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The Impact of Negative Interest Rate Policy on Interest Rate Formation and Lending

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The Impact of Negative Interest Rate Policy on Interest Rate Formation and Lending*

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Abstract

This paper examines the impact of the introduction of the negative interest rate policy (NIRP) on interest rate formation and lending in Japan through literature reviews and empirical analyses. Previous studies indicated that NIRP had the effect of lowering the effective lower bound on nominal interest rates and encouraging search for yield behavior among investors, pushing down not only short-term interest rates but also long-term interest rates. Analyzing data from Japan and the euro area, we find that NIRP had a significant downward effect on interest rates for longer maturities in addition to the short-term interest rates. Next, with regard to the impact on lending, previous studies suggested that the introduction of NIRP could create accommodative financial conditions and increase lending as with conventional monetary policy that guides short-term interest rates, while it could impede the financial intermediation function by deteriorating the profitability of financial institutions ("reversal interest rate" mechanism). In this regard, analyzing data on Japanese financial institutions, we find no evidence that even financial institutions with a larger amount of deposits relative to total assets, whose earnings are likely to be affected by NIRP, experienced a declining trend in lending after the introduction of the policy. This result may have been influenced by factors such as the introduction of the three-tier system for current accounts at the Bank of Japan that eased the contractionary impact on financial institutions' earnings and maintained their risk-taking capacity.

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1. Introduction

Following the Global Financial Crisis of the late 2000s, many advanced countries experienced a decline in the natural rate of interest, and their policy rates reached the zero lower bound on nominal interest rates. In order to achieve accommodative financial conditions, central banks in each country considered new monetary policy measures beyond the conventional framework, such as forward guidance that affects future interest rate forecasts, and large-scale asset purchases. In this context, a negative interest rate policy (NIRP) was also discussed to overcome the zero lower bound on nominal interest rates. Central banks in European countries introduced NIRP in order to stabilize exchange rates and achieve inflation targets. The Bank of Japan (BOJ) also decided to introduce NIRP in January 2016 in order to create accommodative financial conditions.

In general, NIRP applies a negative interest rate to a portion of current accounts at the central bank and lowers the short-term interest rate, which is the starting point of the yield curve, into negative territory.[1] NIRP aims to stimulate the economy and prices by pushing down the overall yield curve, especially in the short term (Draghi, 2014; Kuroda, 2016).[2] However, some researches argue that this policy of applying negative interest rates to current accounts may have different mechanisms from those when interest rates are in positive territory, and may affect financial markets and the behavior of financial institutions through various channels (Arteta *et al*., 2016; Eisenschmidt and Smets, 2019; Bhattarai and Neely, 2022). In particular, the reversal interest rate mechanism suggests that because financial institutions cannot apply negative interest rates to retail deposits, lowering the policy rate below a certain level − the reversal interest rate − could squeeze profits of financial institutions and force them to raise lending rates and reduce lending supplies, leading to depressing the economy and prices (Ulate, 2021; Abadi *et al*., 2023; Eggertsson *et al*., 2023). In this regard, Tenreyro (2021) notes that there was strong empirical evidence that it could provide significant stimulus, while there was no clear evidence that negative rates reduced bank profits overall. In contrast, Powell (2020) states that the evidence on negative rates was mixed. He also notes that Fed officials had debated whether to follow other central banks in that direction and opted to use other monetary policy tools. The evaluation of the impact of NIRP is still being debated.

Based on these discussions, this paper examines the impact of NIRP on Japanese

[1] Although traditional discussions in economics such as Hicks (1937) considered that nominal interest rates cannot be negative because of the existence of money with zero interest yield, it has been pointed out that nominal interest rates can, in reality, be negative if the cost of holding money, which is discarded in this discussion, is taken into account (Rognlie, 2016).

[2] Note that some countries, such as Denmark and Switzerland, introduced NIRP to prevent appreciation of their currencies and capital inflows (e.g., Arteta *et al*., 2016).

economy through literature reviews and empirical analyses. Specifically, we focus on the impact of NIRP on interest rate formation in the financial market and lending by financial institutions, which are important transmission channels of the policy. Our literature review covers a wide range of studies on NIRP in Japan and abroad. In our empirical analyses of the impact on interest rate formation and lending, we use daily data on interest rates and granular data that combines firms and financial institutions in Japan.[3]

The remainder of the paper is organized as follows. Section 2 provides an overview of NIRP in Japan. Section 3 summarizes previous studies on the impact of NIRP on interest rate formation in the government bond market and discusses the impact of NIRP in Japan. Section 4 summarizes the transmission mechanism of NIRP into lending, reviews the literature, and discusses the impact in Japan. Section 5 concludes.

2. Overview of NIRP in Japan

In January 2016, the BOJ decided to introduce NIRP to further strengthen downward pressure on nominal interest rates in combination with large-scale JGB purchases. At the same time, in order to avoid excessive pressure on financial institutions' profits, a three-tier system for current account balances at the BOJ was introduced to keep the amount of the policy-rate balances on which a negative interest rate was applied small.

Specifically, under NIRP, current account balances held by financial institutions at the BOJ were divided into three tiers: (1) "basic balances," the level of which was set the same as that before the introduction of NIRP; (2) "macro add-on balances" (including required reserves), which increased or decreased in line with changes in the BOJ's fund provision and the Benchmark Ratio; and (3) "policy-rate balances," which were calculated by deducting "basic balances" and "macro add-on balances" from current account balances. The BOJ decided to apply interest rates of plus 0.1% to basic balances, 0% to macro add-on balances, and minus 0.1% to policy-rate balances (Chart 1).[4] During this period, the amount of policy-rate balances to which negative interest rates were applied remained small relative to the overall current account balances at the BOJ (Chart 2).

Looking at the changes in various interest rates before and after the introduction of

[3] Although it should be noted that the focus of analysis in not limited to the effects of NIRP, Bank of Japan Financial System and Bank Examination Department (2024) provides a comprehensive examination of the impact on the financial system of the BOJ's monetary easing over the past 25 years. Abe *et al*. (2024) conduct a counterfactual analysis using an econometric model and report that the BOJ's large-scale monetary easing contributed to the smooth functioning of financial intermediation.

[4] A tiered system of current accounts at the central bank to reduce the negative impact on financial institutions' profits was also introduced in Switzerland, Sweden, Denmark, and the euro area.

negative interest rates (Chart 3), long-term interest rates showed a downward trend following the introduction of "Quantitative and Qualitative Monetary Easing," and have again shown a significant decline since the introduction of NIRP in 2016. The corporate bond rate and lending rates also experienced a declining trend during this period, suggesting that the decline in market interest rates spilled over to these rates.

Studies on the impact of NIRP on market interest rate formation and lending by financial institutions have accumulated, particularly in Europe. In the next section, we present a review of previous studies and the results of our empirical analysis on these topics.

3. Impact on Interest Rate Formation in the Financial Markets

3.1. Literature Review

(1) Transmission Channel of Impact on Interest Rates

There are three main channels through which NIRP could affect interest rates in financial markets (Chart 4). The first channel is directly affecting interest rates in the short-term zone by changing the policy rate.[5] This channel is not necessarily unique to NIRP, but is also common when policy rates are set in positive territory, as in the case with conventional monetary policy.

Second, it is possible for NIRP to have an effect not only in the short-term zone but also in the long-term and super-long-term zones by changing economic entities' expectations of future short-term interest rates. Based on the pure expectations hypothesis, the long-term interest rate is assumed to be equal to the expected value of short-term interest rates from the present to the future. In this regard, what is distinctive compared with the conventional monetary policy of guiding the short-term interest rate is that it pushes down the expected short-term interest rate and thus the long-term interest rate by lowering the lower bound of the distribution of future short-term interest rates (the lower bound of interest rates) from zero into negative territory (Lemke and Vladu, 2017; Kortela 2016). If the introduction of negative interest rates can push down the lower bound of interest rates, their impact on the overall yield curve can be stronger than that of conventional monetary policy (Grisse *et al*., 2017).

Third, the low interest rate environment created by NIRP and other monetary easing

[5] Bank of Japan Financial Markets Department (2024) introduces a mechanism by which negative interest rates spill over into the short-term money market by creating incentives for financial institutions to engage in arbitrage transactions through the three-tier system of current accounts at the BOJ.

measures affects interest rates in the long-term and super-long-term zones by increasing investor demand for assets with relatively high yields (encouraging search for yield behavior) (Rajan, 2005; Borio and Zhu, 2012; Dell'Ariccia and Marquez, 2013; Dell'Ariccia *et al*., 2014; Paligorova and Santos, 2017). Search for yield behavior possibly exerts downward pressure on the term premium of long-term and super-long-term interest rates.[6] Hanson and Stein (2015), for example, used a theoretical model to highlight that when short-term interest rates fall due to monetary easing, investors increase their demand for higher-yielding assets such as super-long-term government bonds and corporate bonds in order to maintain their earnings. The encouraged search for yield behavior is discussed by Stein (2013) for banks, by Domanski *et al*. (2017), Carboni and Ellison (2022), and Kaufmann *et al*. (2024) for insurance companies and pension funds, and by Rajan (2005) for investment funds. These studies do not necessarily focus solely on negative interest rates; however, one example is Bubeck *et al*. (2020), which uses granular data on securities investment by investors in the euro area and argues that NIRP increased banks' investment in securities with longer duration and higher yields.

As an issue regarding the magnitude of policy effects, it is noted that NIRP has a significant impact on interest rates if introduced in combination with other unconventional monetary policies, such as forward guidance and large-scale asset purchase policies. Rostagno *et al*. (2019) argue that NIRP enhances the effectiveness of forward guidance in some respects because it actually makes short-term interest rates negative, thereby relieving the zero interest rate constraint on short-term rates. Sims and Wu (2021) point out that NIRP may have a greater effect on expectations because it involves action by the central bank to actually guide short-term interest rates.

