Credit Allocation and Real Effects of Negative Interest Rates: Micro-Evidence from Japan *

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Abstract. This paper investigates the effects of the negative interest rate policy on bank credit and borrowing firms' behavior by using ten thousands of bank-firm matched data for Japanese listed firms. By utilizing difference-in-difference method, it finds that the implementation of the negative interest rate policy on February 2016 by the Bank of Japan significantly decreases loans from banks that are more affected by the introduction. Furthermore, the negative interest rate has heterogeneous credit allocation effects; more financially unstable banks increase loans to risky firms, or firms with lower distance-to-default, more than banks with the sound balance sheet. In addition, non-financial firms that borrow from banks with more exposure to the negative interest rate decrease the firm fixed investment.

Keywords: negative interest rates; credit supply and allocation effects; loan-level data; bank risk taking; firm’s corporate policies

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1. **Introduction**  After the Global financial crisis (GFC), central banks in many advanced economies implemented expansionary monetary policies with the aggressive stance, so-called “whatever it takes,” in order to lift the economy from depression and raise inflation rates. Even in such an urgent circumstance, however, central banks kept policy rates around zero and mainly focused on unconventional monetary policies such as an asset purchase program. Meanwhile, most researchers assumed a “zero lower bound” on policy rates and investigated the effect of the zero lower bound on economy. However, some central banks sought the unexplored territory of the interest rate policy by reducing their policy rates below zero as they faced continuing deflationary pressure: starting with Danmarks Nationalbank, ECB and Swiss National Bank introduced a negative interest rate policy (NIRP).

The Bank of Japan (BOJ) also announced the introduction of a negative policy rate in January 2016 to raise the inflation rate to the target level of 2 percent. Therefore, the negative policy rate in Japan is nothing new in terms of its timing. However, the introduction in Japan is unprecedented in terms of the situation when it was introduced. Specifically, the Japanese economy had already employed a low interest rate policy for two decades before the introduction of the negative policy rate. Due to the prolonged low inflation period, short-term rates in Japan had been substantially low for a much longer period than in other economies with a negative interest rate, which led to tight lending margins in the Japanese bank loan market. In fact, as pointed out by Bank of Japan (2019), the deposit rate in Japan had been less than 0.5 percent well before the introduction of a negative policy rate and was much closer to zero while those in European countries with the NIRP were more than 1 percent. Thus, in Japan, there was less room for deposit rates to decline when the negative policy was introduced, compared to the case in European countries. This fact implies that Japanese banks were not able to pass through a reduction in the policy rate to the deposits rate, resulting the tightening of lending margins. Furthermore, the deposit to loan ratio of Japanese banks is higher than that of European banks, which hinders them to reduce funding cost when a negative policy rate is introduced as deposit rates continue to have a zero lower bound in general even after the introduction of the NIRP.
Studying the Japanese case provides insight on a negative interest rate policy for other economies because central banks including ECB seem to continue their NIRP for some extended periods and therefore a similar situation to that in Japan could occur in future. Nonetheless, thus far, few studies investigated the effects of the negative interest rate policy in Japan.

To fill this gap, this paper investigates the effects of the negative interest rate policy on bank credit and borrowing firms' behavior by using bank-firm matched loan data for Japanese listed firms. By utilizing difference-in-difference approach, we find three main effects of the negative interest rate policy on banks and firms. First, we find that the implementation of the NIRP on February 2016 by the Bank of Japan significantly decreased loans from banks with excess deposits held at the BOJ, i.e., banks exposed to the NIRP. Second, the negative interest rate policy has allocation effects on lending; loans to risky firms decreased more than those to firms with relatively low credit risk. In addition, highly leveraged banks increased loans to firms with high credit risks more than banks with low leverage. Third, borrowing firms whose lender banks are more exposed to the NIRP decreased the business fixed investment. These results imply the negative interest rate policy has real effects by curtailing the investment of borrowing firms.

To disentangle the effects of the negative interest rate policy on bank lending from other factors such as loan demand shocks, this paper exploits the difference in excess deposits that are held by commercial banks at the BOJ as a treatment. When the BOJ introduced the negative interest policy, it has adopted a three-tier system for applying negative interest rates to bank deposits on current accounts at the central bank. That is, the deposit balance on the current accounts held by banks at the BOJ is divided into three tiers: Basic Balance, Macro Add-on Balance, and Policy-Rate Balance. To Basic Balance, which is the average outstanding balance of each bank’s current account from January to December 2015, a positive interest rate of 0.1 percent is applied. In other words, the Basic Balance corresponds to the existing balance when the policy introduced. The second tier, Macro Add-on Balance, is calculated as a certain proportion of the Basic Balance in order to take account increasing demand for the current account at the BOJ. \(^1\) To the Macro Add-on
Balance, which was set zero in the time of the introduction, a zero interest rate is applied. Finally, a negative interest rate of minus 0.1 percent is applied to the Policy-Rate Balance, which is the outstanding balance of the current account at the BOJ in excess of the sum of the Basic and the Macro Add-on Balance. Because the introduction of the negative interest rate policy was unpredicted by the financial market and banks, the introduction can be interpreted as a quasi natural experiment. Banks whose Policy-Rate Balance were positive in March 2016 are assigned to the treatment group. March 2016 was the first calculation date of these balances for Japanese banks just after the introduction of the negative interest policy at February 2016. In other words, banks in the treatment group paid interest to the central bank just after the policy introduction, whereas banks in the control group did not.

