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Pushed Past the Limit? How Japanese Banks Reacted to Negative Interest Rates

by Gee Hee Hong and John Kandrac

I N T E R N A T I O N A L   M O N E T A R Y   F U N D

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Pushed Past the Limit? How Japanese Banks Reacted to Negative Interest Rates

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Abstract

In this paper, we investigate how negative interest rate policy (NIRP) introduced in January 2016 by the Bank of Japan (BoJ) affected Japanese banks' lending and risk taking behavior. The BoJ's announcement was an unexpected surprise to the market and was followed by a sharp drop in equity prices of Japanese financial firms. We exploit the cross-sectional variation in the change of share prices on the day of the announcement to measure banks' differential exposure to NIRP. We show that more exposed banks increased their credit and took on more risk compared to banks that were less exposed to negative rates.

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1 Introduction

Of all the unconventional monetary policy measures employed in the decade since the Global Financial Crisis, the breach of the so-called "zero lower bound" by central banks adopting negative policy rates is perhaps the most striking and controversial. Although the transmission of interest rate cuts to negative territory would not necessarily differ from rate reductions in positive territory, negative policy rates were unprecedented, and possible frictions could limit or negate their intended expansionary effects (Eggertsson et al. 2017, Beck and Malkhozov 2016). Nevertheless, the European Central Bank, Danmarks Nationalbank, Sveriges Riksbank, Swiss National Bank, and Bank of Japan (BoJ) have all adopted a negative interest rate policy (NIRP) in recent years. Because the experience with NIRP is still limited, however, empirical studies of its efficacy are scarce.

In this paper, we examine the transmission of negative rates through the banking system using the experience in Japan. While some evidence exists that the transmission of negative policy rates to longer-term benchmark rates is not impaired (Grisse and Schumacher 2017, Grisse et al. 2017), there is a growing consensus that frictions in the banking system may affect the transmission of negative rates through banks (see, *inter alia*, Heider et al. 2017; Basten and Mariathasan 2018). However, testing how NIRP impacts banks presents a significant challenge because it is difficult to find a single measure of bank-level exposure to NIRP. This challenge is evident in the variety of factors identified as drivers of banks' differential sensitivity to negative rates, including deposits (Heider et al. 2017), reserves (Basten and Mariathasan 2018), fee income (Nucera et al. 2017), and liquidity provision to borrowers (Arseneau 2017). Of course, all of these factors may contribute to the net effect of negative rates on banks, and the importance of each factor may vary from bank to bank.

A unique feature of this paper is that we employ a summary measure of each bank's exposure to NIRP, which allows us to be agnostic about the channels through which NIRP affects banks' business models. In this way, we are able to examine the effects of NIRP on banks without facing issues that arise from choosing a single characteristic to determine a bank's NIRP exposure.

Specifically, we exploit the wholly unexpected nature of the BoJ's NIRP announcement, which resulted from misdirection by Governor Kuroda in the week leading up to the announcement. We show that the introduction of NIRP was clearly interpreted as an accommodative policy surprise, which resulted in unequivocally positive implications for non-financial businesses. In contrast, the financial sector experienced an uncharacteristic and uniquely adverse reaction. Such a reaction indicates an assessment that banks would see their profits decline and/or that investors required a higher rate of return for holding bank shares. Therefore, the extent of each bank's stock price decline in the minutes after the NIRP announcement can be used as a summary measure of the *net* exposure of the bank's business model to NIRP.

We proceed to show that measures of profitability did not correlate with our measure of exposure to negative rates in the first year of the new policy. Instead, banks with business models that were more exposed to NIRP were evidently able to counteract the additional pressure on profits by, at least in part, taking on more risk. Market-based measures of riskiness increased markedly for the most exposed banks after NIRP was announced, and measures of riskiness or vulnerability based on balance sheet adjustments also rose. Turning to more important measures for monetary policy transmission under negative rates, we examine banks' lending activity and find that more exposed banks did not lower interest rates on their loans as much, which may in part result from a shift towards longer-maturity loans. Finally, we show that credit supply increased more for banks that were more affected by NIRP. This result is consistent with a decrease in credit standards (and an increase in risk taking) by banks that are more exposed to NIRP, leading them to originate loans that less affected banks would not. Because banks looking to manage earnings to avoid reporting a decline in profitability under-provision for loan losses (Beatty et al. 2002), the additional risk taking can help offset contemporaneous negative profit shocks.

We rule out the possibility that our measure of bank exposure to NIRP captures variation in exposure to different types of industries. We also examine a measure of "abnormal" returns around the announcement that purges the effects owing to changes in the benchmark stock prices, bond yields, and currency movements to ensure that our exposure measure is not polluted by differences in cyclical sensitivity, duration gaps, or debt denominated in foreign currency. In a final exercise, we confirm that the reaction of bank stock prices to NIRP did not characterize banks' response to previous announcements of rate cuts into nonnegative territory, offering evidence that negative rate policy is indeed special in its effects on banks.

Our paper joins the nascent literature examining the transmission of NIRP and its effects on banks. Most of the studies acknowledge that a key potential challenge for banks facing negative rates is the inability to adjust borrowing costs downwards, even as interest income continues to fall. In fact, theory suggests that the resultant pressure on financial institutions' profits can possibly negate the intended expansionary effects of NIRP (Van den Heuvel 2002; Brunnermeier and Koby 2017; Eggertsson et al. 2017).

Due to the earlier adoption of NIRP in Europe, the existing empirical studies of negative rates focus on the European experience. Heider et al. (2017) broke the ground in this literature by examining the syndicated lending behavior of banks in the Euro area, and find that banks that are less able to translate the rate cut to lower funding costs shift their loan composition towards riskier borrowers. Notably, this reaction is not present following earlier rate cuts to positive values. Also examining Euro area banks, Nucera et al. (2017) find that bank risk falls on average following cuts to negative rates, but that this effect obscures the substantial heterogeneity in responses across different business models. The authors also use the same placebo as that in Heider et al. (2017) to demonstrate that banks' reaction to negative rates is unique under NIRP. Basten and Mariathasan (2018) study the Swiss experience with negative rates using excess reserves as the key determinant of exposure, and find that retail banks witnessed no net change in profitability as a result of NIRP, but that banks increased their risk taking. Importantly, the authors are unable to identify any increase in corporate lending. Finally, Arseneau (2017) uses stress test responses of large US bank holding companies to investigate the cross-sectional differences in the effects of negative rates. A substantial degree of heterogeneity in the effect of NIRP on banks' profitability is demonstrated, and it appears that incomplete pass through to deposit rates is not necessarily a concern for banks. Rather, he finds that the degree of liquidity provision to borrowers is evidently the most important determinant of adverse effects on profits for large US banks.

We contribute to the literature in four ways. First, to our knowledge, this constitutes the first study of the negative rate experience in Japan. Second, recognizing that banks are affected by NIRP in myriad ways, we construct a novel summary measure of bank-level exposure to NIRP. Third, we document some of the economic and banking conditions under which NIRP will be detrimental to the banking sector, as was evidently the case in Japan. Fourth, we show that banks will engage in additional risk taking in an effort to offset the expected pressure on their profits engendered by NIRP. Such behavior can help explain the relative expansion in loan supply that we observe among banks that are most affected by NIRP.

2 The BoJ's Negative Interest Rate Announcement

Having first introduced zero interest rate policy (ZIRP) to modern central banking in the late 1990s, the BoJ has operated with ultra-low short term interest rates for most of the last two decades. Since famously targeting a rate "as low as possible" in 1999, the BoJ has not targeted a level for the overnight unsecured interbank lending rate (the call rate) above 0.5%. Consequently, the Bank pioneered unconventional policy measures such as quantitative easing (QE) and forward guidance years before the financial crisis. Faced with low policy rates in the years since the crisis, major central banks around the world have pursued similar policies.

Since the crisis, the BoJ has also pioneered so-called "quantitative and qualitative" (QQE) monetary easing in 2013, which combines an emphatic commitment to achieving the inflation target with an unprecedented scale of asset purchases (Kuroda 2016). Compared to this pioneering history, however, the BoJ was relatively slow to adopt negative interest rate policy (NIRP). By early 2015, Denmark, Sweden, Switzerland, and the Eurozone had all adopted NIRP while the BoJ maintained a target for the call rate of no less than zero percent.