Chart 5 shows the changes in the yield curves of Japan and the euro area (Germany) before and after the introduction of NIRP. The chart shows that not only short-term interest rates, which are the starting point of the yield curve, but also long-term rates fell significantly. In particular, the decline in the longer maturities widened over time after the introduction of NIRP, suggesting the possibility of a combination of various mechanisms at work. In previous studies, Arteta *et al*. (2016) report that the spread between long- and short-term interest rates (the difference between 10-year and 2-year rates) declined after the introduction of NIRP in the euro area, Japan, and Denmark. Christensen (2019) finds that the yield curve flattened after the introduction of NIRP as

[6] The term premium refers to the additional premium that investors claim when investing in long-term bonds instead of short-term bonds. It is determined by a variety of factors, including expectations on future inflation and economic activities and monetary policy uncertainty, as well as the supply and demand for bonds reflecting holdings for collateral purposes (Bernanke, 2015).

well.[7]

(2) Empirical Analyses

Next, we review empirical studies on the effects of NIRP on interest rate formation in the government bond market. Previous studies employed time series models and finance theory such as the term structure model of interest rates, and many of them reported lowering effects on the yield curve. A summary of various empirical studies on the effects on interest rate formation is summarized in Chart 6.

As a study that uses time series models to identify the effects of NIRP, Rostagno *et al*. (2021), for example, estimate the change in market participants' expected short-term interest rates using interest rate option premiums and analyze the effects of NIRP, forward guidance, and the asset purchase policy introduced by the European Central Bank (ECB). They report that between 2014 and 2020, NIRP pushed the yield curve down in parallel by about -50bps through changes in expected short-term interest rates. In addition, Altavilla *et al*. (2021) use NIRP shocks identified from high-frequency data and note that NIRP had a strong lowering effect on the yield curve, particularly on the 5-year rate.

As research that employs finance theory, Lemke and Vladu (2017), for example, argue that the decline in the yield curve in the euro area in September 2014 could be partially explained by a decline in the lower bound of the interest rate that reflected a further policy rate cut, using a term structure model of interest rates that allows the lower bound of the nominal interest rate to change dynamically. Kortela (2016) also finds, based on an analysis using a term structure model of interest rates, that a decrease in the lower bound of interest rates could explain most changes in the 2-year rate since September 2014. In addition, Wu and Xia (2020) examine the impact of the ECB's NIRP on the yield curve using a term structure model of interest rates where market participants expect the lower bound of future interest rates to decline. They reported the estimates of the impact of NIRP on interest rates divided into the contribution of lower short-term interest rates and forward guidance.

Looking at studies for Japan, BOJ (2016) uses a time series model and points out that the impact of negative interest rates on long-term interest rates is estimated to be about -20bps to -30bps. It also notes that after the introduction of NIRP, the effect of lowering interest rates through the purchase of government bonds became stronger for

[7] Christensen (2019), on the other hand, points out that the background to such results is a subject for future analysis after showing that interest rates responded differently in different countries, with the yield curve in Switzerland and Sweden instead steepening after the introduction of NIRP.

longer maturities.[8] Ueno (2017) estimates a term structure model of interest rates and reported that the yield curve declined following the introduction of NIRP, mainly due to the contribution of the expected short-term interest rate component for short-term maturities and the term premium for long-term maturities. In addition, Suganuma and Yamada (2017) construct a model of option premiums that can be applied to negative interest rates and note that the distribution of market participants' expected short-term interest rates shifted into negative territory immediately after the introduction of NIRP.

3.2. Impact on the Yield Curve in Japan and Euro Area

To examine the impact of the introduction of NIRP on the yield curve, we first compare the changes in the yield curves of Japan and the euro area (Germany) before and after the introduction of negative interest rates. Using the term structure model of interest rates allows us to decompose the interest rate for each maturity into the "expected short-term interest rate component," which is calculated as the average forecasts of future short-term rates, and the "term premium," which is the other component. For the expected short-term interest rate component, we use the estimates by Krippner (2022) for various maturities.[9] Chart 7 shows that in both Japan and the euro area, the expected short-term interest rate component was lowered across a wide range of maturities immediately after the introduction of NIRP. Two months later, the decline in the term premium was observed in the long-term and super-long-term maturities. These observations suggest that after the introduction of NIRP, the expected short-term interest rate component declined, and that the term premium declined mainly for longer maturities through search for yield behavior among investors, as pointed out by previous studies.[10]

However, the above simple data observations do not take into account the effects exerted by other changes in the economic condition and do not formally identify the impact of NIRP. Therefore, in the following, we examine the impact of negative interest rates on the yield curve by local linear projection (Jordà, 2005). The data used is panel data of daily yield curves and monetary policy shocks reported by previous studies. The estimation equation is as follows:

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[8] See Nakazawa and Osada (2024) for a study analyzing the effect of large-scale government bond purchases on the formation of long-term interest rates in Japan.

[9] The data for the expected short-term interest rate component was downloaded from: https://www.ljkmfa.com/visitors/. The website provides the decompositions of the yield curve for seven jurisdictions (U.S., euro area, Japan, U.K., Canada, Australia, and New Zealand).

[10] Because of the large uncertainty in estimating the expected short-term interest rate component and term premium due to differences in models, the results should be interpreted with considerable latitude. Even so, we compared the expected short-term interest rate components and term premiums estimated by the model of Imakubo and Nakajima (2015) for Japan with the baseline results, and found no significant differences in our conclusions.

$$y_{t+h,i} - y_{t-1,i} = \alpha_{0,h}\Delta r_{t,i}^{NIRP} + \sum_{\tau=1}^{h} \alpha_{\tau,h}\Delta r_{t+\tau,i}^{NIRP} + \sum_{\tau=0}^{h} \theta_{\tau,h}\Delta r_{t+\tau,i}^{Others} + \eta_i + \eta_t + \epsilon_{t,\,t+h,\,i}, \quad (1)$$

where the subscript t indicates the time (daily), i is the country, and $\Delta r_{t,i}^{NIRP}$ is the NIRP shock. $\Delta r_{t,i}^{Others}$, η_i, and η_t represent other monetary policy shocks, fixed effects, and time fixed effects, respectively. They are used to control the effect of monetary policy other than NIRP, time-invariant country-specific factors, and time-variant factors that commonly affect all countries. We use the interest rates or term premiums for different maturities (2-, 5-, 10-, and 30- year) as y on the left hand side of Equation (1). $\alpha_{0,h}$ represents the impulse response of y to the NIRP shock.

The data sources are as follows. First, government bond interest rates by maturity for five countries (Japan, Germany, France, Italy, and Spain) are downloaded from Bloomberg.[11] The term premiums are calculated by subtracting the expected short-term interest rates estimated by Krippner (2022) from the nominal interest rates. The NIRP shocks are reported in Grisse *et al*. (2017). In their study, the NIRP shocks were calculated as the difference between the actually announced policy rate and experts' expectations when negative interest rates were introduced or when additional rate cuts were made. Other monetary policy shocks used as control variables are those originally reported in Kubota and Shintani (2022) for Japan and Altavilla *et al*. (2019) for the euro area. These shocks are transformed to be orthogonal to the NIRP shocks.[12] The estimation period is from the beginning of January 2014 to the end of December 2018.

Chart 8 illustrates the impulse response to a -10bp NIRP shock: (1) on the day of the NIRP announcement, and (2) 60 business days later. This shows that negative interest rates push down interest rates for a wide range of maturities, and that the magnitude is

[11] Due to data constraints related to the monetary policy shocks, our analysis focuses on Japan and the euro area. Analyzing the impact on the yield curve including other jurisdictions that have introduced NIRP is a subject for future work.

[12] Specifically, we obtained monetary policy shocks $\Delta r_{t,i}^{MP}$ measured as changes in long-term government bond futures for Japan and long-term German government bond rates for the euro area, standardized so that the mean is zero and the standard deviation is one. Next, we estimated $\Delta r_{t,i}^{MP} = a\Delta r_{t,i}^{NIRP} + c_i + \omega_{t,i}$ in OLS and calculated other monetary policy shocks that are orthogonal to the NIRP shocks as $\Delta r_{t,i}^{Others} = \Delta r_{t,i}^{MP} - \hat{a}\Delta r_{t,i}^{NIRP}$. Here, c_i, $\omega_{t,i}$, and $\hat{a}$ denotes a fixed effect, residuals, and the estimated parameter, respectively. Note that while previous studies reported monetary policy shocks identified by various market indicators, we supposed that asset purchases such as government bonds introduced by the BOJ and the ECB after the Global Financial Crisis had a significant effect on long-term interest rates. For this reason, we selected shocks measured as changes in long-term government bond futures for Japan and in terms of long-term German government bond rates for the euro area that represent other monetary policy shocks.

larger for longer maturities, suggesting a flattening of the yield curve. It also suggests that the impact of lowering interest rates remains not only on the day of the announcement, but also until 60 business days later. The impact of lowering interest rates through a decline in the term premium tends to be more pronounced for longer maturities, such as 30-year rates, and tends to be lagged to a certain extent. This result suggests that search for yield behavior toward relatively higher-yielding bonds was encouraged, which had the impact of lowering and flattening the entire yield curve.

It should be noted, however, that there is some uncertainty in the results of our analysis, given the limited number of NIRP events that we analyze. In addition, the impact on the yield curve may vary depending on the combination of other unconventional monetary policies, such as forward guidance, and the central bank's communication methods. Therefore, the results of the analysis in this paper should be viewed with considerable latitude.[13]

4. Impact on Lending

As discussed in Section 3, NIRP pushed down market interest rates for a wide range of maturities, both by lowering the effective lower bound on nominal interest rates and by encouraging search for yield behavior among investors. As a result, it is possible to assume the decline in market interest rates propagated to lending rates and stimulated the demand for funds by private economic entities. However, as for the transmission to the lending market, some research argues the possibility that financial intermediation activities are inhibited by the squeezed profitability of financial institutions (reversal interest rate mechanism).

In this section, we review Japanese and overseas studies on the impact of NIRP on lending rates and loans outstanding. Then, using financial statements of individual Japanese firms and financial institutions, we examine whether the introduction of NIRP caused a decline in lending, as assumed by the reversal interest rate mechanism.