By investigating the firm-bank level loan data, this paper quantify the effects of negative interest rate policy on bank loans. In contrast to previous researches that used the bank-level data, the firm-bank loan data allow us to control for the demand factor completely. Furthermore, as existing literature including Jimenez et al. (2012; 2014) demonstrated, by exploiting the firm-bank data, we can investigate the interaction effects of the negative interest rate policy, bank and firm factors.

A growing literature studies the negative interest rate policy. However, the previous empirical research has mainly addressed the issue of whether the supply of bank credit decreased or not due to the introduction of negative interest rates by employing program evaluation methods, such as the difference-in-difference estimation method. However, few papers investigated the effects of the NIRP by using loan-level data. Among them, Heider et al. (2019) and Bottero et al. (2019) use loan-level datasets, and the former shows that the NIRP significantly reduced bank loans, while the latter shows that it had expansionary effects not only bank loans, but also on firm investment. Meanwhile, Nucera et al. (2017), Molyneux et al. (2017), and Gunji (2018) use bank-level datasets. They show that the NIRP significantly reduced bank loans, but they could suffer from omitted variable problems as it is difficult to control demand factors. Our bank-firm matched dataset allows us to fully control for demand factors and disentangle the policy effects.

of credit through the Loan Support Program and the Funds-Supplying Operation to Support Financial Institutions in Disaster Areas affected by the Great East Japan Earthquake. See Bank of Japan (2016a) for detail.
In addition, to our knowledge, no existing studies except Bottero et al. (2019) investigate the effects of the reduction in bank loans due to the NIRP on borrowing firms’ behavior. The NIRP should affect not only the bank loan market but also other financial and economic conditions. Therefore, it is not obvious how borrowing firms respond to the change in bank loans ex ante. This is because such borrowing firms have access to other financial markets and it entails the complex effects on firms’ funding and management. This real effect on borrowing firms is also important for the policy implication of the NIRP.

In addition, Bottero et al. (2019) studied the effect of the NIRP based on Italian loan data. As mentioned above, the deposit rates in Euro area have been still well above zero. Therefore, banks and firms behavior are expected to be different from those in Japan, where the deposit rates are almost zero. However, even in the euro area, the deposit rate continue to decline. Therefore, in future banks in the euro area could face a similar situation to one in Japan. This paper shed light on the important aspect of the NIRP for real economy.

As well as empirical studies, the NIRP attracts attention of researchers in the theoretical fields. Among others, Gunji and Miyazaki (2016), Dong and Wen (2017), Eggertsson et al. (2019), and Honda and Inoue (2019) theoretically consider the effect of negative interest rates. The discussion on impacts of the NIRP on economy is still ongoing. For example, Eggertsson et al. (2019) show that a negative interest rate could have adverse effect on economy while Dong and Wen (2017) show that a negative interest rate could have an expansionary effect. Thus, our paper also gives some insight to theoretical researches.

Our paper is organized as follows. Sections 2 presents our econometric model and explains our data. Section 3 reports the estimation results for the effects on bank lending. Section 4 shows the estimation results for the real effects on firms and Section 5 provides conclusions.

2. Econometric Model and Data In this section, we introduce three econometric models to investigate the different effects of NIRP on bank lending and borrowing firms’ behavior, namely supply effects, allocation effects, and real effects on borrowing firms. Then, we describe the bank-firm matched data set for Japanese listed firms.
2.1. **Model for Supply Effects and Definition of Treatment Variables**  As discussed in Introduction, we use a loan-level matched dataset of Japanese banks and their listed borrowers to identify the effect of the negative interest rate on bank lending. The loan-level matched data allow us not only to control for borrower-side factors through firm-year fixed effects, but also to analyze the credit allocation effect through the interaction between bank health and firm performance variables.