At the conclusion of its monetary policy meeting on January 29, 2016, the Policy Board of the BoJ announced its decision (by a narrow 5-4 majority) to target a negative call rate by imposing a negative interest rate of minus 0.1 percent to banks' current accounts held at the BoJ. The announcement explained that bank deposits would be remunerated using a three-tier system that subjected only a portion of banks' balances to the negative rate, while the remainder would earn a rate of either positive 0.1 or zero percent. Importantly, the announcement made clear that rates would be cut further into negative territory if judged necessary.[1] According to the minutes of the meeting (released on March 18, 2016), the stated reasons for the additional monetary accommodation included financial turmoil abroad, and the recognition that recent modest gains in inflation and inflation expectations should be reinforced through additional easing. Policy Board members worried that Japanese firms' deflationary mindset was not fully expunged and thus, absent a further commitment to monetary easing, a rise in wages might not materialize. In light of these threats to its mandate, the Policy Board voted to cut rates into negative territory in the hopes of hastening the achievement of its 2 percent inflation target.

Although there was some speculation in advance of the meeting that additional easing measures would be announced, contemporaneous policy surveys reported modal expectations of no additional accommodation, and the adoption of negative rates was entirely unexpected. The implementation of NIRP came as a surprise primarily because Governor Kuroda denied that such a move was on the table just one week prior to the monetary policy meeting. Speaking to the Japanese parliament on January 21, the Governor seemingly ruled out negative rates as a policy option, claiming that, "we are not considering a cut in the interest on bank reserves." Following these remarks, it was widely reported in the financial press that the BoJ was opting to follow a different path than the ECB and other European central banks by choosing not to charge banks a fee on their central bank deposits. In fact, the NIRP announcement came as such a shock that BoJ officials were reportedly calling commercial banks to explain and apologize for the surprising change.[2]

The fall in the overnight call rate subsequent to this announcement is shown in Figure 1.

[1] On March 16, BoJ Governor Kuroda told lawmakers that it would be theoretically possible to lower the rate to as low as negative 0.5 percent as a policy space.

[2] See the Reuters article "Bank of Japan scrambles to find positives in negative rates." `http://www.reuters.com/article/us-japan-economy-boj-insight-idUSKCN0WG04E`

The call rate did not fall below zero immediately for two reasons. First, the implementation of NIRP did not take effect until the maintenance period beginning February 16, 2016. Second, it took time for banks to adjust their trading software to handle negative rate trades in this market. Although manually entered trades could be conducted, trading at negative interest rates expanded beginning on April 18th when some larger banks completed IT upgrades and investment trusts began lending at rates well below zero. This lack of advanced preparation on the part of banks to handle negative rates underscores the unexpected nature of the BoJ's NIRP announcement.

3 The Reaction to the Announcement and Japanese Banks' Exposure to NIRP

3.1 The reaction to the NIRP announcement

In light of the relatively low expectations for policy action at the January meeting, the surprise NIRP announcement led to sharp reactions in financial markets. After changing little during the day prior to the announcement, the Tokyo Stock Price Index (TOPIX) increased by about 3% by the close of trading. These gains were extended on the following trading day (February 1), for a total two-day change of over 5% (see the solid line in Figure 2). In currency markets, the Japanese Yen fell about 2% versus the U.S. dollar on the day of the announcement, with little net change on the following day. The 10-year Japanese government bond (JGB) also moved sharply, with its yield falling by more than half from 0.23% to 0.10%. Long-term bond yields continued to decline on the day after the announcement, closing at 0.07% on February 1.

The combination of a rise in stock prices and a fall in the exchange rate and longer-term interest rates is consistent with an accommodative monetary policy surprise. Of course, absent any special frictions unique to NIRP, cutting rates into negative territory by the central bank should transmit to the economy through interest rate and credit channels in familiar ways that have been well documented. Lower rates should improve the financial positions of borrowers, increase the number of profitable investment projects, and boost the demand for credit. The interpretation of the announcement as an accommodative surprise is bolstered by the broad-based increase in equity prices of nonfinancial Japanese companies. For example, Figure 3 demonstrates that investors took an optimistic view of the effects of NIRP on Japanese businesses across industries. Share prices for nonfinancial companies rose dramatically on the 29th, and maintained their gains over the next two trading days.

The stock price reaction of Japanese banks, shown in Figure 2, indicates that the NIRP announcement carried different implications for the financial sector. Such a reaction runs counter to the typical pattern of stock price *increases* for banks subsequent to accommodative monetary announcements (Altavilla et al. 2017).[3] Why might NIRP have detrimental effects on banks? Statements by BoJ Policy Board members and contemporaneous reports of financial analysts offer some insight into the negative response of bank shares. In a 2015 speech outlining key differences in the unconventional monetary policies of the BoJ and ECB, a BoJ Policy Board member explained that the decision to maintain a nonnegative interest on reserves rate in Japan was based at least in part on a concern for the banking sector (Shirai 2016). Specifically, the concern was that instituting NIRP risked "undermining the intermediary function of financial institutions by lowering profitability in the banking system," as banks would be unlikely to pass on the increased cost to their retail depositors. According to the minutes from the January BoJ meeting, a dissenting Policy Board member echoed this concern, noting that "a negative interest rate policy would have large side effects on the functioning of financial markets and the financial system."

Commentary from ratings agencies and financial firms near the time of the announcement corroborated the assessment that bank profits were vulnerable to NIRP. Standard & Poor's estimated that NIRP would reduce the profitability of banks by 8 to 15%. Similarly, Fitch Ratings included NIRP as one of three key profitability pressures faced by Japanese banks in a report released after the adoption of NIRP. Lastly, Tokyo-based analysts at SMBC Nikko Securities initially estimated that NIRP would lower net interest margins by as much as six basis points, which could translate into a 4-5% reduction in banks' ordinary profit.

[3] As we show in Section 7, this decoupling of Japanese banks' stock prices from the broader market around monetary policy announcements does not characterize the behavior around previous announcements of rate cuts in Japan.

Japanese banks' stock price responses to the NIRP announcement are summarized in Figure 4 for several time intervals beginning at 12:35pm, about five minutes before the policy decision was issued. It is evident that the decline was broad-based, with not a single bank's stock achieving a positive return over the 40 and 60 minute intervals. In less than one hour after the announcement, the median publicly-traded Japanese bank stock price was over 5% lower. Judging from this universally negative reaction unique to banks, it is natural to interpret the introduction of NIRP as an adverse shock to Japanese banks.

However, the channels through which NIRP negatively affects banks may differ across banks depending on their characteristics. For example, some trust banks may be forced to hold a disproportionately high share of reserves that earn the negative rate, while other banks may have a large retail deposit base that makes it difficult to reduce interest expense further. Other factors such as the level of competition in a bank's loan or deposit market and the extent of increase in the share of fee income during the ZIRP years could also play an important role in a bank's ability to protect income and reduce interest expense amid falling rates. Because there are myriad bank characteristics that can differentially expose banks to NIRP, we use each bank's stock price change around the unexpected NIRP announcement as a single summary measure of the *net* exposure of a bank's business model to NIRP.

As a check to verify that banks' stock price response to the announcement reflects the vulnerability of its business model to negative short-term rates, we estimate cross-sectional regressions to explain the observed variation in price changes. Using the percent change in each bank's stock price over several different horizons around the announcement as dependent variables, our specifications take the following form:

$$\Delta ln(\text{Price}_i) = \alpha + \beta \cdot \left(\frac{Reserves_i}{Assets_i}\right) + \gamma \cdot \left(\frac{TimeDeposits_i}{Assets_i}\right) + \delta \cdot Controls_i + \varepsilon_i. \qquad (1)$$

In Equation (1), we focus on the effect of reserves and time and wholesale deposits as a share of assets. These bank-level controls are measured as of year-end 2015, and reflect commonly-cited risk measures for banks subject to NIRP (Heider et al. 2017, Basten and Mariathasan 2018). Negative rates are applied directly to reserve holdings, subjecting banks to a new fee, and banks that rely more on non-retail wholesale deposits (including negotiable CDs) would have funding costs that are more downwardly-flexible than banks that have a higher share of ordinary retail deposits.[4] As shown in Figure 5, retail deposit rates were very low in absolute terms prior to the introduction of NIRP, and banks appear to be reluctant to cut deposit rates below zero as argued in Heider et al. (2017). By contrast, rates on wholesale time-deposits with longer stated maturities had much more room to fall in absolute terms. The vector of controls includes other factors that could explain the response of a banks' stock price to the NIRP announcement, including the return on assets, dividend yield, risk-weighted assets divided by total assets, assets, the square of assets, the capital ratio, and loan exposures to different industries. Bank-level financial information is gathered from S&P Global Market Intelligence (formerly SNL Financial).

The results are reported in Table 1, and show that at all time horizons, the change in a bank's stock price was negatively associated with its reserve holdings, and positively associated with its share of wholesale deposit funding. These results are consistent with contemporaneous explanations that NIRP would threaten bank profits. Lastly, we note that although we focus on the 40 minute price change in the analysis below, our results are robust to using longer 1 or 2 day windows. As we later show in robustness tests, our results are not sensitive to using abnormal returns that strip out the portion of each stock's response that can be accounted for by changes in stock prices, JGB yields, or exchange rates.