4.1. Literature Review

(1) Mechanism of Encouraging Lending and Reversal Interest Rates

Basically, the policy rate cut entails lowered market interest rates and lending rates, and stimulates demand for funds by private economic entities. Through lowering yields,

[13] For example, Denmark and Switzerland introduced negative interest rates with the aim of responding to currency appreciation, which may have had a different impact on the yield curve from other countries that introduced negative interest rates to improve economic activity and achieve inflation targets.

it also reduces the incentive of financial institutions to hold current accounts at central banks and government bonds, which promotes rebalancing portfolios toward lending (Bernanke, 2016; Rostagno *et al*., 2019) and thereby boosts the economy and prices. In particular, some studies point out that the latter effect of portfolio rebalancing is strengthened under NIRP. For example, Altavilla *et al*. (2018a) and Eisenschmidt and Smets (2019) argue that, unlike when the policy rate was positive, financial institutions had a strong incentive to increase loan supply under NIRP because of the cost of holding excess reserves.

However, some studies point out a contractionary effect of NIRP. That is, when the policy rate falls below the reversal interest rate, financial institutions' profits are squeezed. This forces them to raise lending rates and reduce loan supplies, and thereby depresses the economy and prices (Chart 9). One of the representative studies in this field is Abadi *et al*. (2023). They develop a theoretical model in which, while a policy rate cut generates valuation gains on securities holdings, it reduces the lending-deposit interest margins of financial institutions through the mechanism whereby the negative interest rate is not fully transferred to the deposit rate under the existence of cash. Using this model, they point out that once the policy rate reaches a reversal interest rate, which is the level of the interest rate where net interest income declines more than the valuation gains on securities, financial institutions decrease loan supplies.[14] Eggertsson *et al*. (2023) also incorporate a mechanism by which applying negative interest rates to deposit rates is restricted in their theoretical model. They show that NIRP worsened financial institutions' profits, and financial institutions raised lending rates, which led instead to a contraction in economic activity. In addition, based on a theoretical model that assumes that the deposit rate does not fall below zero, Ulate (2021) highlights that NIRP was likely to lead to higher lending rates and lower lending through the capital losses of financial institutions, which in turn could deteriorate economic welfare.

However, there are several assumptions in these theoretical models for the sake of simplification. Specifically, Abadi *et al*. (2023) mention that their study abstracts from the impact of monetary easing on credit costs, the potential modifications of financial institutions' business models, and the possibility of applying negative interest rates on deposits, which could mitigate decreased earnings.[15] Eggertsson *et al*. (2023) point out

[14] Abadi *et al*. (2023) also analyze the mechanism by which the level of reversal interest rates increases when the low interest rate environment is prolonged, as securities held by financial institutions reach redemption and valuation gains become less effective in mitigating the effects of reduced net interest income.

[15] It is reported that in Europe, negative interest rates were actually applied to deposits, especially to corporate deposits (Eisenschmidt and Smets, 2019; Adolfsen and Spange, 2020; Boucinha and Burlon, 2020; Altavilla *et al*., 2022).

that their theoretical model dismissed transmission channels through exchange rates and asset prices, as well as the possibility of greater room for government to conduct fiscal policy. Ulate (2021) also states that his model eliminates the increase in financial institutions' valuation gains on securities, the decrease in credit costs, the encouraged search-for-yield behavior of financial institutions, and the reduction of the interest payment due to the tiered system for current accounts at central banks. He notes that in reality they might mitigate the negative impact of NIRP on financial institutions' profits.

As mentioned above, it can be seen that theoretical studies highlight both the positive and the negative impact of NIRP on lending. In the next section, we review overseas empirical studies on the impact of NIRP on lending.

(2) Empirical Analyses on Countries Other than Japan: Impact on Lending Rates

A number of empirical studies covering Europe reported that NIRP lowered lending rates. For example, Madaschi and Nuevo (2017) analyzed Sweden and Denmark, and found no significant differences in the response of mortgage and corporate lending rates to changes in policy rates (pass-through rates) before and after the introduction of NIRP. They argue that NIRP had the effect of lowering lending rates to the same extent as the conventional monetary policy. Horvath *et al.* (2018) and Eisenschmidt and Smets (2019) report similar results for the euro area, and Erikson and Vestin (2019) for Sweden.

On the other hand, while not necessarily denying the effect of lowering lending rates, a handful of studies suggested that the pass-through rates on lending rates declined after the introduction of NIRP. For example, Adolfsen and Spange (2020) report that the pass-through rates for corporate and households' loans in Denmark declined after the introduction of negative interest rates. However, they note that there was no significant tendency for banks with the higher deposit ratios to increase loan interest rates, and negative interest rates had the effect of decreasing lending rates. In contrast, Eggertsson *et al*. (2023) analyzed mortgage rates in Sweden and report that financial institutions with larger amounts of retail deposits relative to total assets tended to set higher interest rates after the introduction of NIRP. They point out that NIRP might lead instead to higher lending rates. Amzallag *et al*. (2019) report similar results using granular data on mortgage loans in Italy. Various empirical studies on the impact of NIRP on lending are summarized in Chart 10.

Overall, many empirical studies report that lending rates declined after the introduction of negative interest rates in line with the decrease in policy rates. However, a handful of studies also indicate that the pass-through rates to the policy rate declined. Some of these studies argue that the mechanism assumed by the reversal interest rate

mechanism might have materialized.

(3) Empirical Analyses on Countries Other than Japan: Impact on Loans Outstanding

Next, we review the empirical studies on the effects on loans outstanding. First, many previous studies suggest NIRP lowered lending rates (Chart 10). These declines in interest rates should have stimulated demand for funds by private economic entities and increased loans outstanding across the economy as a whole. One study that considers the impact on the whole economy is Rostagno *et al*. (2021), who estimate the respective impact on interest rates of NIRP, forward guidance, and asset purchase policy, using interest rate option premiums. They examine the effects on loans outstanding and the real economy by a counterfactual analysis using time series models. Their estimates show that NIRP increased loans outstanding and had a positive impact on the real economy.

On the other hand, many studies, mainly in Europe, focus on the heterogeneity of individual financial institutions to measure the impact of NIRP, and assess the validity of the reversal interest rate mechanism. These studies examine whether highly affected financial institutions reduced their lending. Specifically, these studies mainly use current account balances at the central bank, to which negative interest rates were applied, relative to total assets (excess reserve ratio) and deposits relative to total assets (deposit ratio) to identify the impact of NIRP.[16] For example, Basten and Mariathasan (2018) use panel data for banks in Switzerland and report that banks with higher excess reserve ratios (i.e., where the negative interest rate has a greater impact) increased their lending. Bottero *et al*. (2022) use granular data on loans to Italian firms and panel data of banks. They found that banks with shorter maturity of assets, and which were thereby more susceptible to lower yields (e.g., banks with a high liquid asset ratio), tended to increase lending after the introduction of negative interest rates. In addition, Demiralp *et al*. (2021) find that financial institutions in the euro area with a high deposit ratio and excess reserve ratio increased their lending, relative to other institutions. Schelling and Towbin (2022) report similar results for banks with a higher deposit ratio in Switzerland.

In contrast, some of the literature provides evidence that is consistent with the reversal interest rate mechanism, highlighting the fact that those financial institutions that were more affected by NIRP reduced their lending. For example, Heider *et al*. (2019) note that after the introduction of NIRP, financial institutions in the euro area with higher deposit ratios reduced their loans outstanding. Eggertsson *et al*. (2023) also conducted an analysis using panel data for Swedish financial institutions and found similar results. Arce

[16] Financial institutions that rely more on deposit funding than on market funding are assumed to be more affected by the decline in margins due to the existence of a zero lower bound on deposit rates.

et al. (2023) show that lending growth was relatively low for financial institutions that reported a larger impact of NIRP on their earnings. They also argue that this trend was not seen before deposit rates reached the zero lower bound.[17]

To sum up, an overview of the empirical studies for Europe suggests that lending increased across the economy as a whole. However, focusing on the heterogeneity of individual financial institutions, the results in the literature are mixed; that is, some research claims NIRP decreased lending, as implied by the reversal interest rate mechanism, while others argue that this mechanism did not materialize.

(4) Empirical Analyses on Japan

Research focusing on the impact of NIRP on lending rates in Japan is limited relative to that for Europe, but one such example is BOJ (2016), which reports that the pass-through rate to policy rates for lending rates, corporate bond rates, and other interest rates after the introduction of NIRP was about the same as the average during past interest rate cut episodes. In contrast, Hausman *et al*. (2019) point out that the short-term prime rate, which was the reference rate for floating-rate loans in Japan, did not change after the introduction of NIRP. They argue that NIRP did not lead to a decrease in the interest burden of existing mortgage-holding households (Chart 10).

Regarding the impact on loans outstanding, NIRP seems to have contributed to an increase in lending across the country as a whole, since lower lending rates should have stimulated demand for funds by private economic entities. Hirata *et al*. (2024b) use a time series model and conclude that various unconventional monetary policies over the past decades in Japan, including NIRP, lowered lending rates and increased loans outstanding, although this study does not focus solely on NIRP. Similarly, Abe *et al*. (2024) use the BOJ's Financial Macro-econometric Model (FMM) and show that the decline in market interest rates due to large-scale monetary easing, including NIRP, contributed to lower lending rates and increased lending.

