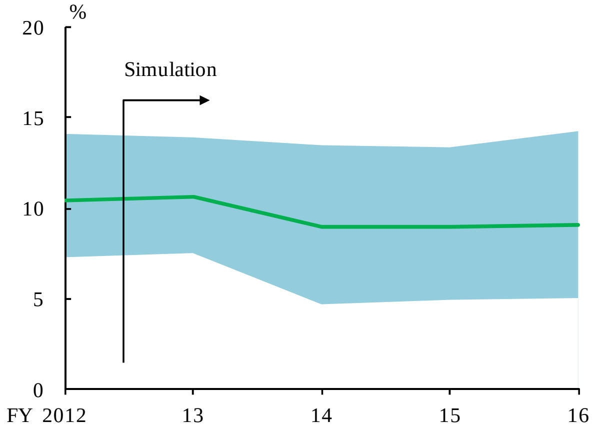
2. The left-hand chart shows the CET I capital ratio of internationally active banks. The right-hand chart shows the Tier I capital ratio of domestic banks. The CET I capital ratio of internationally active banks is based on the Basel III requirements (taking the phase-in arrangements into consideration).

3. "Increase in unrealized losses on securities holdings" is calculated by taking account of tax effects.

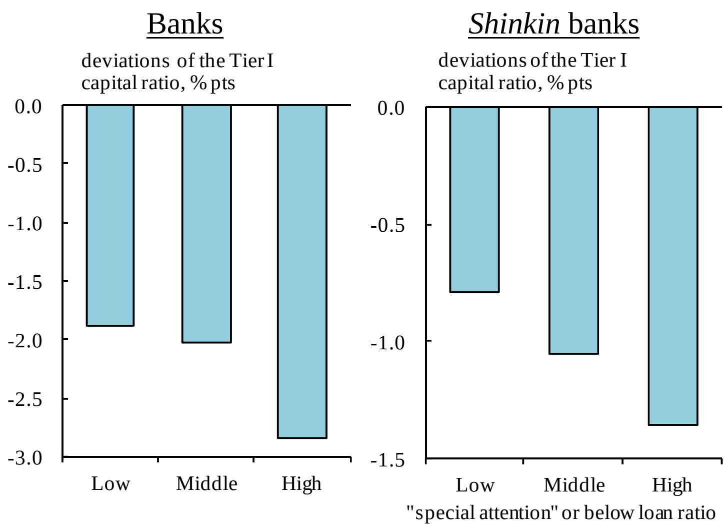
(Figure 12)

Domestic Banks' Distribution of Tier I Capital Ratio (Economic Downturn Scenario)

(1) Domestic banks' distribution of Tier I capital ratio



(2) Changes in the Tier I capital ratio and shares of loans to domestic bank borrowers classified "Special attention" or below



Notes: 1. Banks and *shinkin* banks are counted.

2. The shaded area of (1) indicates the 10th-90th percentile range measured by each bank's share of loans.

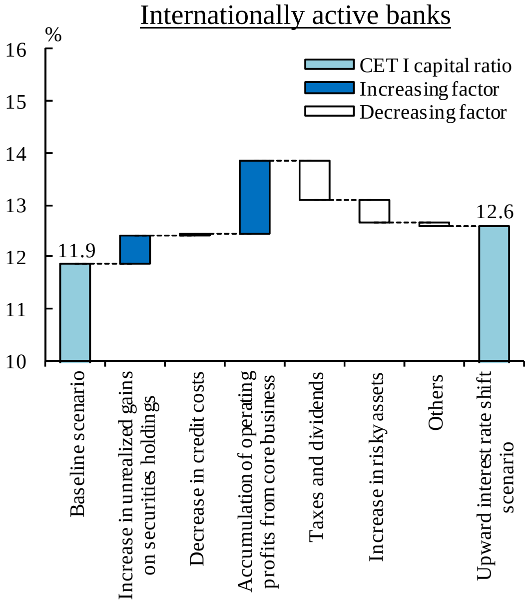
3. The horizontal axis of (2) shows the share of "special attention" or below loans in the total amount outstanding of loans as of the end-March 2014. In the left-hand chart, "low" is less than 2.8%, "middle" is 2.8-3.8% and "high" is 3.8% or more. In the right-hand chart of (2), "low" is less than 5.15%, "middle" is 5.15-7.75% and "high" is 7.75% or more. The vertical axis shows the average of each bank's deviations of the Tier I capital ratio from the baseline scenario as of the end-March 2015.