Baseline specification using the difference-in-difference approach for examining the effect of bank lending in response to the negative interest policy is as follows:

\[
\Delta \text{LOAN}_{jt} = \alpha + \beta \text{TREAT}_i \times D_{2017} + \gamma X_{it-1} + v_i + u_{jt} + \varepsilon_{jt},
\]

(1)

where the dependent variable, \(\Delta \text{LOAN}_{jt}\), indicates the growth rate of the total amount of loans outstanding between bank \(i\) and domestic listed firm \(j\) at time \(t\). \(X_{it}\) denotes bank-level control variable vector. \(v_i\) denotes bank \(i\)’s time-invariant fixed effects to control for its time-invariant unobservables, while \(u_{jt}\) denotes firm \(j\)’s time-varying fixed effects to control for the borrowing firm’s total demand factors at each sample period \(t\).

The treatment variable, \(\text{TREAT}_i\), is one for banks whose Policy-Rate Balance was positive at March 2016, and zero otherwise, following Gunji (2018). As discussed in Introduction, March 2016 was the first settlement month of this tier system for Japanese banks just after the introduction of the negative interest policy in February 2016. In other words, banks in the treatment group paid interest to the central bank, whereas banks in the control group did not. \(D_{2017}\) is a dummy variable that takes one after the policy introduction, and zero otherwise. Thus, the estimate of \(\beta\) presents the causal impact of the negative interest policy on the supply of bank credit given the appropriate assumption.

As the balance of the current account of each bank held at the BOJ is not publicly available, we use cash and deposits on the bank balance sheet as the proxy for it. More concretely, the treatment variable, \(\text{TREAT}_i\), takes one if the cash and deposits in March 2016 is greater than the average of 2015 and zero otherwise. More concretely, the treatment
variable is defined as follows,

\[
TREAT_i = \begin{cases} 
1 & \text{if } \text{RESERVE}_{i,\text{Mar.2016}} - \text{Mean(RESERVE}_{i,\text{2015}}) > 0 \text{ or } \\
0 & \text{otherwise},
\end{cases}
\]

where \(\text{RESERVE}_{i,\text{Mar.2016}}\) and Mean(\(\text{RESERVE}_{i,\text{2015}}\)) indicate the cash and deposits holding of bank \(i\) in March 2016 and its average in 2015, respectively.

Note that to control for borrower-side factors in the baseline specification with \(u_{jt}\), we employ the fixed-effects approach proposed by Khwaja and Mian (2008) and Jiménez et al. (2012; 2014). The fixed-effects approach assumes that all potential borrower-side factors are embodied in time-varying firm unobservables, which are captured by firm-year fixed effects \((u_{jt})\).\(^2\)

**Treatment Variable and Timing of the NIRP introduction**  Although the introduction of NIRP is not predicted by banks, the treatment variable is defined by the balance sheet information after the introduction of the NIRP, which implies the treatment is not necessarily exogenous because banks had time to adjust the balance sheet to the NIRP. However, several evidence shows that banks had difficulty of changing the balance sheets for the following reasons. First, the excess reserve of major banks was large until March 2016 although it continued to be zero after April 2016.\(^3\) Major banks have a tendency to keep excess reserve zero as pointed out by the Bank of Japan (2016b). The fact that even such major banks had to have a positive excess reserve by March 2016 means that it was not easy to completely adjust their balance sheet to the policy change immediately. Second, the survey conducted by the Bank of Japan indicates that banks had some system constraints on trading in the uncollateralized loan market, which is a main money market for banks to smooth their funding (Bank of Japan (2016b)). This also shows the evidence that in Mar. 2016 banks had not optimized the composition of their balance sheet yet.

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\(^2\) Hosono and Miyakawa (2014) and Nakashima (2016) employed this fixed-effects approach with Japanese loan-level matched data. The former identified the effects of monetary policy on bank loan supply through the bank balance sheet channel, while the latter examined the effects of Japan’s public capital injections on bank lending.

\(^3\) The excess reserve of city banks (or major banks) that bear the policy rate of minus 0.1 percent was positive in Feb. and Mar. 2016 (600 bil. yen in Feb. and 2.1 tril. yen in Mar. 2016). However, it has continued to be zero after April 2016).
Control Variables We include a set of control variables to identify the causal effect of the NIRP. To control bank time-varying factors, in addition to bank fixed effect, we include the logarithm of the bank total assets, the bank Tobin’s Q, the bank ROA, bank market capital ratio, and bank regulatory capital ratio.