On the other hand, studies focusing on the heterogeneity of individual financial institutions, as in Europe, show results both consistent and inconsistent with the reversal interest rate mechanism. For example, one study that is not consistent with the reversal interest rate mechanism is Hong and Kandrac (2021). They use an event study approach that assumes that banks that experienced a larger decline in their own stock prices immediately after the introduction of NIRP were those that experienced greater

[17] Some empirical studies examine the impact of NIRP on the quality of loans. For example, Heider *et al*. (2019) report that financial institutions with higher deposit ratios increased their lending to riskier firms after NIRP.

downward pressure on earnings due to negative interest rates, and reports that these banks increased their lending more than others. Shikimi (2023) reports that after the introduction of negative interest rates, banks with lower capital adequacy ratios and more liquid asset increased their lending to riskier firms. She points to the possibility that financial institutions pursued higher-yielding loans due to the lower bound constraint on deposit rates. In contrast, there are studies that show consistent results with the reversal interest rate mechanism. Gunji (2024) tries to identify banks with negative interest rates under certain assumptions. He found that banks with negative interest rates reduced loans more than others. Similarly, using granular data on lending by listed firms, Nakashima and Takahashi (2021) use the same identification strategy and argue that banks with negative interest rates experienced a relative decline in lending after the introduction of NIRP.

As discussed above, while the number of empirical studies on Japan is limited relative to Europe, many of them suggest a decrease in lending rates and an increase in loans outstanding for the country as a whole. However, studies focusing on the heterogeneity of financial institutions report both an increase and a decrease in lending by financial institutions highly affected by NIRP. There is room for further empirical analysis.

4.2. Impact on Lending in Japan

In this section, following previous studies, we use the difference-in-differences methodology (DID) [18] and examine whether lending declined more for financial institutions highly affected by NIRP.[19] The impact of NIRP is identified as the potential impact on earnings of individual financial institutions due to the existence of the zero lower bound on deposit rates. The unique feature of our analysis is combining the financial statements of firms (nonfinancial firms) widely surveyed by Teikoku Databank with the financial statements of related financial institutions. This dataset allows us to analyze lending for not only large firms but also small- and medium-sized firms, while controlling for characteristics of financial institutions and firms that could affect loan demand and supply.

(1) Identification

In our analysis, the "deposit ratio" before the introduction of NIRP is used to measure

[18] DID is a method of estimating the effect of an intervention by comparing the difference in means of the outcome for the treatment group (the group that received the policy intervention) and the control group (the group that did not receive the policy intervention) before and after the policy intervention. It is assumed that the results of the treatment and control groups include the common effect of the change in time, and that only the treatment group includes the effect of the intervention.

[19] The financial institutions analyzed in this paper are banks and *shinkin* banks.

the impact on the profitability of financial institutions. This indicator has been widely used as a proxy to evaluate the impact of the introduction of NIRP on bank earnings in many empirical studies, mainly in Europe (Chart 10).[20]

The deposit ratio is the amount of deposits ($Deposit$) divided by total assets (TA). The data is as of March 2015 (before the announcement of NIRP) to address the endogeneity. The deposit ratio is defined as follow:

$$Share_b^{Deposit} = \frac{Deposit_b}{TA_b}.$$

Previous studies indicate that financial institutions with a higher ratio of deposit funding are more likely to be affected by negative interest rates due to the existence of the zero lower bound on deposit rates. In fact, Chart 11 suggests that the deposit interest rate showed little movement following the introduction of negative interest rates, unlike market and lending rates. Therefore, the higher deposit ratio would suggest negative interest rates had a larger negative impact on the profitability of financial institutions. The distribution of deposit ratios among Japanese financial institutions is shown in Chart 12.

Before the estimation, we briefly observe the relationship between the deposit ratio and the loans outstanding using the raw data. Chart 13 compares the median values of the growth rate of loans outstanding for two groups of financial institutions: one consisting of financial institutions with deposit ratios above the median, and the others. This chart suggests that while both groups showed roughly the same developments before the introduction of NIRP, the group with a higher deposit ratio experienced a higher growth rate in loans outstanding after the introduction of NIRP. Note that we find the difference in the growth rate of loans outstanding between the two groups is statistically significant after the introduction of negative interest rates, which supports the finding that financial institutions with higher deposit ratios increased their lending. However, these raw data observations do not control the omitted variables that can affect the loan demand and supply by firms and financial institutions. Therefore, in the following sections, we control factors other than the deposit rate and examine the impact of NIRP on lending.

[20] Another indicator used for identification in previous studies is the "excess reserve ratio" at the time of policy introduction. As seen in Section 2, in Japan, the policy-rate balance to which negative interest rates are applied is the current account balance at the BOJ minus the "basic balance" and the "macro add-on balance" as of the time before the policy was introduced. Therefore, from the perspective of measuring the degree of impact of NIRP, it should be noted that the "excess reserve ratio" cannot take into account the impact of "macro add-on balances." In light of this point, this paper uses the "deposit ratio," which has been widely used in previous studies, as an indicator of the degree of impact of NIRP.

(2) Empirical Model

In this paper, we identify the impact of NIRP by the deposit ratio and use DID to estimate the impact of NIRP on lending. The empirical model to be estimated is shown below. Our identification assumption is the parallel trend assumption that the deposit ratios were randomly distributed independent of lending growth, and that the trend before the policy intervention was the same for both the treatment and control groups.

$$\Delta Loan_{t,b,f} = \beta\left(Share_b^{Deposit} \times AfterNIRP_t\right) + \gamma_{b,f} + \gamma_{size_f,industry_f,t} + \sum \delta_n X_{n,t-1} + u_{t,b,f.} \quad (2)$$

In Equation (2), the subscript t denotes the time, b denotes the financial institution, and f denotes the firm. $\Delta Loan_{t,b,f}$ indicates the year-on-year change in borrowings of firm f that has a business relationship with financial institution b. $AfterNIRP_t$ is the dummy variable which equals to 1 after the introduction of NIRP and 0 otherwise. $\gamma_{b,f}$ describes the fixed effect of the pair of financial institution and firm to capture the time-invariant effect between financial institutions. $\gamma_{size_f,industry_f,t}$ is the time fixed effect combining the size of the firm and the industry to which the firm belongs to capture the time-variant effects for the firm size and industry.[21] The time fixed effects by firm size and industry is particularly important to control the loan demand by firms because the loan demand is expected to be affected by various factors specific to the firm size and industry over time. $X_{n,t-1}$ is other variables to control the loan demand and supply. These control variables consist of the financial institution's total assets (log), capital ratio,[22] and non-performing loan ratio and the firm's leverage ratio (borrowings/TA), ROA (EBITDA/TA), and cash and deposits ratio (cash and deposits/TA). In Equation (2), if the parameter β, which captures the impact of negative interest rates, is negative and significant, then it suggests the possibility that financial institutions that were more affected by NIRP decreased their lending and the reversal interest rate mechanism had materialized.[23]

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[21] The size of firms is classified as large (capital of 1 billion yen or more), medium (100 million yen to 1 billion yen), or small (less than 100 million yen). Industries are classified into 12 categories, including construction and manufacturing, based on the Teikoku Databank's categories. The results did not change significantly when the industry was further subdivided into smaller categories.

[22] Because the regulation of capital adequacy ratios differs between internationally active banks and domestic banks in Japan, we control the impact of the different calculation method by separately estimating the parameters using a dummy variable that takes 1 when the financial institution is an internationally active bank and 0 otherwise.

[23] The term for the deposit ratio alone is not used on the right-hand side because using fixed effects

The data sources are as follows. Financial statements of firms and the name of related financial institutions are from Teikoku Databank, and the rest is from Bloomberg. The Teikoku Databank database provides the names of related financial institutions for each firm. Our analysis rests on the assumption that the aggregate borrowings of the firm are supplied by these financial institutions.[24] The estimation period spans three years before and after the introduction of negative interest rates (FY2013-FY2018).

(3) Estimation Results

Chart 14 shows the estimation results of Equation (2). Column (a) and (b) show that the parameter β is positive and significant, suggesting that firms which had a business relationship with more affected financial institutions increased their borrowing. In column (c) and (d), the parameter β is estimated for each fiscal year by creating a cross term with a dummy variable for each year. The result shows that the parameters β are positive and significant after fiscal 2016. The fact that the parameters are not significant for years before the introduction of NIRP also confirms that the parallel trend assumption in the DID is satisfied.

The results of our analysis suggest that the reversal interest rate mechanism, which leads to a decrease in lending through a squeeze on the earnings of financial institutions, has not materialized. This result is consistent with those of Demiralp *et al*. (2021) for the euro area and Schelling and Towbin (2022) for Switzerland.

One of the reasons why lending did not decline even after the introduction of NIRP is that the "three-tier system" on current accounts at the BOJ was concurrently introduced to mitigate the direct negative impact on financial institutions' profits, and financial institutions actively used this system. As highlighted in Section 2, current account balances held by financial institutions at the BOJ were divided into three tiers under NIRP: the basic balance to which the plus 0.1% interest rate was applied, the macro add-on balance to which 0% was applied, and the "policy-rate balance" to which minus 0.1% was applied, and the policy-rate balance was limited to a small portion of financial institutions' current account balances at the BOJ as a whole. Under these circumstances, financial institutions were able to raise the limit on their macro add-on balances by using a facility in which the BOJ passively provides loans to financial institutions on request in exchange for eligible collateral (so called "lending facility"), such as the Fund-

and the deposit ratio at the same time would make the system singular.

[24] For firms with two or more related financial institutions, the dataset is constructed so that the borrowings of those firms are repeated. In this regard, the result and its implication did not change significantly when the repetition of the data was not allowed.

Provisioning Measure to Stimulate Bank Lending.[25] This may have created an incentive to increase lending and use the Fund-Provisioning Measure to Stimulate Bank Lending to reduce policy rate balances, for example.[26]

Note that although our approach is a micro analysis focusing on the heterogeneity of financial institutions, overall lending by financial institutions has also continued to increase during this period. One of the reasons why overall lending has continued to increase is that various actions taken by financial institutions to improve their profitability and the improvement of the real economy have contributed to sustaining their earnings through increased non-interest income and other profits. That is, while lower interest rates due to monetary easing put downward pressure on financial institutions' net interest income through a decline in lending-deposit interest margins, the improvement in the economic environment resulting from monetary easing improved credit costs and other factors, preventing the deterioration of financial institutions' profits (Altavilla *et al*., 2018b; Lopez *et al*., 2018; Boucinha and Burlon, 2020). Although it should be noted that the focus of their analysis is not limited to negative interest rates, Abe *et al*. (2024) use a large macro model (Financial Macro-econometric Model; FMM) to show that the BOJ's monetary easing over the past 25 years has encouraged a decline in credit costs and supported financial institutions' profits through an improved economic environment. In relation to the micro analysis, it is possible that this macroeconomic condition may have contributed to maintaining the risk-taking capacity of financial institutions.