3.2 Banking and economic conditions in Japan, and the policy risks of NIRP

Although NIRP evidently posed issues for banks in Japan, it is not necessarily the case that NIRP has the same deleterious implications for banks when implemented in other countries, particularly at only -0.1%. In fact, the experience when other central banks have cut rates into negative territory indicates that the Japanese experience is unique, as shown in Figures 6–9.

[4]Banks can engage in transactions to reduce their individual reserve holdings in response to a shock, though we note that some features of a banks' business models may necessitate higher-levels of reserves relative to assets.

It is likely that some features of the Japanese economy and financial sector uniquely expose Japanese banks to even modestly negative rates. Such factors could lead to a higher effective lower bound or "reversal rate" (Brunnermeier and Koby 2017) in Japan compared with other countries.

First, as shown in the first two columns of Table 2, currency in circulation in Japan is substantially higher than that for other G7 countries and other NIRP countries. In fact, after the introduction of NIRP, sales of safes spiked, and production of high-denomination ¥10,000 notes increased as demand for hard currency grew. Even if banks could pass on negative rates to their depositors, a willingness to substitute into other assets, such as currency, can still present issues for banks (Arseneau 2017). For this reason, the more common practice of hoarding physical cash in Japan likely raises the effective lower bound relative to other countries.

Also evident in Table 2 is the heavy reliance of Japanese banks on deposit funding. To the extent that this reliance limits banks' ability to pass on lower rates to deposit holders, profit margins would be disproportionately squeezed in Japan (Heider et al. 2017).[5]

Another unique feature of the Japanese banking environment relative to other countries that have adopted NIRP is the high level of reserves. Figure 10 plots home-country (or monetary area in the case of the ECB) central bank assets minus central bank capital and total currency in circulation as a percent of total banking system assets. Essentially, Figure 10 shows the aggregate reserve composition of bank assets. Banks in countries with higher values of this measure may be more negatively affected by NIRP, because the central bank levies a fee on a larger share of banks' assets. It is clear that at the time of the NIRP announcement in 2016, Japan was on pace to have the highest reserves-to-assets ratio of any country. Only the US witnessed comparable levels at the end of QE3. While redemptions and the growth of currency produce a declining measure for the US, the continuation of QQE in Japan means that banks could anticipate this measure to rise further in coming years.

Finally, the low interest rates that persisted for well over a decade in Japan before the finan-

[5] Only Canada and the U.S. have similar levels of deposit funding. Neither the Bank of Canada nor the Federal Reserve bank opted to implement NIRP.

cial crisis resulted in an unfavorable composition of net interest margins (NIMs). Specifically, Japanese banks had reduced interest expense nearly as much as possible prior to the introduction of NIRP, leaving little room to offset the blow to interest income. As seen in Figure 11, the rate paid on bank liabilities in Japan was roughly constant from 2011 through 2016. Conversely, banks in other countries had comparatively high liability yields. Consequently, banks facing falling and ultimately negative policy rates in other countries were able to react to the reduction in interest income by simultaneously reducing their interest expense. Although NIMs in other NIRP countries have been roughly stable, they have fallen from already low levels in Japan. We additionally note that NIM compression during a protracted period of ultra-low rates is a mechanism by which the reversal rate can edge up over time in the model of Brunnermeier and Koby (2017).

In summary, it appears that the frictions presented when breaching the zero "lower bound" combined with the unique features of the Japanese economy and banking environment to produce an adverse outcome for banks. The ultimate effects of NIRP could therefore depend upon the response of banks to the anticipated profit shock. As we demonstrate in the next section, banks face a trade-off between profit stability and risk-taking. Although the decline in profitability could result in a credit supply contraction (Kishan and Opiela 2000; Van den Heuvel 2002) thereby reducing the efficacy of NIRP, if banks take on additional risk to mitigate the effects on profits, this could counteract the contraction and preserve the accommodative effects of rate cuts under NIRP.

4 Theoretical Motivation

In this section, we provide a simple theoretical framework to motivate how and why banks may take on additional risk to reduce reported losses that stem from an industry-wide profit shock such as NIRP. First, we assume banks are loss-averse in future profit changes. Facing a negative profit shock, banks will then engage in practices that can offset a fall in reported profits. Particularly in publicly-traded banks, the literature has documented banks' willingness to offset declines in profits by possibly undermining their safety and soundness (see, e.g., Beatty et al. 2002, Willman et al. 2002).

As a result of banks' loss aversion to profit declines, we specify a state-dependent profit function as follows:

$$\pi_{it} = \begin{cases} \Gamma_i \cdot \Phi_i + \alpha_i \varepsilon_t & \varepsilon_t \geq 0 \\ \Gamma_i \cdot \Phi_i + r_i(\varepsilon_t) + \alpha_i \varepsilon_t & \varepsilon_t < 0 \end{cases}$$

$$\text{where } r_i(\varepsilon_t) \geq 0;\ r_i'(\varepsilon_t) < 0;\ r_i''(\varepsilon_t) < 0$$
$$\text{and } r_i'(\varepsilon_t) = 0 \text{ for } r_i(\varepsilon_t) > R_i^*.$$

A bank's profit is determined by a vector of typical factors Φ_i (such as overhead, borrowing costs, wages, fee income, etc.), from which we abstract. Additionally, profits are affected by an industry-wide shock, ε_t, to which banks are differentially exposed ($\alpha_i > 0$). An individual bank's sensitivity may differ depending on the nature of the industry-wide shock. Banks passively accept the abnormal industry-wide profit shock if it is nonnegative. If the shock is negative, however, banks engage in some degree of *abnormal* risk-taking determined by $r_i(\varepsilon_t)$. In this setting, banks engage in abnormal risk taking until their ability or willingness to offset a profit decline is exhausted at R_i^*. This maximum level of abnormal risk taking can be motivated by, among other things, regulatory capital or liquidity requirements, asset holding restrictions, management preferences/risk aversion, debt covenants, or supervisory pressure.

To the extent that NIRP represents a substantial negative shock to the banking sector, banks would maximize profits conditional on the expected value of ε_t. The first order condition yields the simple relationship:

$$-r_i'(\varepsilon_t) = \alpha_i$$

$$\text{s.t. } r_i(\varepsilon_t) \leq R_i^*.$$

This relationship implies that a bank will set the marginal benefit of abnormal risk taking equal to the (bank-specific) marginal cost of the industry-wide profitability shock. In other words, banks' loss-aversion with respect to future profit changes would cause them to take more risks to compensate for the expected reduction in earnings caused by NIRP. For a given shock ε_t, more exposed banks would optimally choose to shift up their abnormal risk taking function more than less exposed banks.[6] If banks' additional risk taking simply takes the form of higher leverage, insufficient loan loss provisioning, etc., then the effects of NIRP on the banking system will only serve to increase its financial vulnerability. However, if banks in part take on additional risk by easing credit standards, lending to riskier borrowers and increasing credit supply, the stimulative transmission of NIRP through the banking system can be preserved.

5 Measuring Japanese Banks' Response to NIRP: Data, Methods, and Results

5.1 Data

To measure how Japanese banks' profits and risk taking evolved after the implementation of NIRP, we merge data from three main sources. First, we collect balance sheet and income statement items for each bank from S&P Global Market Intelligence (formerly SNL Financial). Because some of the detailed line-items we require for our analysis are not reported for each individual quarter, we sample at the annual frequency. We do not view this as a particularly significant limitation, however, as banks' financial positions can take time to adjust. Second, we use a measure of expected default probability from the Kamakura Corporation. In particular, we examine the 5-year Kamakura Default Probability to assess changes in banks' creditworthiness. Kamakura Default Probability scores have been shown to perform well relative to other commonly used measures of expected default frequency. Finally, we collect stock price information from Bloomberg.[7]

[6] Although we have presented a simple static problem, a bank could be thought to maximize the discounted sum of future profits. If banks' current abnormal risk taking adversely affects future profits, this could mitigate banks' willingness to engage in measures to offset profit shocks. However, even if the current increase in profits was offset one for one in future periods, discounting implies that there must be some values of the parameters for which banks will optimally engage in additional risk taking today. Moreover, short-termism may cause discount rates to be somewhat higher for publicly traded firms.

[7] Stock price responses to NIRP are measured beginning in February 2016, after the announcement.

A summary of some key variables is presented in Table 3. Data are reported for the entire sample of banks, the highest 40-minute stock return tercile (i.e., the least affected banks), and the lowest tercile, as indicated. NIMs dropped a bit overall for both cohorts during the first year of NIRP, but no stark differences were present between the two groups. Return on average assets fell about 17 basis points from already low levels after the introduction of NIRP, with nearly identical declines for both groups of banks. Although banks' profits clearly declined under the negative rate regime, univariate results do not demonstrate any stark differences between more and less exposed cohorts.