2.2. Model for Credit Allocation In addition to the supply of credit, the effect of bank credit allocation in response to the negative interest policy can be investigated in the difference-in-difference approach. Heider et al. (2019) show that negative policy rates by the ECB lead to more risk-taking by banks in the treatment group than banks in the control group. To this end, the baseline specification (1) is modified to

$$
\Delta \text{LOAN}_{it} = \alpha + \beta_1 \text{TREAT}_i \times D2017_t + \beta_2 \text{TREAT}_i \times \text{FIRM}_{j-1}^i + \beta_3 \text{TREAT}_i \times \text{FIRM}_{j-1}^i \times D2017_t + \gamma X_{it-1} + v_i + u_{jt} + \varepsilon_{it},
$$

(3)

where FIRM$^j_i$ denotes a performance variable of a firm $j$. In this paper, instead of using conventional measures of profitability such as the return on assets and the working capital ratio, we use an equity-based measure of franchise values for a firm’s business performance in the future: that is, the distance to default ($\text{FDD}_j^i$). The reason is that the equity-based measures better capture a firm’s current and future profitability than the conventional profitability measures based on its past profit. Considering that banks tend to place more importance on a borrower’s future performance when they evaluate default risk, the equity-based measures are more appropriate for examining their lending behavior. The distance to default is defined as

$$
\text{FDD} = \left\{ \ln \left( \frac{V_A}{D} \right) + \left( r - \frac{1}{2} \sigma_A^2 \right) \right\} / \sigma_A,
$$

where $r$ is the risk-free rate, and $\sigma_A$ is the volatility of firm assets. $V_A$ denotes the market value of firm $i$ that is defined as the sum of the market value of its equity ($V_E$) and the book value of its total liabilities ($D$).\textsuperscript{4} The distance to default can be interpreted as the expected standardized difference between the market value of the firm and the book value

\textsuperscript{4} We calculate the market value of firm equity by multiplying the end-of-year stock price by the number of shares. Firm book value is the book value of total assets.
of its liabilities. If the difference is small (large), a firm is in danger of bankruptcy (healthy). A decrease (increase) in distance-to-default implies greater (lesser) credit risk. We define the volatility of firm assets $\sigma_A$ as $\sigma_A = \sigma_E \times \frac{V_E}{V_A}$. To estimate the volatility of equity ($\sigma_E$), we calculate the standard deviation of the market value of equity for the final month of a firm’s fiscal year and express the estimated volatility as an annual rate.\(^5\) We use the yield on one-year Japanese government bonds as a proxy of the risk-free rate ($r$).

An important coefficient in this specification is on the triple interacted term consisting of the treatment variable, the firm performance variable, and the dummy variable for the year after the policy. The estimate of $\beta_3$ presents the causal impact of the negative interest policy on the allocation of bank credit.

### 2.3. Model for Bank and Firm Interaction Effect

Another specification for examining the allocation of bank credit depending on bank health as follows:

\[
\Delta \text{LOAN}_{jt}^i = \alpha + \beta_1 \text{BMCAP}_{it-1} \times \text{FIRM}_{jt-1}^i + \beta_2 \text{BMCAP}_{it-1} \times \text{FIRM}_{jt-1}^i \times \text{D2017}_t \quad (4)
\]

\[
+ \beta_3 \text{TREAT}_i \times \text{FIRM}_{jt-1}^i + \beta_4 \text{TREAT}_i \times \text{FIRM}_{jt-1}^i \times \text{D2017}_t
\]

\[
+ \beta_5 \text{TREAT}_i \times \text{BMCAP}_{it-1} \times \text{FIRM}_{jt-1}^i
\]

\[
+ \beta_6 \text{TREAT}_i \times \text{BMCAP}_{it-1} \times \text{FIRM}_{jt-1}^i \times \text{D2017}_t + v_{it} + u_{jt} + \varepsilon_{jt}^i,
\]

where $\text{BMCAP}_{it-1}$ denotes a bank $i$’s market capital ratio that is supposed to capture the adequacy of bank capital and the increase in bank default risk (Sarin and Summbers (2016) and Begley et al. (2017)).\(^6\) In this another specification, we control for all potential lender-side factors by utilizing the bank-year fixed effect $v_{it}$. We also examine the interaction

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\(^5\) More specifically, we calculate the annualized estimated volatility of the market value of equity as follows:

\[
\sigma_{E,jt}^E = \sqrt{\frac{1}{D(t)-1} \sum_{d(t)=1}^{D(t)} (\text{ret}_{j,d(t)} - \overline{\text{ret}}_{j,t})^2 \times \sqrt{D(t)}},
\]

where $d(t)$ ($d(t) = 1, \cdots, D(t)$) indexes trading days in firm $j$’s fiscal year $t$. $\text{ret}_{j,d(t)}$ denotes the daily rate of change in equity valuation, and $\overline{\text{ret}}_{j,t}$ is the average rate of change in equity valuation during fiscal year $t$.

\(^6\) The bank market capital ratio is defined as the market value of a bank’s equity divided by the market value of its total assets, where the market value of a bank’s total assets is defined as the sum of the market value of its equity and the book value of its total liabilities. We calculate the market value of equity by multiplying the end-of-year stock price by the number of shares.
effects, or the second derivative effects, on credit allocation using this double fixed-effects approach (see Jiménez et al. (2014) and Nakashima et al. (2018) for the double fixed-effects approach).\(^7\)

In addition, following the theoretical prediction of Brunnermeier and Koby (2018), we also investigate the effect of the bank’s holdings ratio of government bonds in their assets (\(B_{t-1}\)) instead of the bank market capital. They showed that the negative effects of the NIRP is larger when banks could obtain only small capital gain from bond holdings due to the decrease in interest rates. As the firm risk variable \(F_{t-1}\), we use the low distance-to-default dummy variable (FLDD4\(_{t-1}\)) to facilitate the interpretation of the interaction term. The low distance-to-default dummy take one if the firm’s distance-to-default is less than quartile of our samples in year \(t-1\).