5. Conclusion

In this paper, we examine the impact of NIRP on interest rate formation in financial markets and lending by financial institutions in Japan through a review of the literature and through empirical analyses.

First, regarding the impact on interest rate formation in financial markets, a review of the literature suggests that NIRP affects interest rates in long-term maturities by lowering market expectations of the lower bound of the interest rate and future policy rates, in addition to directly affecting the short-term interest rate through changes in the

[25] This measure was introduced in December 2012 and provides financial institutions with funds up to the amount calculated based on the net increase of loans on request. The purpose of the measure is to promote financial institutions' aggressive action and help increase the proactive credit demand of firms and households. For an overview and the impact of the measure, see Hirata *et al*. (2024a).

[26] With regard to the institutional design, similar points have been highlighted in theoretical studies on the reversal interest rate mechanism. Ulate (2021), for example, points out that the tiered system for current accounts at central banks may have mitigated the side effects of negative interest rates, and Abadi *et al*. (2023) also argue that the ECB's lending facility may have eased the deterioration of profits of financial institutions.

policy rate. It is also implied that NIRP reduces the incentive for financial institutions to hold current accounts at central banks and encourages shifts in demand to higher-yield assets. This would exert downward pressure on government bond yields especially in long-term and super-long-term maturities. The review of empirical analyses suggests that the introduction of NIRP had the effect of pushing down the entire yield curve, including not only short-term interest rates but also long-term interest rates. Our empirical analysis of Japan and the euro area shows that NIRP led to a decline in short-term interest rates and the effect of lowering interest rates is significant for longer maturities, as pointed out in previous studies.

Next, with regard to the impact on lending by financial institutions, many previous studies reported that the decline in market interest rates led to a decline in lending rates as well. It can be concluded that that the decline in lending rates stimulated demand for funds by private entities, and thereby increased lending in the economy as a whole. On the other hand, theory suggests that negative interest rates will decrease financial institutions' profits, and thereby reduce loan supplies. A review of empirical analyses suggests that there is an increase in lending across the country as a whole. However, focusing on the heterogeneous impact on individual financial institutions, some studies claim a decrease in loan supplies, as assumed in the reversal interest rate mechanism, while other studies argue that this has not emerged. It seems that no consensus has been reached.

In this regard, our empirical analysis on Japan does not confirm the tendency that the greater the impact of NIRP on financial institutions, the greater the decline in lending, when the adverse impact of NIRP is identified using the deposit ratio. The result has been influenced by factors including the fact that the introduction of NIRP was accompanied by institutional designs such as a three-tiered system for current accounts at the BOJ, as well as improvements in the real economy, which may have mitigated the impact on financial institutions' profits and maintained their risk-taking capacity.

Some caveats should be noted regarding the results of our empirical analysis. First, the impact of NIRP on market interest rate formation may vary depending on the combination of forward guidance, large-scale asset purchase policies, and other policy measures. Second, the impact on the lending behavior of financial institutions also depends on the management actions and earnings conditions of financial institutions at the time of the policy introduction. Therefore, the results of the analyses should be interpreted with some latitude. In addition, this paper does not consider the impact on the quality of loans, which is also an important issue when considering the impact on the financial system as well as the economy. It will be necessary to continue to deepen our analyses of the impact of NIRP on the economy in various economic and financial

conditions, such as the earnings environment surrounding financial institutions.

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Chart 1: Overview of the Three-Tier System

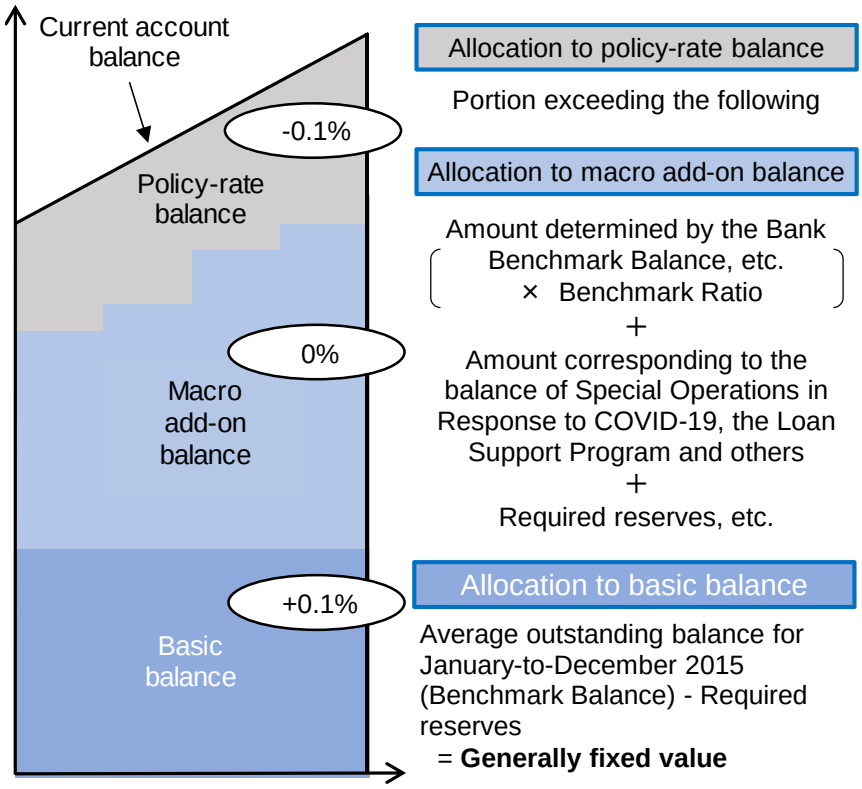
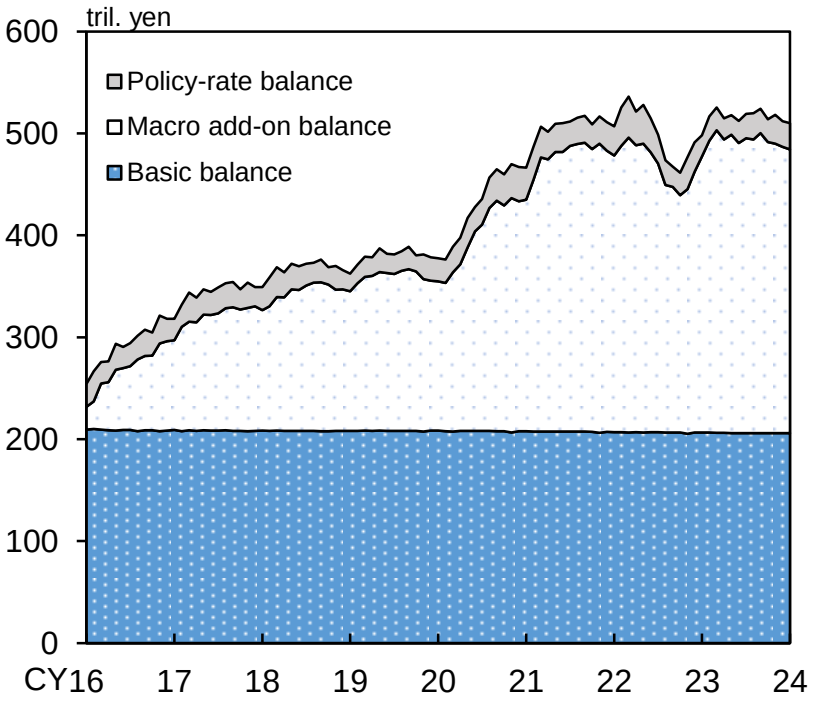
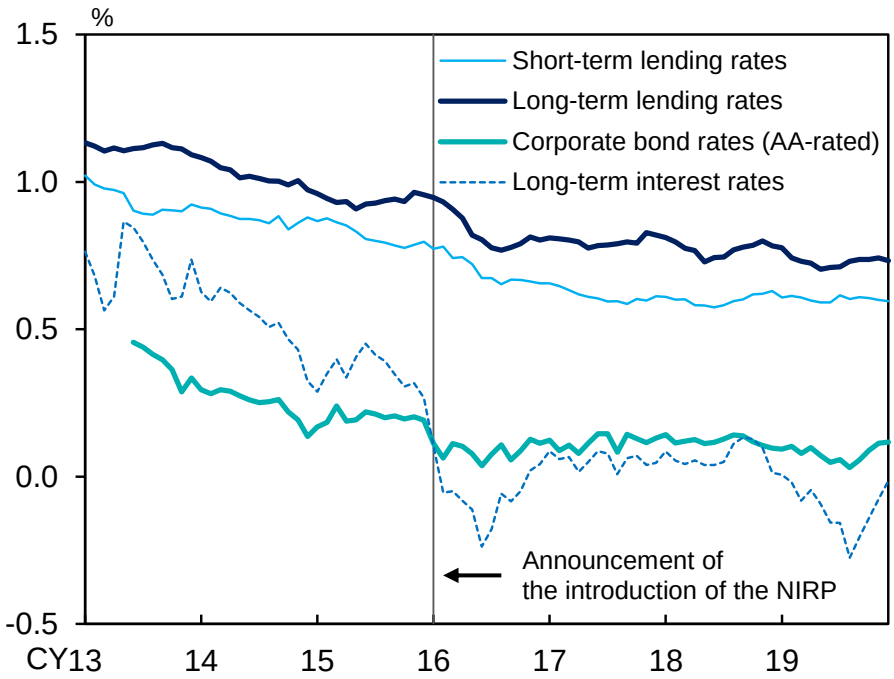


Chart 2: Changes in Current Account Balance at the Bank



Source: Bank of Japan.