(Figure 13)

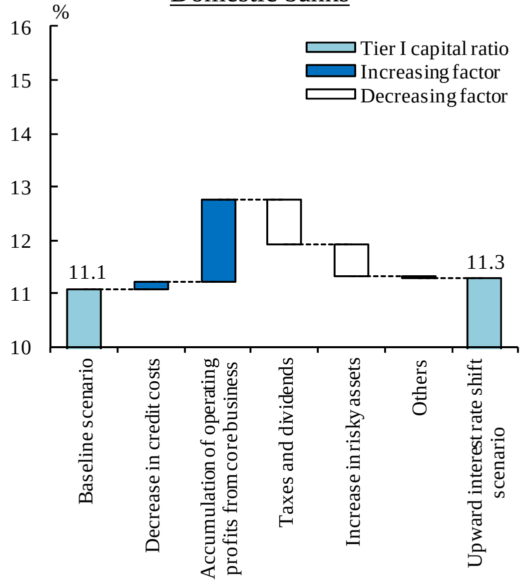
Determinants of the CET I Capital Ratio and the Tier I Capital Ratio (Upward Shift of Interest Rates Scenarios)

(1) With economic improvement

Internationally active banks

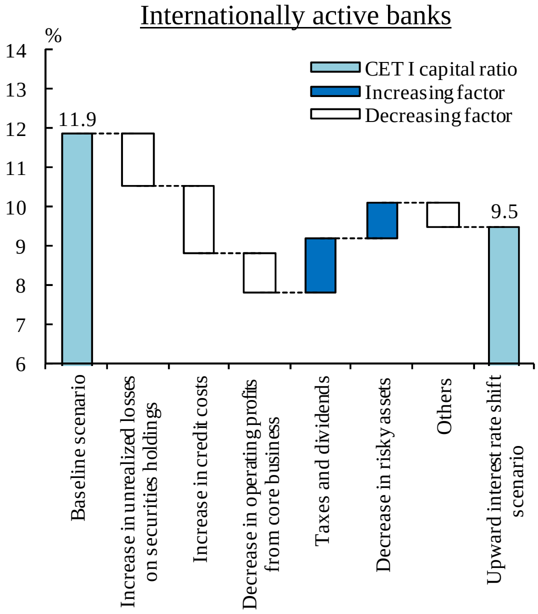


Domestic banks

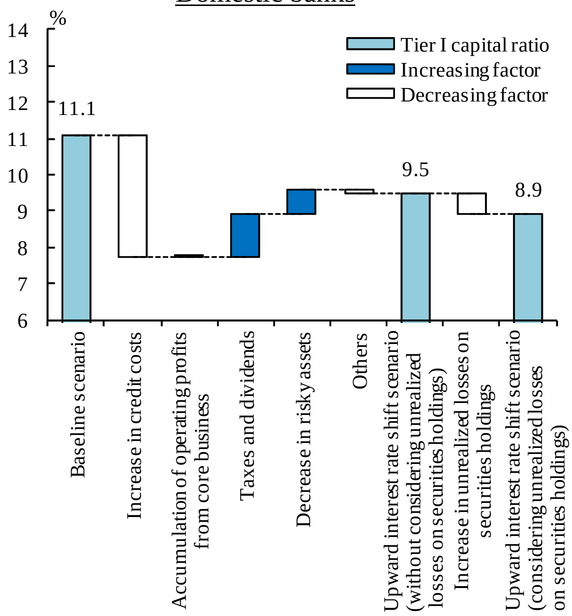


(2) With economic downturn

Internationally active banks



Domestic banks



Notes: 1. Banks and *shinkin* banks are counted.

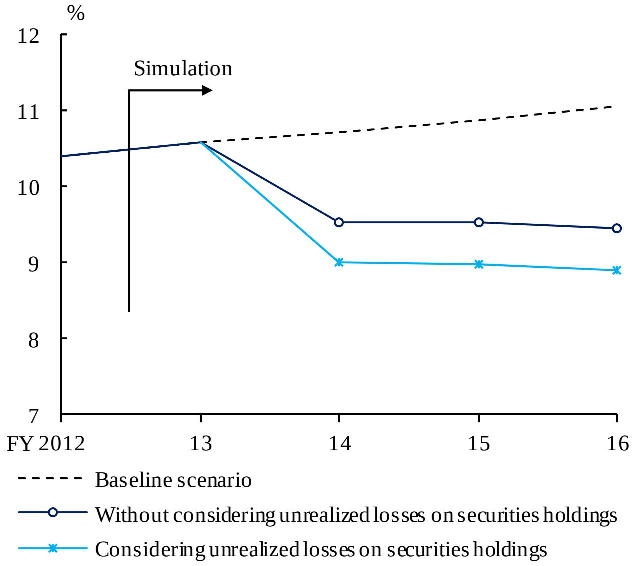
2. The left-hand charts show the CET I capital ratio of internationally active banks. The right-hand charts show the Tier I capital ratio of domestic banks. The CET I capital ratios of internationally active banks are based on the Basel III requirements (taking the phase-in arrangements into consideration).