### 2.4. Model for Real Effects on Borrowing Firms’ Behavior

To investigate the effects of NIRP on firms’ behavior through the bank lending, we use the following firm level equation by utilizing the bank-firm matched data.

\[
FIRM_{jt} = \alpha + \beta_1 WT_{jt} \times FIRM_{j,t-1} \times D2017_t + \beta_2 WT_{jt} \times FIRM_{j,t-1} + \beta_3 Z_{jt-1} + u_j + \epsilon_{jt},
\]

where \(FIRM_{jt}\) denotes a firm variable of our interest. As \(FIRM_{jt}\), we used fixed investment, cash holding ratio, commercial paper funding ratio, corporate bond funding ratio, and leverage ratio. \(WT_{jt}\) is a weighted average of the treatment variable (\(TREAT_i\)). The weight is defined by using the borrowing exposure of firm \(i\) to bank \(j\) at time \(t\). More concretely, \(WT_{jt}\) is defined as follows.

\[
WT_{jt} = \sum_{i \in J_{jt}} [TREAT_i \times \frac{\text{LOAN}_{i,2016}}{\text{LOAN}_{j,2016}}]
\]

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\(^7\) Jiménez et al. (2014) and Nakashima et al. (2018) employed the double fixed-effects approach to identify the risk-taking channel of monetary policy in bank lending, which involves the issue of whether and how monetary policy induces banks to change their credit allocation from firms with lower credit risk to ones with higher credit risk.
Thus, \( WTREAT^j \) captures the degree to which lending banks are exposed to the NIRP. \( J_{j, 2016} \) indicates a set of banks from whom firm \( j \) borrow loans in Mar. 2016. \( \text{LOAN}^j_{2016} \) is the total amount of outstanding loans of firm. \( Z^j_{t-1} \) denotes a vector of firm control variables. Note that we include firm fixed effect \( u_j \) to control for unobservable factors.

2.5. **Data** The empirical analysis developed in this paper uses a loan-level dataset comprising matched samples of Japanese banks and their borrowing firms listed in Japan. We construct our loan-level data using the Corporate Borrowings from Financial Institutions Database compiled by Nikkei Digital Media Inc. This database annually reports short- (a maturity of one year or less) and long-term (a maturity of more than one year) loans from each financial institution for every listed company on any Japanese stock exchange.

The database includes more than 12,000 observations, comprising more than 90 Japanese banks and 800 listed borrowing firms for our sample period from March 2016 to March 2017. Specifically, by Difference-in-Difference method, we compare the change in the variable of our interest from March 2016 to 2017 with that from March 2015 to 2016. Our dataset covers approximately 50% of all loans in the Japanese banking sector for our sample period. We combined the Nikkei database with the financial statement data of Japanese banks and their listed borrowing firms, also compiled by Nikkei Digital Media Inc.\(^8\)

Table 1 reports summary statistics for key variables, including the two bank capital variables and the firm performance variables of the distance to default.

3. *Estimation Results for Bank Lending*

3.1. **Effect on Credit Supply** We start by reporting the estimation results for the causal impact of the negative interest rate on supply of bank credit based on Equation (1). Note that \( D_{2017_t} \) is mere year dummy indicating year after the introduction of the NIRP and we use fiscal year 2015 as a reference period. Column (1) of Table 2 shows that the coefficient on the treatment variable is significantly negative, implying that banks with excess balance on their current account decreased loans to firms on average in response

\(^8\) The end of the fiscal year for Japanese banks is March 31, but this is not necessarily the case for borrowing firms. When combining the Nikkei database for loan-level data with the financial statement data of banks and their borrowing firms, we match bank-side information to borrower-side information in the same fiscal year.
to the introduction of NIRP. In addition, the magnitude of the impact is economically significant, around 3%, which is comparable to the average change in bank loans in 2016 and 2017.\textsuperscript{9} We should note that in Equation (1), firm factors are fully controlled by time-varying firm fixed effects. Furthermore, bank factors such as ROA is controlled and bank fixed effects are included in the equation. This result shows that the NIRP has a contraction effect in the bank loan market on average as predicted by theoretical literature such as Brunnermeier and Koby (2018).