Chart 3: Changes in Interest Rates



Note: Figures for short-term lending rates and long-term lending rates indicate average contract interest rates on new loans and discounts (6-month backward moving averages). Figures for corporate bond rates (AA-rated) are the average yields of AA-rated corporate bonds with remaining maturity of 4-5 years.
Sources: Ministry of Finance; Bank of Japan; Japan Securities Dealers Association.

Chart 4: Transmission Channels of NIRP

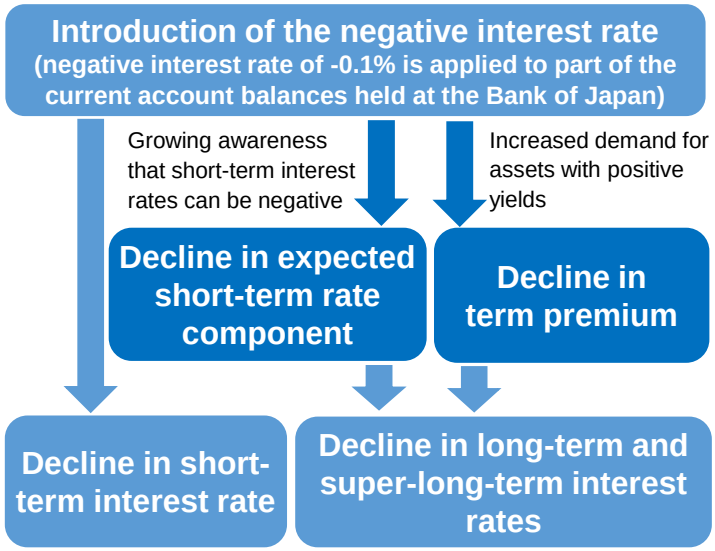
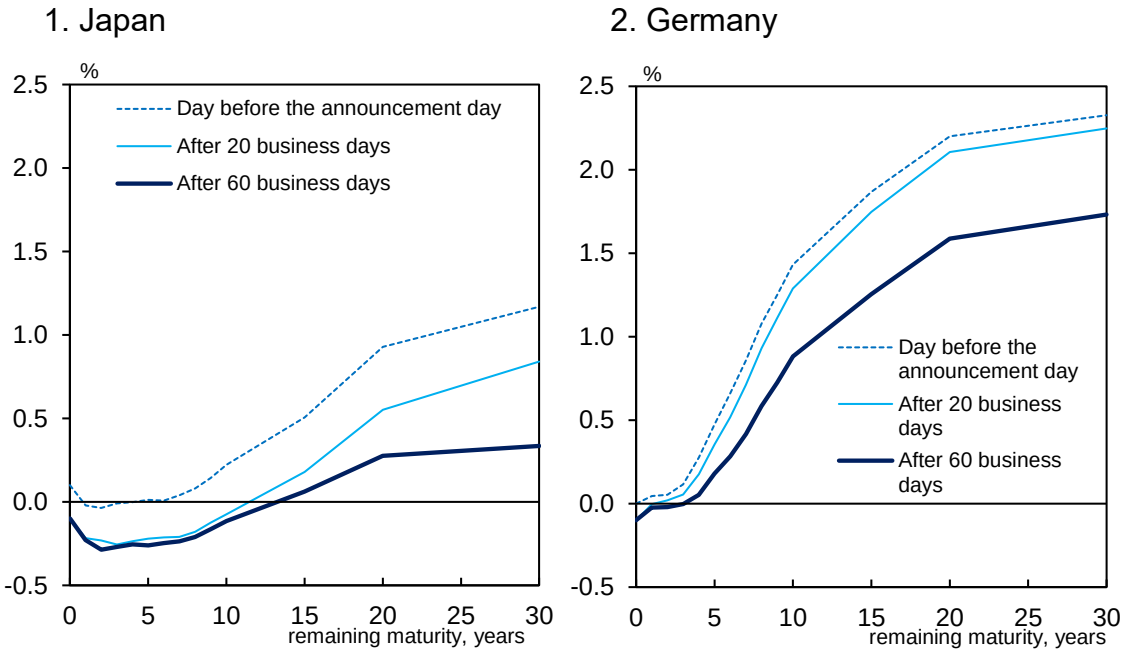


Chart 5: Changes in the Yield Curve before and after Introduction of NIRP

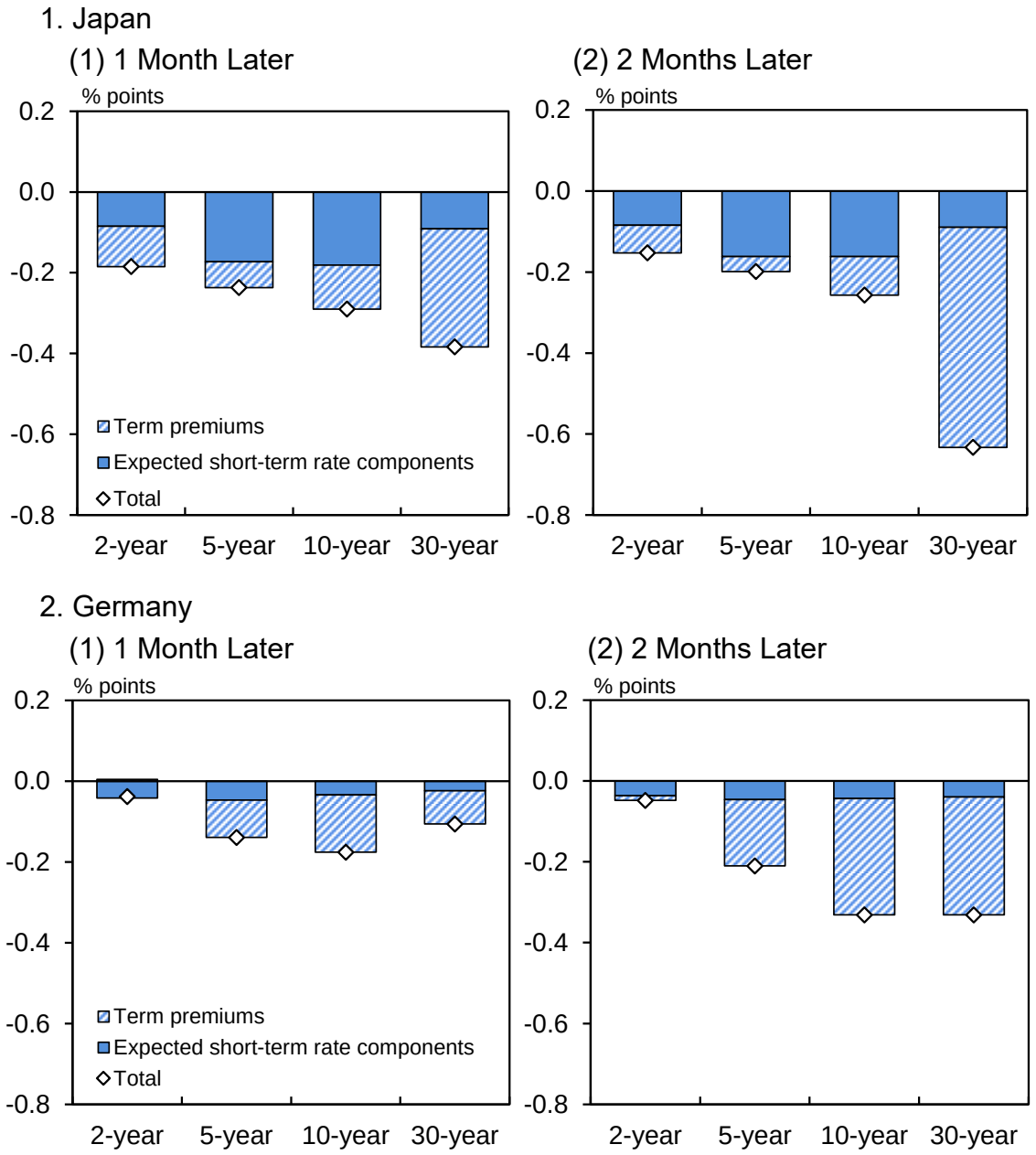


Note: The short ends of the yield curves are the announced policy rates.
Source: Bloomberg.