3. "Increase in unrealized gains/losses on securities holdings" is calculated by taking account of tax effects.

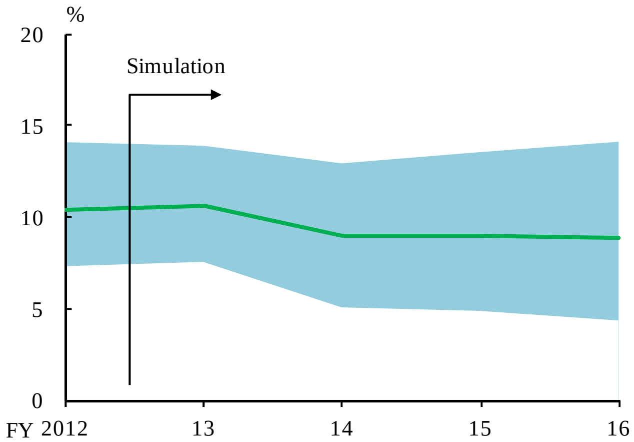
(Figure 14)

Domestic Banks' Distribution of Tier I Capital Ratio (Upward Shift of Interest Rates with Economic Downturn scenario)

(1) Tier I capital ratio of domestic banks



(2) Domestic banks' distribution of Tier I capital ratio



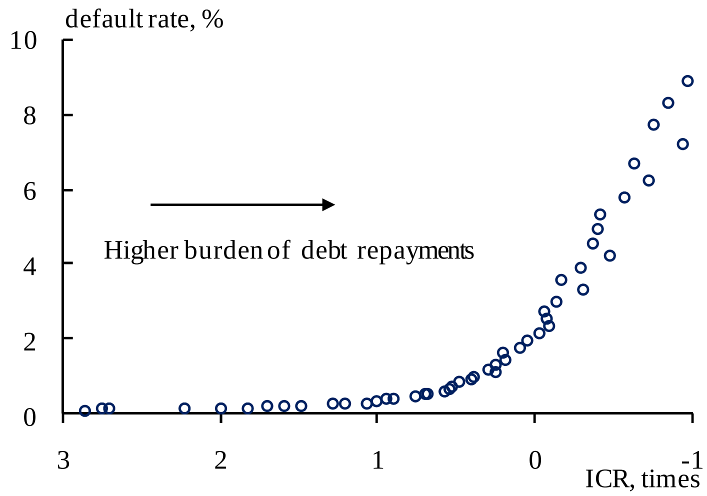
Notes: 1. Banks and *shinkin* banks are counted.

2. The Tier I capital ratio of (2) is considering unrealized losses on securities holdings.

3. The shaded area of (2) indicates the 10th-90th percentile range measured by each bank's share of loans.

(Appendix figure 2-1)

ICR and Default Rate of Small and Medium-Sized Firms



Note: The data are as of 2012. Defaults are defined as loans delinquent for 3 months or more, downgraded to de facto bankrupt or bankrupt, or subrogated by credit guarantee corporations.

(Appendix figure 2-2)

Refinement of Transition Probability Functions

(1) Explanatory variables of previous transition probability functions

<Banks>

period $t+1$ / period t	Normal	Need attention excl. special attention	Special attention	In danger of bankruptcy	de facto of bankrupt / bankrupt
Normal		NGDP NGDP · Quick ratio		NGDP NGDP · Quick ratio	NGDP
Need attention excl. special attention	NGDP			NGDP NGDP · Quick ratio	NGDP
Special attention	NGDP NGDP · Quick ratio			NGDP NGDP · Quick ratio	
In danger of bankruptcy			NGDP		

<*Shinkin* Banks>

period $t+1$ / period t	Normal	Need attention excl. special attention	Special attention	In danger of bankruptcy	de facto of bankrupt / bankrupt
Normal		NGDP NGDP · Quick ratio		NGDP NGDP · ICR	NGDP
Need attention excl. special attention					NGDP
Special attention					NGDP
In danger of bankruptcy			NGDP		

(2) Explanatory variables of refined transition probability functions

<Banks>

period $t+1$ / period t	Normal	Need attention excl. special attention	Special attention	In danger of bankruptcy	de facto of bankrupt / bankrupt
Normal		ICR Quick ratio	Quick ratio	NGDP ICR Quick ratio	NGDP ICR Quick ratio
Need attention excl. special attention	ICR		Quick ratio	ICR	ICR Quick ratio
Special attention	ICR	Quick ratio		O：ICR	ICR
In danger of bankruptcy		Quick ratio	ICR		ICR Quick ratio