3.2. **Credit Allocation Effect** Columns (2) and (3) of Table 2 show the estimation results for the causal impact of the negative interest rate on allocation of bank credit based on Equation (3) with bank fixed effects and bank*year fixed effects, respectively. The estimates for the coefficient of the triple interacted term \((TREAT_i\times FIRM_{t-1}\times D2017_t)\) are significantly positive for all treatment variables. Note that a higher firm variable \(FIRM_{t-1}\) implies less risky firms. The estimation result means that banks that are more exposed to the negative interest policy decreased their loans toward risky firms, compared to less risky firms. As we control for time-varying firm effects, loan demand does not explain the difference. Given the fact that the deposit rate had been closed to zero already before the introduction of NIRP as discussed in Introduction, this result suggests that banks that are heavily exposed to negative interest rates decreased loans with more credit risks to balance the return and risk involved.

3.3. **Heterogeneous Effect across Banks** To investigate the prediction by Brunnermeier and Koby (2018) for the heterogeneous effects on credit supply, we include the bank market capital ratio and government bond holding ratio as the bank variable. The coefficients on both the bank balance sheet variables are estimated to be not significant as shown in Columns (4) and (5) of Table 2. This means that the Japanese case does not exactly coincide with the situation described by Brunnermeier and Koby (2018).

\textsuperscript{9} The total bank loans in Japan in this period increased mainly by the increase in loans to small and medium-sized firms. On the other hand, loans to large firms, in which listed firms in our sample are basically included, decreased.
3.4. **Bank and Firm Interaction Effect** Columns (6) of Table 2 present the estimates based on Equation (4), where bank and time-varying firm fixed effects are controlled. As a firm risk variable, we use low distance to default dummy FLDD4, which takes one if the distance to default is below the lower quartile of samples in each year. The coefficient of the quadruple interacted term (TREAT$_i \times$ BMCAP$_{it-1} \times$ FLDD4$_{it-1} \times$ D2017$_i$) is estimated to be significantly negative. This means that the negative interest rate has heterogeneous credit allocation effects across banks and firms; more financially unstable banks increase loans to risky firms, or firms with lower distance-to-default measure, more than banks with high capital.

To summarize the results so far, the NIRP has a negative effects on bank loan supply on average and the negative impact is relatively small for loans to less risky firms. In addition, lowly capitalized banks relatively increased loans to risky firms than highly capitalized banks, which suggests that the NIRP changes the quantity of aggregate total loans but its quality.

4. **Real effects of the NIRP on Borrowing Firms**

4.1. **Effects on Firms’ Funding and Leverage** In this subsection, we investigate the effects of the NIRP on firms’ funding and liquid assets. Columns (1) and (2) in Table 3 show the estimation result of Equation (5) with the change in the ratio of cash and deposits (CASH$_j^t$), commercial paper (CP$_j^t$) and corporate bond (SB$_j^t$) to the total debt, and the leverage ratio (LEV$_j^t$) as a dependent variable. All of the estimated coefficients are not significantly different from zero. Given the result in the previous section of the credit supply effect, the NIRP did not have effects on other funding sources of borrowing firms although it decreased lending from banks.

4.2. **Firms’ Fixed Investment** To uncover the real effect of the NIRP, the firm fixed investment variable is included in Equation (5) as a dependent variable. The fixed investment variable, INV$_j^t$, is defined as the growth rate of firm fixed assets. The estimation result are shown in Column (1) of Table 4 indicate that the NIRP have a significantly negative effect on the firm fixed investment, implying that borrowing banks decreased fixed investment due to the decrease in loans from banks that are heavily affected by the NIRP.
In other words, the NIRP has a negative real effect on firm investment. In addition, to investigate the heterogeneous effect of the NIRP on firm investment, we include the interaction term of the low distance to default dummy. The estimation result in Column (2) of Table 4 indicates that the interaction term is not significant. Given that the NIRP has credit allocation effect as shown in Table 2, this result indicates that low risk firms did not decrease the investment more than firms with relatively low credit risk.

4.3. Robustness Check In the previous sections, we showed the NIRP has a negative credit supply effect by using the DID approach, which relies on the assumption that the difference in the growth rate of bank loans between the control and treatment group arises from the NIRP; in other words, this categorization should not have any effects on the loan growth rates in other sample periods. To show the robustness of our result, we estimate the same baseline model by using the different sample periods from 2016-2017 and thereby showing the difference occurs only before and after the introduction of the NIRP.

The estimation results for the other sample periods are shown in Table 5, indicating that the coefficients for the treatment effect are not significant for all periods. This implies that the treatment variable successfully captures the effects of the introduction of the NIRP; in other periods, the treatment variable has no impacts on banks when the NIRP is irrelevant.