Chart 6: List of Previous Studies on the Impact of NIRP on Interest Rates

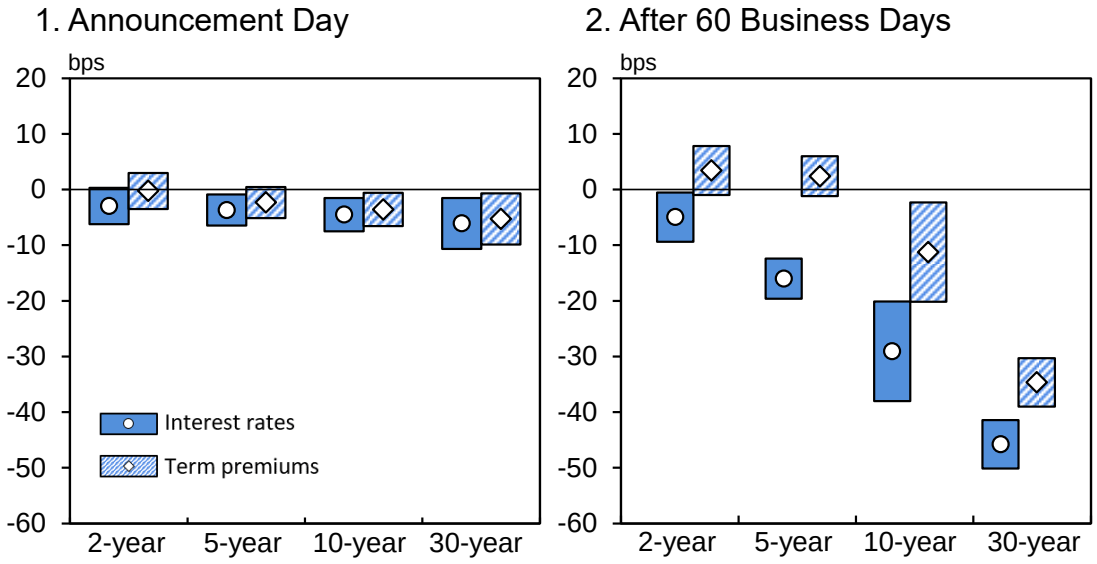
Area	Authors	Method of Analysis	Impact of NIRP			
			Differences in Effects between Maturity Years	Long-term Interest Rates	Expected Short-term Interest Rate Components	Term Premiums
Euro Area Denmark Switzerland Sweden Japan	Arteta *et al*. (2016)	Comparison before and after the introductions of NIRP	Decline in the spreads between short- and long-term interest rates (Euro Area, Denmark, and Japan)	Decline in long-term interest rates	Decline in expected short-term interest rate components (Euro Area and Japan)	
	Christensen (2019)	Comparison before and after the introductions of NIRP	Flattening yield curves (Euro Area, Denmark, and Japan)	Decline in long-term interest rates with a lag		
Euro Area Denmark Switzerland Sweden Japan ＋US etc.	Grisse *et al*. (2017)	Difference between market participants' expectations of policy rates and actuals		Introductions of NIRP push down long-term interest rates in other countries		
Euro Area	Bech and Malkhozov (2016)	Comparison before and after the introduction of NIRP		Decline generally in line with short-term market rates		
	Kortela (2016)	Estimating the lower bound of short-term interest rates using a term structure model of interest rates	The impact of declining the lower bound of interest rates is large for the 2-year rate and partial for the 10-year rate	Decline in lower bound of interest rate explains some of the decline in 10-year rates		
	Lemke and Vladu (2017)	Estimating the lower bound of short-term interest rates using a term structure model of interest rates	Decline mainly in short-term interest rates	Decline in lower bound of interest rates partially pushes long-term rates down	Decline in expected short-term interest rate components	
	Rostagno *et al*. (2019)	1. Estimating market participants' expectations of short term interest rates using interest rate option prices 2. Conducting a counterfactual analysis (without NIRP) using a time-series model and the changes in the expected short-term interest rates, estimated in above process	Decline in overall yield curve	Decline in long-term interest rates	Decline in expected short-term interest rate components	
	Boucinha and Burlon (2020)	1. Estimating market participants' expectations of short-term interest rates using interest rate option prices 2. Conducting a counterfactual analysis (without NIRP) using a time-series model and the changes in the expected short-term interest rates, estimated in above process	Decline in overall yield curve	Decline in long-term interest rates	Decline in expected short-term interest rate components	
	Wu and Xia (2020)	Estimating the market participants' expectations of lower bound of short-term interest rates using a term structure model of interest rates	Decline mainly in 2-year interest rates	1. Decline in long-term interest rates 2. Further decline when combined with forward guidance	Decline in expected short-term interest rate components	
	Altavilla *et al.* (2021)	1. Using high frequency data, identifying NIRP shocks 2. Estimating market participants' expectations of short term interest rates using interest rate option prices	Decline mainly in 5-year interest rates	Decline in long-term interest rates	Decline in expected short-term interest rate components	
Germany Switzerland Japan	Ueno (2017)	Decomposing interest rates into expected short-term interest rate components and term premiums using a term structure model of interest rates and compare before and after the introduction of NIRP		Decline in long-term interest rates	Decline in expected short-term interest rate components, mainly in the short-term interest rates	Decline in term premiums, mainly in the medium- to long-term interest rates
Japan	Bank of Japan (2016)	Comparison before and after the introduction of NIRP Assessing the impacts on interest rates using time-series models	The longer the maturity, the lower the interest rate	Decline in long-term interest rates		
	Suganuma and Yamada (2017)	Estimating the market participants' expectations of lower bound of short-term interest rates using interest rate option prices			The distribution of expected short-term interest rates shifted into negative territory after NIRP	
	Yoshino *et al*. (2017)	Comparison before and after the introduction of NIRP	The longer the maturity, the lower the interest rate	Decline in long-term interest rates		

Chart 7: Sources of Changes in the Yield Curves



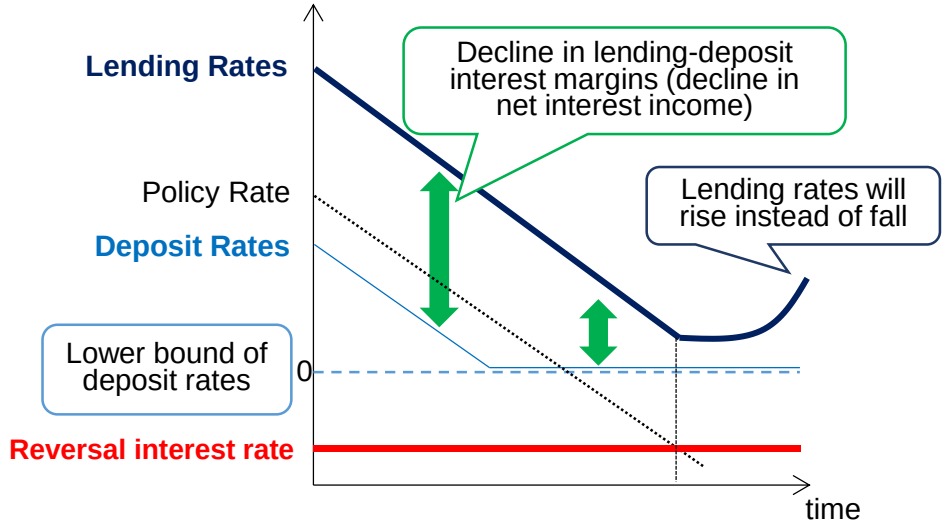
Note: Figures show the changes from the day before the announcement of the introduction of NIRP.
Sources: Bloomberg; LJKmfa.

Chart 8: Impulse Responses to an NIRP shock



Note: The points represent the cumulative impulse responses of interest rates and term premiums for each maturity (2-, 5-, 10-, and 30-year) to a -10 bps NIRP shock. The shaded areas indicate the 90 percentile bands.
Sources: Bloomberg; LJKmfa.

Chart 9: Overview of the Reversal Rate Mechanism



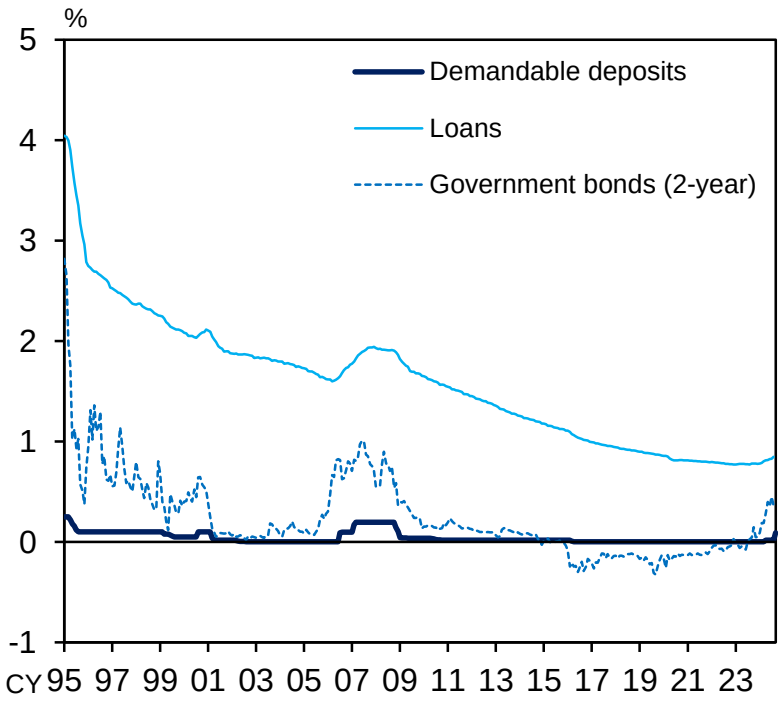
Note: The figure briefly summarises how the reversal rate is realized. Specifically, the following mechanisms are assumed. (1) When the policy rate is lowered to negative territory, lending rates fall, while (2) deposit rates do not fall sufficiently. This causes financial institutions' lending-deposit interest margins to shrink. As a result, (3) when the policy rate falls below a certain level (reversal interest rate), financial institutions raise lending rates in order to secure their lending-deposit interest margins. Therefore, in this setting, NIRP is assumed to have a contractionary effect on the economy and prices.