Neither group altered its loan share of assets much, with both hovering around 60%. One notable feature of data is that a few very large banks in the lowest tercile skew the average assets higher for this group (the medians are much closer).[8] The most affected banks witnessed a smaller reduction in the yield on their overall loan portfolio, and their capital-to-asset ratios did not increase as much over the year. Turning to other measures of risk taking, the banks that were expected to be more affected by NIRP saw their z-scores fall more, the volatility of their stock price increase more, their distance to default decrease more, and their 5-year default probability increase more. This pattern—more exposed banks becoming riskier—is consistent with the stylized model outlined above. For all banks, the changes in z-scores, standard deviation of stock returns, distance to default, and 5-year default probability all point to an increase in bank riskiness after the implementation of NIRP.

5.2 Results

5.2.1 The Effect of NIRP on Bank Profits

In our first analysis, we examine the effect of NIRP exposure on profits in the year after the announcement. We take two approaches to estimating this relationship. In the first specification, we estimate a straightforward cross-sectional regression in order to examine the effect of banks'

[8] By far, the largest Japanese banks in the sample are Mitsubishi UFJ, Japan Post, Mizuho Financial, and Sumitomo Mitsui Financial. Three of these banks are in the lowest tercile, while the fourth is in neither group. Excluding these banks from our sample does not change the conclusions reached below.

exposure to NIRP on their realized profits under NIRP:

$$\Delta y_i = \alpha + \beta \cdot \Delta \text{Price}_{i,40\text{min}} + \boldsymbol{\Phi'} \boldsymbol{X_i} + \varepsilon_{it}. \quad (2)$$

In Equation (2), Δy_i represents the change in a measure of bank profits under NIRP (i.e. from 2015 to 2016). The coefficient of interest is β, which measures the extent to which the percent change in banks' stock price responses on announcement predict future profit growth. The vector of controls, $\boldsymbol{X_i}$, includes the return on assets, dividend yield, loans to total assets, risk weighted assets to total assets, leverage ratio, total assets, total assets squared, and industry loan shares. Even though all non-financial industries reacted positively to the NIRP announcement, the industry loan shares are included to account for the possibility that banks' differential responses to the announcement reflects differences in the anticipated fortunes of their borrowers.[9]

Our second method employs a difference-in-differences strategy wherein treatment is measured with a continuous variable that again captures banks' differential exposure to NIRP:

$$y_{it} = \alpha + \beta \cdot (\Delta \text{Price}_{i,40\text{min}} \times D_{\text{NIRP}}) + \gamma_i + \delta_t + \boldsymbol{\Phi'}(\boldsymbol{X_{i,2015}} \cdot D_{\text{NIRP}}) + \varepsilon_{it}. \quad (3)$$

In Equation (3), y_{it} represents the level or log-level of each measure of bank profits from 2014-2016, with β again being the coefficient of interest. In order to avoid a bad control problem, bank-level covariates are measured as of year-end 2015 and interacted with a post-treatment "NIRP" dummy that takes a value of one in 2016.

In Table 4, we present the results for each specification with and without bank controls, as indicated. None of our measures of bank profitability—net interest margins, earnings per share, and net income—show any clear relationship with changes in banks' stock prices around the time of the NIRP announcement.

While this may be surprising based on the contemporaneous explanations for changes in bank share prices after the NIRP announcement, our theoretical framework presented in Section 4 offers a possible explanation. In particular, it may be that banks that were more exposed to

[9]In Section 6, we offer additional evidence that this is not the case by examining banks' abnormal returns.

NIRP took on more risk in order to at least partially offset the profit declines that NIRP would have otherwise induced. Thus, sharp stock price declines may still be justified as investors would require a higher rate of return in the event that banks insulate their profits by boosting risk taking. We now turn to an exploration of the relationship between banks' exposure to negative policy rates and changes in risk-taking under the NIRP regime.

5.2.2 The Effect of NIRP on Bank Risk Taking and Lending

To measure the effect of NIRP on bank risk taking, we estimate a series of regressions that mirror those described by Equations (2) and (3) above. In our first exercise, Δy_i and y_{it} represent various measures of bank risk taking that are at least in part based on market-based outcomes.

The results for our first measure of bank risk, the standard deviation of daily returns, are presented on the left side of Table 5. Evidently, banks that experienced larger stock price declines immediately after NIRP was announced witnessed more volatility in their stock price in the year after the announcement. The coefficient of -0.08 in column (4) implies that a 1 percentage point decline in a bank's stock price response to the NIRP announcement resulted in a roughly 4% increase in the standard deviation of daily returns (Table 3, columnn 1).

In the middle columns of Table 5, we show the results for banks' distance to default. As expected, a larger fall in a bank's stock price at impact corresponds to a smaller distance to default by the end of the first year of NIRP. This result also suggests that banks that are more exposed to the negative effects of NIRP became riskier after its implementation.

The final result in Table 5 offers further support for this conclusion by regressing the percent change (or log-level in the difference-in-differences specification) in the 5-year Kamakura Default Probability (KDP) on banks' NIRP response. Across all specifications, the coefficients imply that a one percentage point decline in a bank's stock price resulted in between a 10 and 15% higher probability of default within the next five years. Consistent with the previous results, it appears that banks that are more exposed to NIRP increase their chances of failure. In total, our first set of market based risk taking measures offers evidence that Japanese banks became riskier on average under NIRP, and the degree of riskiness increases in a bank's exposure to NIRP.

To demonstrate that banks indeed became riskier after NIRP, we next examine banks' balance sheet responses to NIRP exposure in Table 6. First, on the left side of the table, we find that z-scores decreased more for banks that were more exposed to NIRP, indicating an increase in riskiness. In the middle columns, we find some evidence that asset growth was higher for banks that were more exposed to NIRP. Attempting to outgrow profitability concerns is a strategy that has been well documented in the banking literature (Capie and Wood 1991; Beck and Casu 2017). However, we note that conventional levels of statistical significance are not achieved in the cross-sectional specifications in columns (1) and (3). Even if banks' asset growth did not differ by NIRP exposure, we show in the rightmost columns of Table 6 that capitalization levels did not improve as much for those banks that were expected to be more affected under a NIRP regime.[10] For context, the coefficient of 0.58 in column (4) implies that an increased exposure to NIRP characterized by a 1 percentage point decline in stock price corresponds to a 0.58%, or 0.04 percentage point, decrease in a bank's capital-to-asset ratio.

If the increase in banks' risk taking is confined to actions such as under-provisioning for loan losses and increasing leverage, then the response to NIRP may simply increase fragility in the financial sector. If, however, banks also engage in activity that would translate into faster economic growth—such as increasing the supply of lending to credit-constrained borrowers—the stimulative transmission of rate cuts through the banking system would be preserved under negative rates.

To this end, we turn our focus to banks' lending activity in our next set of tests. The results for our first outcome variable—the weighted-average interest rate on each bank's loan portfolio—are presented on the left of Table 7. In columns (1) and (2), we find that banks with more exposure to NIRP wound up with a relatively higher average interest rate after NIRP was implemented. Interest rates on loans can be indicative of increased risk taking, but it could

[10]Recall that there was no difference in changes in profitability between banks that were differentially affected by NIRP. Also, as shown in Table 3, more-affected banks did not have higher dividend yields. Consequently, the change in capital is not likely to be explained by differences in retained earnings.

also be that banks that are more exposed to NIRP were simply more exposed to industries that would fare worse under negative rates.[11] For this reason, we introduce industry lending shares as controls in columns (3) and (4), along with the standard complement of bank characteristics and the 2015 loan yield. Although the point estimates are a bit lower in these specifications, the point estimates still imply that a 1 percentage point decline in a bank's stock price resulted in loan portfolio yield that was 0.6 basis points higher. This confirms the pattern evident in the univariate results reported in Table 3.

Banks can also increase risk taking through their loan portfolios by boosting their maturity risk. In fact, choosing to extend loan maturities may drive the loan portfolio yield results just described. On the right side of Table 7, we find some evidence of this behavior, with longer-maturity loans expanding more for banks with business models that were most affected by NIRP.

Finally, we investigate whether NIRP exposure can explain differences in credit supply under negative rates. If institutions boosted their appetite for risk to counteract the potential hit to profits, credit standards might be relaxed, and a relative increase in credit supply would result.[12] To test this channel, we estimate Khwaja and Mian (2008)-style regressions, using a bank-industry credit panel. With these data, we are able to control for differences in loan demand across industries with a fixed effect for each industry j as follows:

$$\Delta ln(Loans_{ij}) = \alpha + \beta \cdot \Delta \text{Price}_{i,40\text{min}} + \gamma_j + \boldsymbol{\Phi' X_i} + \varepsilon_{ij}. \quad (4)$$

Each observation used in the estimation of Equation 4 contains the volume of lending between each bank-industry pair, such that β measures the effect of a one percentage point change in a bank i's stock price around the announcement of NIRP on the percent change in its average supply of credit after controlling for industry-level loan demand.