5. Conclusion This paper investigates the effects of the negative interest rate policy on bank credit and borrowing firms’ behavior by using bank-firm matched data for Japanese listed firms. By utilizing difference-in-difference method, it finds that the implementation of the negative interest rate policy on February 2016 by the Bank of Japan significantly decreases loans from banks with excess deposits. More concretely, this paper exploits the difference in excess deposits that are held by commercial banks at the Bank of Japan as a treatment. Because the introduction of the negative interest rate policy was unpredicted by the financial market and banks, the introduction can be interpreted as a quasi natural experiment. By investigating about ten thousands of firm-bank level loan data, this paper quantify the effects of negative interest rate policy on bank loans. In contrast to the previous research that used the bank-level data, this firm-bank loan data allows us to control for the demand factor completely. Hence, it shows that the finding of the effect is robust for
omitting variable problems, which is of first order importance in the identification of supply-
side factors. Furthermore, the negative interest rate has heterogeneous credit allocation
effects; more financially unstable banks increase loans to risky firms, or firms with lower
distance-to-default measure than banks with the sound balance sheet. In addition, non-
financial firms that are borrowing from banks with more exposure to the negative interest
decrease their fixed investment. This result indicates that the negative interest rate policy
has a real effect on economy through credit supply and allocations.
REFERENCES


Table 1: Summary statistics

<table>
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<th>Variable</th>
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<th>Std. Dev.</th>
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<th>Max.</th>
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<td>Relation level</td>
<td></td>
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<tr>
<td>$\Delta LOAN$</td>
<td>-3.328</td>
<td>31.747</td>
<td>-98.902</td>
<td>118.471</td>
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<tr>
<td>TREAT*D2017</td>
<td>0.373</td>
<td>0.484</td>
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<td>13114</td>
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<td>Bank level</td>
<td></td>
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<tr>
<td>TREAT*D2017</td>
<td>0.244</td>
<td>0.43</td>
<td>0</td>
<td>1</td>
<td>197</td>
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<td>Bank size</td>
<td>15.095</td>
<td>1.339</td>
<td>12.915</td>
<td>19.309</td>
<td>196</td>
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<td>Bank ROA</td>
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<td>0.18</td>
<td>0.096</td>
<td>1.273</td>
<td>196</td>
</tr>
<tr>
<td>Bank tobinq</td>
<td>97.155</td>
<td>1.678</td>
<td>94.171</td>
<td>108.21</td>
<td>186</td>
</tr>
<tr>
<td>Bank market capital ratio</td>
<td>2.75</td>
<td>1.807</td>
<td>0.571</td>
<td>13.892</td>
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<tr>
<td>Bank regulatory capital ratio</td>
<td>11.399</td>
<td>2.675</td>
<td>6.53</td>
<td>19.97</td>
<td>202</td>
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<tr>
<td>Firm level</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>INVEST</td>
<td>1.338</td>
<td>13.116</td>
<td>-59.952</td>
<td>71.566</td>
<td>1691</td>
</tr>
<tr>
<td>WTREAT</td>
<td>0.051</td>
<td>0.086</td>
<td>0</td>
<td>0.534</td>
<td>1610</td>
</tr>
<tr>
<td>Firm Size</td>
<td>10.399</td>
<td>1.496</td>
<td>7.184</td>
<td>15.053</td>
<td>869</td>
</tr>
<tr>
<td>Firm tobinq</td>
<td>114.568</td>
<td>59.621</td>
<td>32.165</td>
<td>467.032</td>
<td>869</td>
</tr>
<tr>
<td>log(# of lenders)</td>
<td>1.596</td>
<td>0.658</td>
<td>0</td>
<td>3.611</td>
<td>869</td>
</tr>
<tr>
<td>Firm leverage ratio</td>
<td>51.201</td>
<td>17.551</td>
<td>4.709</td>
<td>98.490</td>
<td>869</td>
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</table>
Table 2: Causal Impact on Bank Lending