<*Shinkin* Banks>

period $t+1$ / period t	Normal	Need attention excl. special attention	Special attention	In danger of bankruptcy	de facto of bankrupt / bankrupt
Normal		ICR	Quick ratio	ICR	ICR Quick ratio
Need attention excl. special attention	ICR		Quick ratio	D: Quick ratio	ICR Quick ratio
Special attention	DE ratio	D: Quick ratio		D: Quick ratio	ICR
In danger of bankruptcy	D: ICR	D: Quick ratio	NGDP		ICR Quick ratio

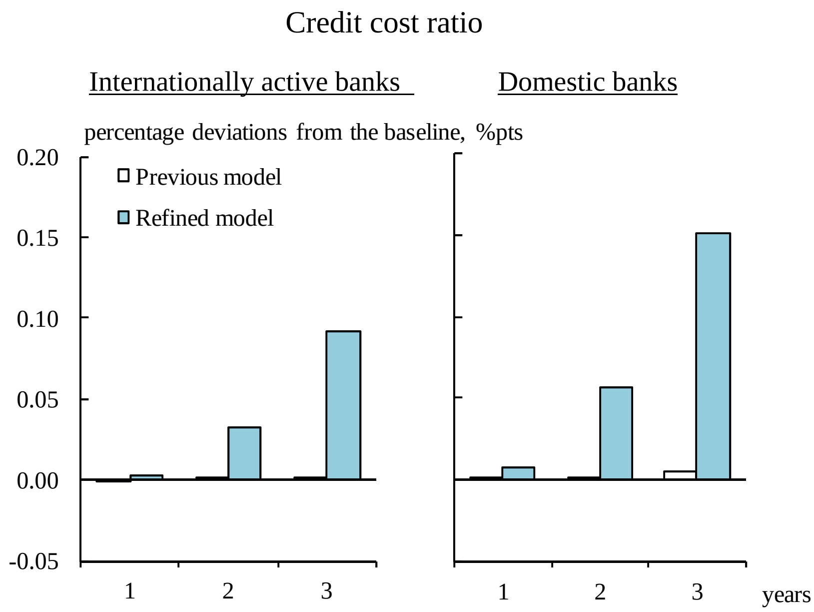
Notes: 1. Areas shaded show that the transition probability functions could not be estimated with statistical significance.

2. 'NGDP' shows nominal GDP growth rate and 'O' is the independent variable for major banks, 'D' shows the independent variable between from fiscal 2005 to fiscal 2008.

(Appendix figure 2-3)

Effects of an Upward Interest Rate Shift on Credit Cost Ratio

Assumption: Long-term interest rates steepen by two percentage points for the first year



Note: Banks and *shinkin* banks are counted.

(Appendix figure 5-1)

Estimation of Bond Matrix

(1)

Sample of the share of maturity ladder outstanding (%)	
3 months or less	**14.3**
⑦ Over 3 to 6 months	**8.7**
⑥ Over 6 months to 1 year	**13.4**
⑤ Over 1 year to 3 years	**21.6**
④ Over 3 years to 5 years	**17.6**
③ Over 5 years to 7 years	**9.6**
② Over 7 years to 10 years	**13.2**
① 10 years or more	**1.6**
Total	**100.0**

Maturity(quarter)	3-month	6-month	1-year	3-year	5-year	7-year	10-year	14-year
1	**5.6**	2.0	4.0	0.5	1.0	0.1	1.0	0.1
2	⑦	**2.0**	4.0	0.5	1.0	0.1	1.0	0.1
3		⑥	**4.0**	0.5	1.0	0.1	1.0	0.1
4			**4.0**	0.5	1.0	0.1	1.0	0.1
5			⑤	**0.5**	1.0	0.1	1.0	0.1
6				**0.5**	1.0	0.1	1.0	0.1
⋮				⋮	⋮	⋮	⋮	⋮
12				**0.5**	1.0	0.1	1.0	0.1
13				④	**1.0**	0.1	1.0	0.1
14					**1.0**	0.1	1.0	0.1
⋮					⋮	⋮	⋮	⋮
20					**1.0**	0.1	1.0	0.1
21					③	**0.1**	1.0	0.1
22						**0.1**	1.0	0.1
⋮						⋮	⋮	⋮
28						**0.1**	1.0	0.1
29						②	**1.0**	0.1
30							**1.0**	0.1
⋮							⋮	⋮
40							**1.0**	0.1
41							①	**0.1**
42								**0.1**
⋮								⋮
56								**0.1**
Total	5.6	4.0	16.0	6.0	20.0	2.8	40.0	5.6

(2)

(3)

(1) We assume that there are eight types of bonds; 3-month, 6-month, 1-year, 3-year, 5-year, 7-year, 10-year, and 14-year.

(2) We assume that the shares of each quarter for a certain type of bond are the same.

(3) We assume that matured bonds are reinvested to the same type of bond.