As before, we also estimate a difference-in-differences version of Equation 4 that uses three years of data and measures the dependent variable in log-levels, with errors again clustered at

[11] As documented in Section 3, however, all non-financial industries were expected to benefit from the introduction of NIRP.

[12] We note that this could also explain the relative increase in the yield on loans that we documented above.

the bank level. For this specification, we construct a three-dimensional (bank-industry-time) panel that allows us to include industry-year fixed effects and thus remove industry specific factors affecting loan demand in a given year:

$$ln(Loans_{ijt}) = \alpha + \beta \cdot (\Delta\text{Price}_{i,40\text{min}} \times D_{\text{NIRP}}) + \eta_i + \gamma_j \cdot \delta_t + \boldsymbol{\Phi'}(\boldsymbol{X_{i,2015}} \cdot D_{\text{NIRP}}) + \varepsilon_{ijt}. \quad (5)$$

As shown in Table 8, the more that NIRP threatens a bank's business model, the more that bank increased its credit supply. The point estimates of the key coefficient in Table 8 imply that for every one percentage point change in a bank's stock price at announcement, its credit supply expanded by between 0.5 and 2.9% over the year on average. The upper end of the estimate (column 4) seems particularly large in light of the average bank-industry loan growth in 2016 of about 3%. We note that the standard deviation of bank-industry loan growth is rather large (2.9% equals about 20% of the standard deviation of annual loan growth).

5.3 Discussion

The results described above offer insight in how Japanese banks responded to the pressures imposed by negative rate policy. Given their high deposit funding, inability to further reduce their funding costs after decades of ZIRP, and large (and growing) central bank balances, Japanese banks stood to experience a decline in profitability owing to NIRP, as was widely reported at the time. However, banks with business models that were more susceptible to NIRP apparently counteracted the additional pressures on profit margins at least in part by taking on more risk relative to less exposed banks.

Specifically, we find that banks' stock price volatility, distance to default, and 5-year default probability all increased as their sensitivity to NIRP increased. These banks saw higher z-scores and became more levered relative to less affected banks. We also find evidence that more affected banks accumulated higher interest rate loans with longer maturities. Such behavior can be explained by an easing of lending standards, which is corroborated by the results of tests showing a relative increase in loan supply by banks with business models that were more exposed to NIRP. Therefore, it appears that interest rate cuts into negative territory, at least for the level of negative policy rates we observe, still positively affect credit supply.

Judging the amount of risk taking that is considered excessive is beyond the scope of this paper, but we note that such a response by banks could be desired by the central bank. This is because one of the goals of unconventional policy measures is to restore a healthy amount of risk taking to an overly timid financial system. Relative to other countries, however, excessive risk taking by banks in Japan does not presently appear to be a significant concern.

6 Robustness: Abnormal Returns and Longer Event Windows

In this section, we establish robustness to different formulations of our key measure of NIRP exposure. We first address the possibility that banks' stock prices responded to movements in other financial benchmarks. This may be of interest given the relatively sharp changes in stock prices and yields witnessed around the NIRP announcement. Insofar as these movements in financial markets were caused by the introduction of NIRP, it is not clear that cleansing their explanatory power from our measure of NIRP exposure is warranted if we wish to measure the effects of NIRP (broadly defined) on bank behavior. To the extent that we are interested in how the implementation of NIRP affects banks' business models on an ongoing basis, it may be useful to purge our exposure measure of effects owing to high-frequency changes in financial markets. For instance, it may be that some banks or their customers are simply more cyclically sensitive than others. If the rise in the broad stock market upon the NIRP announcement reflects an expected increase in aggregate demand, the more cyclically sensitive banks may respond accordingly.

To this end, we calculate bank-specific betas for several financial benchmarks to measure their systematic risk. Specifically, we measure the sensitivity of each stock to changes in the stock market, 10-year JGB yields, and the U.S. dollar-Japanese Yen currency pair.[13]

$$\begin{aligned}\Delta ln(\text{Price}_t) = \alpha + \beta_{Stock} \cdot \Delta ln(\text{Topix}_t) + \beta_{Bond} \cdot \Delta(\text{JGB10}_t) \\ + \beta_{Currency} \cdot \Delta ln(\text{USDJPY}_t) + \varepsilon_t\end{aligned} \tag{6}$$

Equation 6 is estimated for each stock for the calendar year prior to the NIRP announcement. We then calculate abnormal stock price responses using the estimated betas as follows:

$$\begin{aligned}\widehat{\Delta\text{Price}}_{i,40\text{min}} = \Delta ln(\text{Price}_{i,40\text{min}}) - \hat{\beta}_{i,Stock} \cdot \Delta ln(\text{Topix}_{40\text{min}}) - \hat{\beta}_{i,Bond} \cdot \Delta(\text{JGB10}_{40\text{min}}) \\ - \hat{\beta}_{i,Currency} \cdot \Delta ln(\text{USDJPY}_{40\text{min}}).\end{aligned} \tag{7}$$

Having cleansed our stock price responses of the portion owing merely to their systematic risk according to equation 7, we proceed to regress our dependent variables on this new measure of NIRP exposure. For brevity, we report only the richest specifications in the left two columns of Table 6. The first column contains the coefficient estimates on NIRP exposure for cross-sectional regressions, and the second column lists the coefficient estimates from the DiD regressions. Comparing against the earlier results, it is clear that accounting for banks' systematic risk and cyclical exposure does not alter our conclusions.

Lastly, we consider a longer event window around the NIRP announcement. In the rightmost columns of Table 6, we report the results using the percent change in banks' stock prices over a two day period. As before, we observe no statistically significance using measures of profits as the dependent variable, while market-based measures of riskiness point to similar conclusions. Balance-sheet based measures of risk-taking do not achieve conventional levels of statistical significance, but the sign of the point estimates is preserved. Most importantly, as shown in the bottom two rows, we continue to find evidence that more affected banks extended the maturity of their loan portfolios, while also increasing their supply of credit relative to less affected banks.

7 Placebo Tests: Prior BoJ Interest Rate Cuts

In this section, we show that banks' reaction to the NIRP announcement was uncharacteristic. Specifically, we examine the reaction to the two rate cuts prior to the introduction of NIRP.

[13]Our results are very similar if we limit the exercise to the stock market only.

We find that the effects of negative rates are indeed special, consistent with Heider et al. (2017) and Nucera et al. (2017).

First, Figure 12 shows the reaction to the December 2008 reduction in the overnight call rate by 20 bps to 0.1%. Contrary to the NIRP reaction, bank shares tracked the overall Topix Index closely. Similarly, Figure 13 shows the reaction to the October 2010 reduction in the call rate to a range of 0 to 0.1%. This policy action represented a clear accommodative surprise, and also included an announcement of a QE program. Again, Japanese bank stocks responded to policy easing in much the same way as the broader set of industries. The reaction to NIRP (Figure 2) was starkly different from the typical reaction to policy accommodation delivered through either a reduction in the call rate or a QE program.

To confirm this, we estimate stock price determinants regressions for our sample of Japanese banks for each of the two earlier policy actions. Table 10 shows key determinants that have been identified as predictors of the reaction to NIRP in 2016. The patterns evident in Panels A (2008 call rate cut) and B (2010 call rate cut and QE) do not follow the patterns that emerged upon the announcement of negative rates. Specifically, reserves do not appear to predict returns, with very imprecise estimates in general. In the one specification with a highly significant result (Panel A Column 1), the sign is reversed from that seen earlier. The share of wholesale deposit funding is also generally insignificantly different from zero. When this is not the case, the point estimates are much smaller than those observed in the wake of the NIRP announcement.

Importantly, we note that the R^2 is very low in both absolute terms and compared with the values reported in Table 1. Evidently, banks' holdings of reserves and time deposits did not explain much of the variation in stock price moves at the 40 minute horizon. In both prior episodes, these characteristics explained none of the variation in stock price movements by the close of the trading day following the announcement (shown in the rightmost columns). We therefore conclude that banks face special challenges under NIRP that are not present in a nonnegative interest rate environment.

8 Conclusion

For central banks that have imposed or considered negative interest rates to counter a weak economy, the possibly adverse effects on the banking sector are often cited as cause for caution. Complicating this matter is the fact that banks' exposure to NIRP is multifaceted and difficult to measure. Such complications frustrate attempts to study the impact of NIRP on banks.

In this paper, we overcome these problems by using a novel measure of banks' net exposure to NIRP by isolating the response of bank stock prices in the wake of an entirely unexpected NIRP announcement by the Bank of Japan. In this way, we are able to extract a single summary statistic that measures the extent to which a bank's business model is threatened by the move to negative rates.