<table>
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<tr>
<th>Model</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
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<tbody>
<tr>
<td>TREAT&lt;sub&gt;i&lt;/sub&gt;×D2017&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-3.33**</td>
<td>-12.45**</td>
<td>0.614</td>
<td>-6.49**</td>
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</tr>
<tr>
<td></td>
<td>(1.578)</td>
<td>(5.230)</td>
<td>(3.590)</td>
<td>(3.04)</td>
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<tr>
<td>TREAT&lt;sub&gt;i&lt;/sub&gt;×FLDD&lt;sub&gt;j&lt;/sub&gt;&lt;sub&gt;t&lt;/sub&gt;−1×D2017&lt;sub&gt;t&lt;/sub&gt;</td>
<td>6.46*</td>
<td>6.90*</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(3.457)</td>
<td>(3.562)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TREAT&lt;sub&gt;i&lt;/sub&gt;×FLDD&lt;sub&gt;j&lt;/sub&gt;&lt;sub&gt;t&lt;/sub&gt;−1×D2017&lt;sub&gt;t&lt;/sub&gt;</td>
<td></td>
<td></td>
<td>0.26</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(4.538)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TREAT&lt;sub&gt;i&lt;/sub&gt;×BMCP&lt;sub&gt;it&lt;/sub&gt;−1×D2017&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-1.282</td>
<td>1.63</td>
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<tr>
<td></td>
<td>(1.324)</td>
<td>(1.446)</td>
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<tr>
<td>TREAT&lt;sub&gt;i&lt;/sub&gt;×BGBOND&lt;sub&gt;it&lt;/sub&gt;−1×D2017&lt;sub&gt;t&lt;/sub&gt;</td>
<td>7.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(23.8)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>TREAT&lt;sub&gt;i&lt;/sub&gt;×BMCP&lt;sub&gt;it&lt;/sub&gt;−1×FLDD&lt;sub&gt;j&lt;/sub&gt;&lt;sub&gt;t&lt;/sub&gt;−1×D2017&lt;sub&gt;t&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td>-4.172**</td>
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<td></td>
<td></td>
<td>(2.094)</td>
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<td>8660</td>
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<td>8534</td>
<td>8696</td>
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<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Bank*Year fixed effects</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Firm*Year fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at levels of 0.10, 0.05, and 0.01, respectively. The dependent variable is ΔLOAN, which indicates the growth rate of the total amount of loans outstanding.

Table 3: Causal Effects on the Firm Funding and Leverage

<table>
<thead>
<tr>
<th>Firm Outcome Variable</th>
<th>ΔCASH</th>
<th>ΔCASH</th>
<th>ΔCP</th>
<th>ΔCP</th>
<th>ΔSB</th>
<th>ΔSB</th>
<th>LEV</th>
<th>LEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTREAT&lt;sub&gt;j&lt;/sub&gt;×D2017&lt;sub&gt;t&lt;/sub&gt;</td>
<td>-2.306</td>
<td>-3.074</td>
<td>-0.036</td>
<td>-0.049</td>
<td>0.300</td>
<td>0.338</td>
<td>0.507</td>
<td>1.053</td>
</tr>
<tr>
<td></td>
<td>(2.318)</td>
<td>(2.536)</td>
<td>(0.100)</td>
<td>(0.125)</td>
<td>(0.454)</td>
<td>(0.513)</td>
<td>(2.554)</td>
<td>(2.437)</td>
</tr>
<tr>
<td>WTREAT&lt;sub&gt;j&lt;/sub&gt;×FLDD&lt;sub&gt;j&lt;/sub&gt;&lt;sub&gt;t&lt;/sub&gt;−1×D2017&lt;sub&gt;t&lt;/sub&gt;</td>
<td>3.952</td>
<td>0.053</td>
<td>-0.180</td>
<td>-2.529</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.842)</td>
<td>(0.141)</td>
<td>(0.774)</td>
<td>(5.299)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Industry fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Firm fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Firm control variables</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>1534</td>
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<td>1523</td>
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<td>1536</td>
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</tbody>
</table>

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at levels of 0.10, 0.05, and 0.01, respectively.
Table 4: Real Effects on the Firm Fixed Investment

<table>
<thead>
<tr>
<th>Firm Outcome Variable</th>
<th>INVEST</th>
<th>INVEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTREAT$^j \times D2017_t$</td>
<td>-7.67*</td>
<td>-7.41*</td>
</tr>
<tr>
<td></td>
<td>(4.383)</td>
<td>(4.051)</td>
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<tr>
<td>WTREAT$^j \times FLDD4_{j-1}^t \times D2017_t$</td>
<td>-2.45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(7.283)</td>
<td></td>
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</tbody>
</table>

Industry fixed effects: Yes  Yes  
Firm fixed effects: Yes  Yes  
Firm control variables: Yes  Yes  
N: 1492  1491

Notes: Robust standard errors are in parentheses. * , ** , and *** denote significance at levels of 0.10, 0.05, and 0.01, respectively.

Table 5: Placebo test: Causal Impact on Bank Lending

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
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<td>TREAT$^i \times D2014_i$</td>
<td>-1.24</td>
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<td></td>
<td>(1.338)</td>
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<tr>
<td>TREAT$^i \times D2015_i$</td>
<td></td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.528)</td>
<td></td>
</tr>
<tr>
<td>TREAT$^i \times D2016_i$</td>
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<td></td>
<td>-1.36</td>
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<td>(1.516)</td>
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<td>10068</td>
<td>9080</td>
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<td>Bank fixed effects</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Bank*Year fixed effects</td>
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<td>No</td>
</tr>
<tr>
<td>Firm*Year fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors are in parentheses. * , ** , and *** denote significance at levels of 0.10, 0.05, and 0.01, respectively. The dependent variable is $\Delta$LOAN, which indicates the growth rate of the total amount of loans outstanding.