Chart 10: List of Previous Studies on the Impact of NIRP on Lending

Areas	Authors	Method of Identification	Impact of NIRP		
			Lending Rates	Loans Outstanding	Quality of Loan
Euro Area	Altavilla *et al*. (2018a)	Impact on profits reported by banks		Banks that answered the larger impact on profits showed the higher loan growth rate.	
	Horvath *et al*. (2018)	Post NIRP dummy	Pass-through rates of lending rates were unchanged before and after NIRP.		
	Amzallag *et al*. (2019)	Deposit ratio	Banks with the higher deposit ratio increased the fixed mortgage rate more. No significant relationship between deposit ratios and floating mortgage rates.		Banks with the higher deposit ratio increased supply of mortgages with floating rates more rather than fixed rates.
	Eisenschmidt and Smets (2019)	Deposit ratio Post NIRP dummy	Banks with the higher deposit ratio lowered the lending rates more. Pass-through rates of lending rates were unchanged before and after NIRP.	Banks with the higher deposit ratio showed the higher loan growth rate.	
	Heider *et al*. (2019)	Deposit ratio		Banks with the higher deposit ratio showed the lower loan growth rate.	Banks with the higher deposit ratio increased lending to firms with high credit risk.
	Tan (2019)	Deposit ratio	No tendency for banks with the higher deposit ratios to set higher loan spreads.	Banks with the higher deposit ratio showed the higher loan growth rate.	
	Bittner *et al.* (2020)	Deposit ratio			Banks with the higher deposit ratio increased lending to riskier firms.
	Demiralp *et al*. (2021)	Deposit ratio Excess reserve ratio		Banks with the higher deposit or excess reserve ratios showed the higher loan growth rate.	
	Bottero *et al.* (2022)	Net interbank position Liquid asset ratio	Banks with the larger interbank position or higher liquid asset ratio decreased the lending rates more.	Banks with the larger interbank position or higher liquid asset ratio showed the higher loan growth rate.	Banks with the larger interbank position or higher liquid asset ratio increased lending to firms with high credit risk.
	Grandi and Guille (2023)	Deposit ratio		Banks with higher deposit ratio showed the higher loan growth rate.	Banks with the higher deposit ratio increased lending to small and medium-sized firms.
	Arce *et al*. (2023)	Impact on profits reported by banks	No tendency for banks that answered a greater impact on profits to set higher lending rates.	Banks that answered greater impact on profits showed the lower loan growth rate.	Banks with the lower capital ratio and that answered greater impact on profits decreased lending to firms with high risk.
Euro Area Japan	Lopez *et al.* (2018)	Deposit ratio		Banks with the higher deposit ratio increased the ratio of loans outstanding to total assets more.	Banks with the higher deposit ratio increased the ratio of non-performing loan to total assets.
Switzerland	Bech and Malkhozov (2016)	Comparison before and after the introduction of NIRP	Mortgage rates rose after NIRP.		
	Basten and Mariathasan (2018)	Excess reserve ratio	Banks with the higher excess reserve ratio increased mortgage rates more.	Banks with the higher excess reserve ratio showed the higher loan growth rate.	
	Schelling and Towbin (2022)	Deposit ratio	Banks with the higher deposit ratio decreased spread in lending.	Banks with the higher deposit ratio showed the higher loan growth rate.	Banks with the higher deposit ratio relaxed the loan terms and conditions (lending volume per loan, fees, etc.) Relaxation in loan terms and conditions were more pronounced for higher-risk firms.
Sweden	Erikson and Vestin (2019)	Comparison before and after the introduction of NIRP	Pass-through rates of corporate lending rates were unchanged before and after NIRP. Pass-through rates of mortgage rates declined.		
	Eggertsson *et al*. (2023)	Deposit ratio	Banks with the higher deposit ratio showed the decrease in pass-through rates of mortgage rates.	Banks with the higher deposit ratio showed the lower loan growth rate to households.	
Denmark	Adolfsen and Spange (2020)	Post NIRP dummy Deposit ratio	Pass-through rates of lending rates declined after NIRP. No tendency for banks with the higher deposit ratio to set higher lending rates.	No tendency for banks with a higher deposit ratio to decrease the loans outstanding more.	
Sweden Denmark	Madaschi and Nuevo (2017)	Post NIRP dummy	Pass-through rates of lending rates were unchanged before and after NIRP.		
Japan	Bank of Japan (2016)	Comparison before and after the introduction of NIRP	Pass-through rates of lending rates were similar to that in previous episodes of policy interest rate cuts.		
	Hausman *et al*. (2019)	Comparison before and after the introduction of NIRP	Short-term prime rate did not decline.		
	Hong and Kandrac (2021)	Changes in financial institution' stock price (high frequency data)		Banks with the larger fall in its stock price showed the higher loan growth rate.	Banks with the larger fall in its stock price showed the higher long-term loan growth rate.
	Nakashima and Takahashi (2021)	Policy-rate balance ratio		Banks with a positive policy-rate balance ratio had a relative decrease in loans outstanding.	Banks with a positive value of the policy-rate balance ratios relatively decreased lending to riskier firms.
	Shikimi (2023)	Post NIRP dummy			Banks with the lower capital ratio and more liquidity increased lending to riskier firms.
	Gunji (2024)	Policy-rate balance ratio		Banks with a positive policy-rate balance ratio had a relative decrease in loans outstanding.	

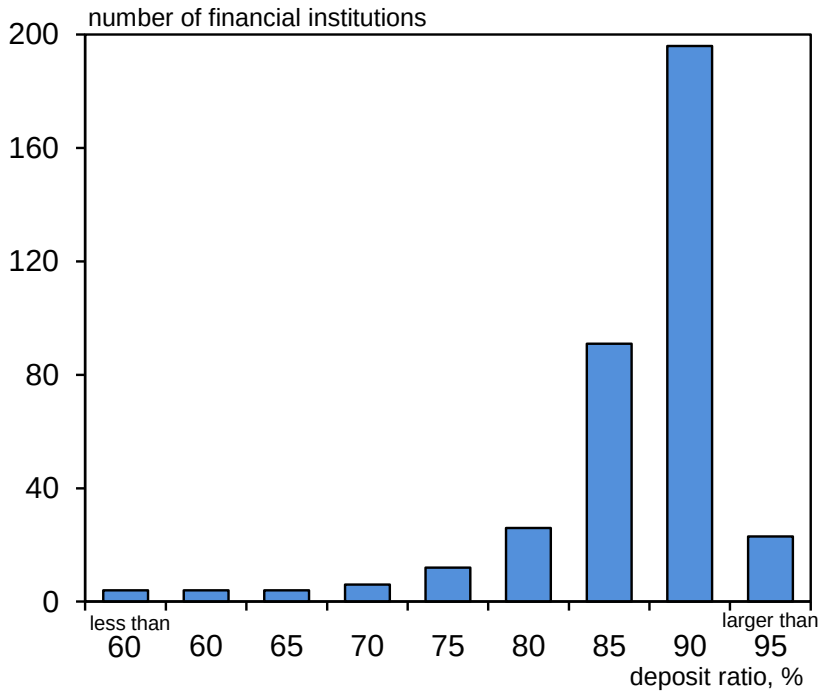
Note: Prepared by authors following Tenreyro (2021). Red text in the "Lending Rates" column indicates studies that pointed out that the pass-through rates did not change or lending rates decreased after NIRP (green text indicates the opposite). Red text in the "Loans Outstanding" column indicates studies that noted an increase in loans outstanding (green text indicates studies that pointed to a decrease).

Chart 11: Changes in Deposit Rates



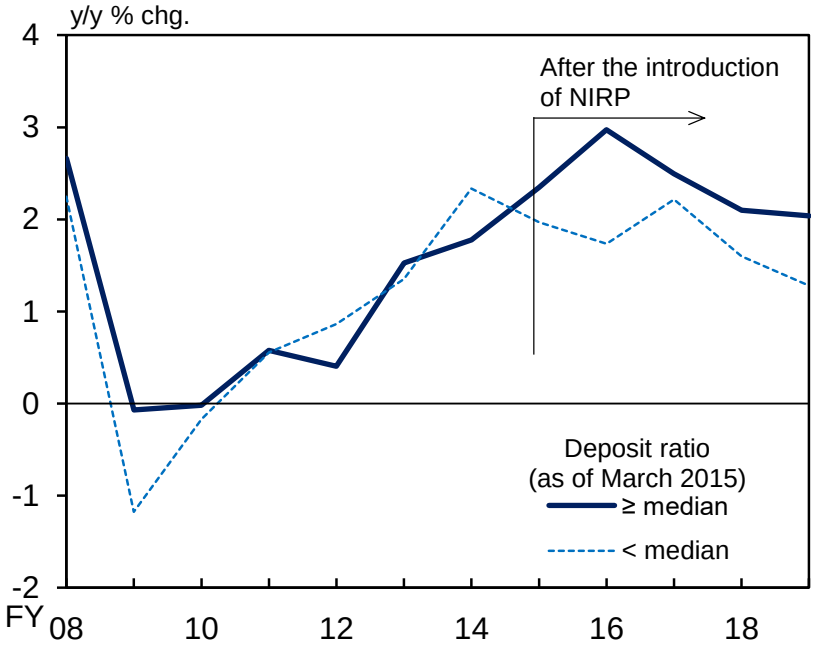
Sources: Ministry of Finance; Bank of Japan.

Chart 12: Distribution of Deposit Ratio as of March 2015



Source: Bloomberg.

Chart 13: Changes in Loans Outstanding



Note: The figures show the median value of growth rate of loans outstanding within each group, after classifying financial institutions based on the level of deposit ratios.
Source: Bloomberg.

Chart 14: Estimation Results

	Dependent variable: Total borrowings (y/y)			
	a	b	c	d
Deposit ratio				
×Post NIRP dummy	0.012 ***	0.012 ***	-	-
	[0.003]	[0.003]		
×2014 fiscal year dummy	-	-	-0.001	-0.001
			[0.004]	[0.004]
×2015 fiscal year dummy	-	-	0.005	0.006
			[0.005]	[0.005]
×2016 fiscal year dummy	-	-	0.014 ***	0.014 ***
			[0.005]	[0.005]
×2017 fiscal year dummy	-	-	0.013 ***	0.013 ***
			[0.004]	[0.005]
×2018 fiscal year dummy	-	-	0.012 **	0.016 ***
			[0.005]	[0.005]
Financial institution control				
Total assets	-	0.072	-	0.121
		[0.003]		[0.334]
Capital ratio	-	-0.024	-	-0.022
		[0.023]		[0.023]
×Internationally active banks dummy	-	0.051 *	-	0.052 *
		[0.028]		[0.028]
Non-performing loan ratio	-	-0.013	-	-0.012
		[0.017]		[0.017]
Firm control				
Leverage ratio	-	0.048 **	-	0.048 **
		[0.024]		[0.024]
ROA	-	0.012 ***	-	0.012 ***
		[0.004]		[0.004]
Cash holding ratio	-	-0.111 ***	-	-0.111 ***
		[0.003]		[0.003]
Financial institution×Firm fixed effect	Yes	Yes	Yes	Yes
Firm size×Industry×Time fixed effect	Yes	Yes	Yes	Yes
Adj. R^2	0.10	0.10	0.10	0.10
Number of financial institutions×Firms	519,267	479,407	519,267	479,407
Sample size	1,890,362	1,714,406	1,890,362	1,714,406
Estimation period	FY 2013-2018			

Note: ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels, respectively. The values in brackets are cluster-robust standard errors. All variables are winsorized at the 1st and 99th percentile values.