We find that banks responded to the prospect of a NIRP-induced profit shock by broadening their appetite for risk, which included an increase in credit supply. Consequently, our results demonstrate that the transmission of monetary policy through banks is preserved when nominal rates are negative. However, central banks that are concerned about the extent of risk taking in the banking system may find reason for caution in our results. We have also begun to identify several characteristics of the banking and economic environment that contribute to an adverse effect on financial companies. However, further research is needed to identify the effective lower bound in each country, and to determine whether and at what point the strain on profits imposed by NIRP outstrips banks' ability or willingness to counteract profit pressures via additional risk taking.

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Figure 1: **Unsecured overnight call rate**

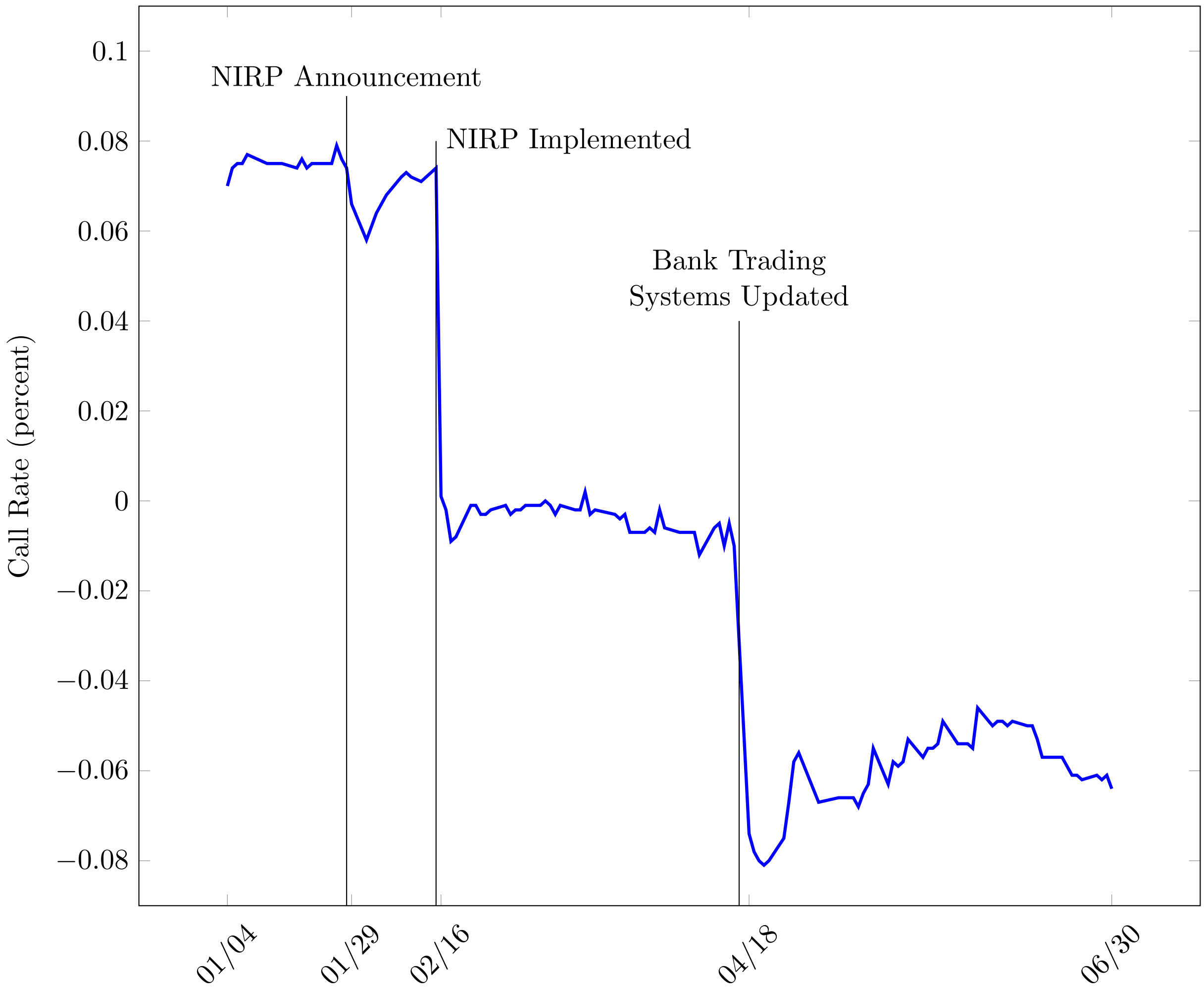


Figure 2: **Topix and Topix Bank Index**

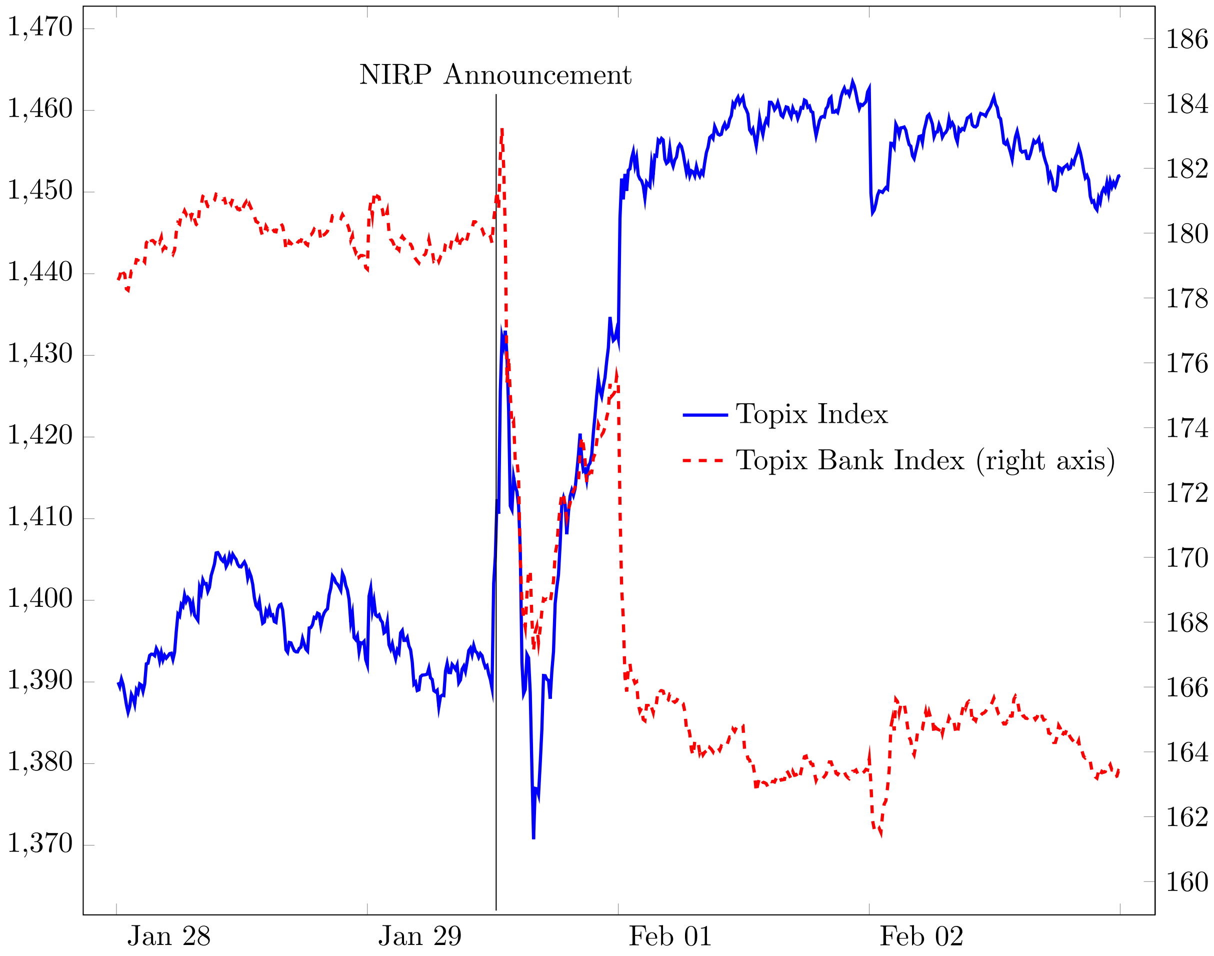
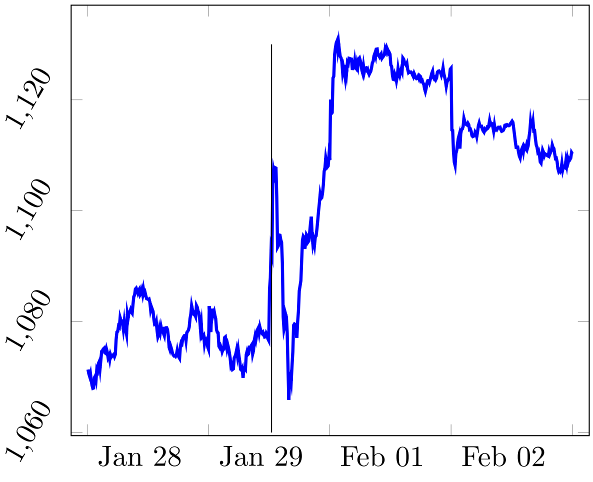
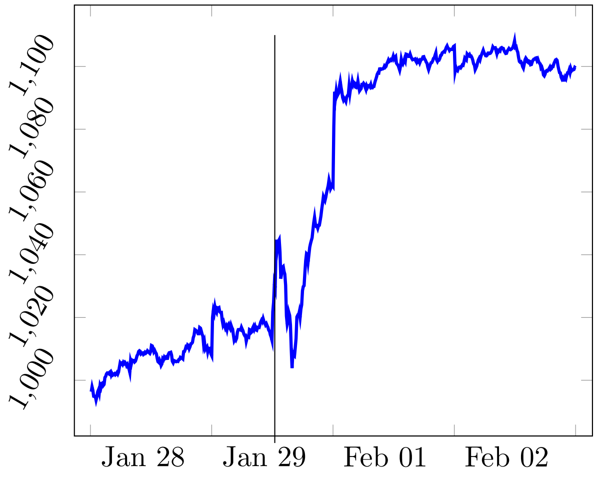


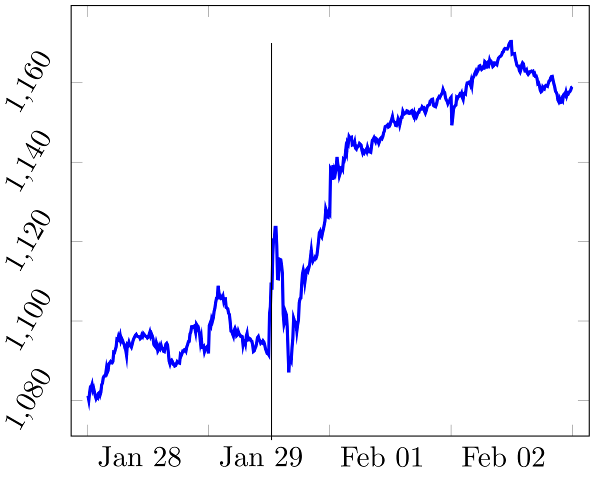
Figure 3: **Nonfinancial Industry Response to NIRP**



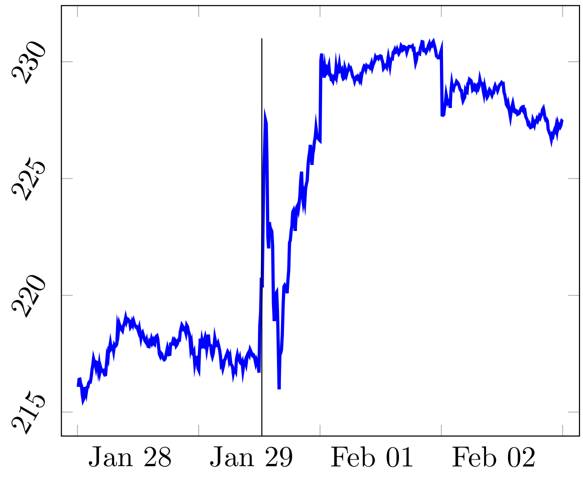
(a) Wholesale Trade



(b) Construction



(c) Retail Trade



(d) Autos & Transport.

Figure 4: **Bank stock price changes around NIRP announcement**

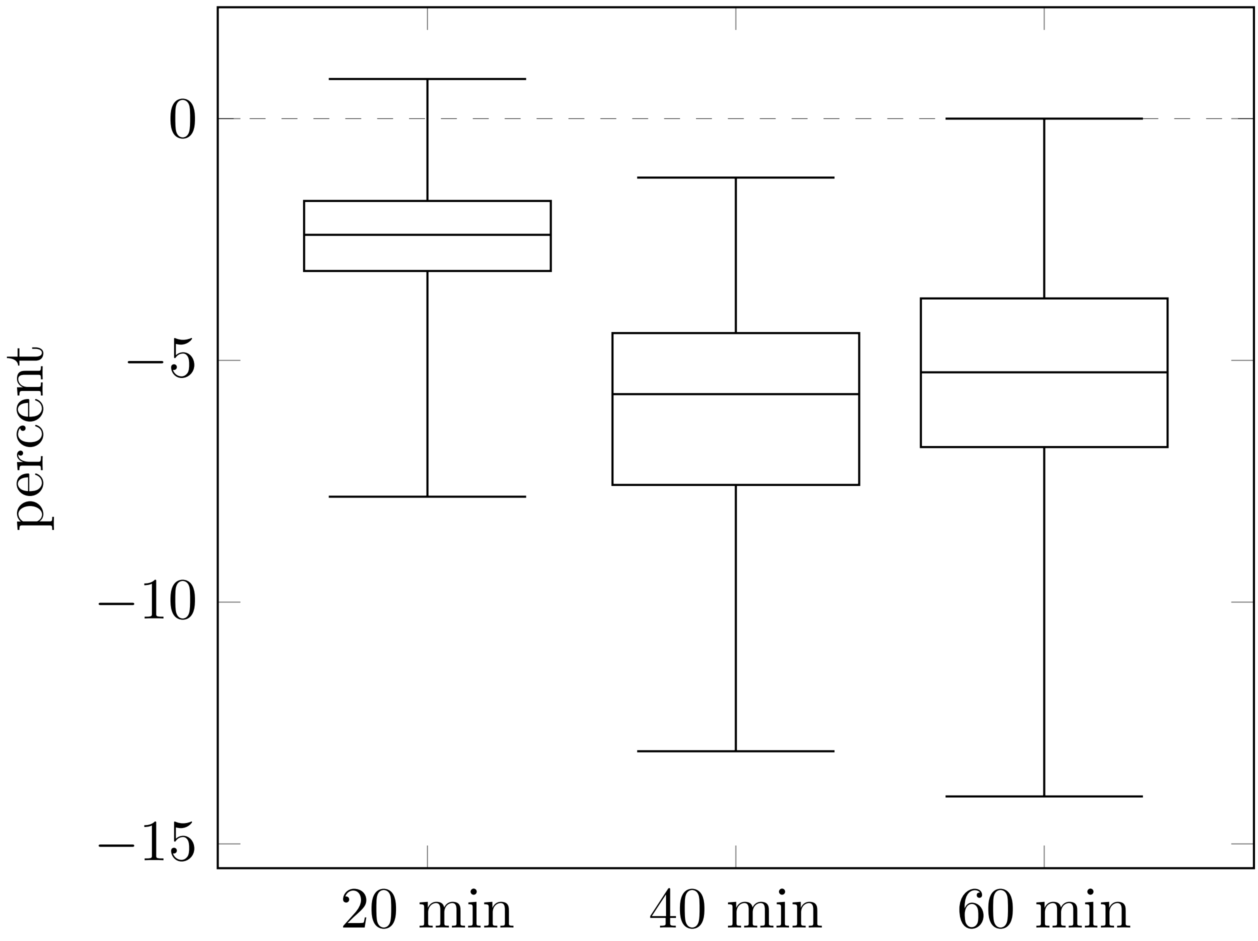


Figure 5: **Deposit rates paid by Japanese banks**

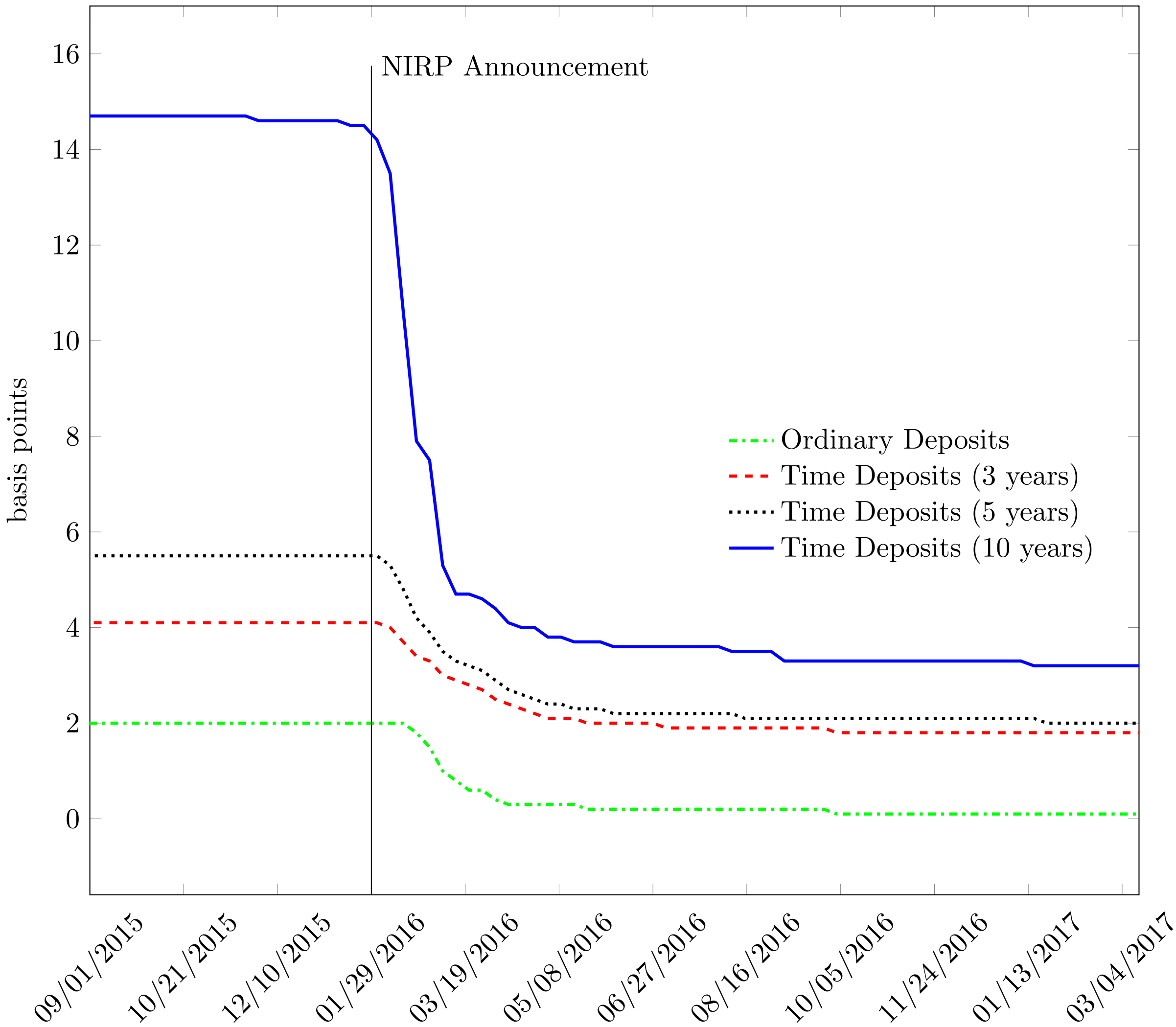
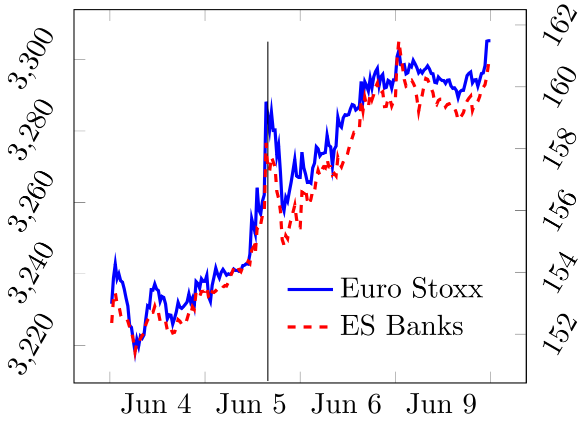
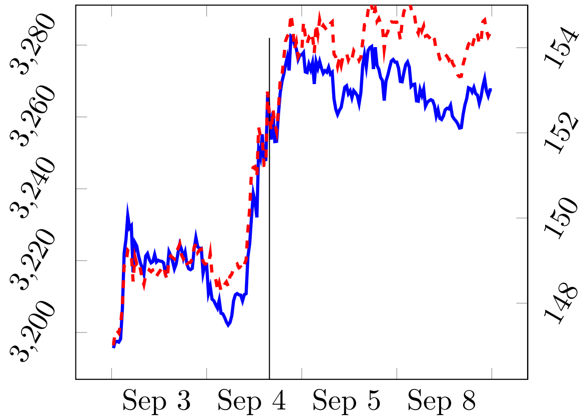


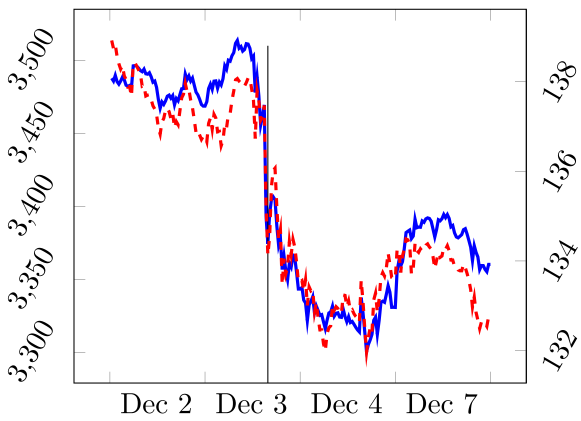
Figure 6: **Reaction to ECB Negative Rate Cuts**



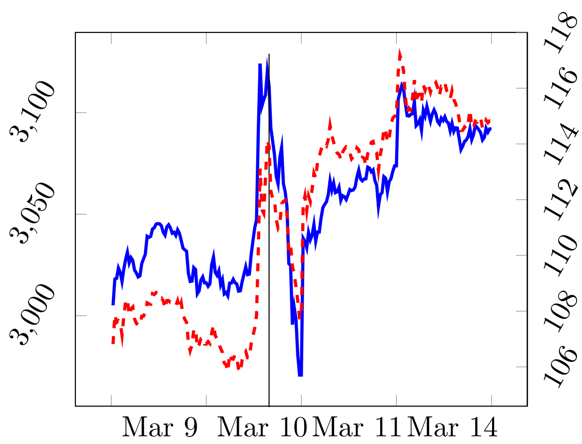
(a) June 5, 2014



(b) September 4, 2014

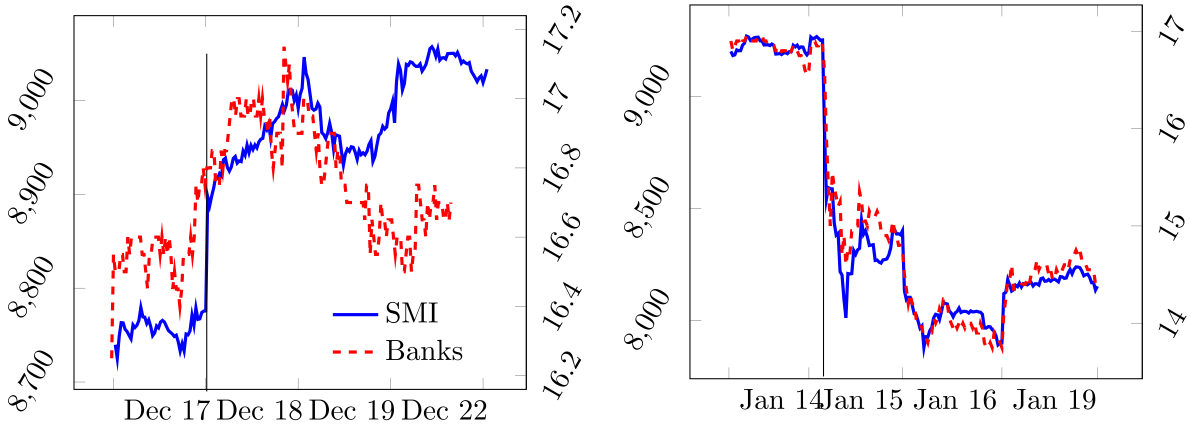


(c) December 3, 2015



(d) March 10, 2016

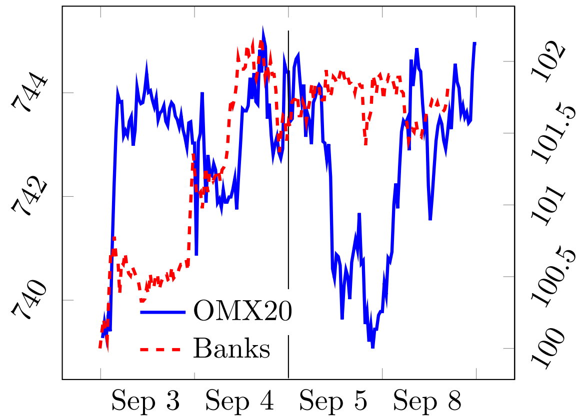
Figure 7: **Reaction to SNB Negative Rate Cuts**



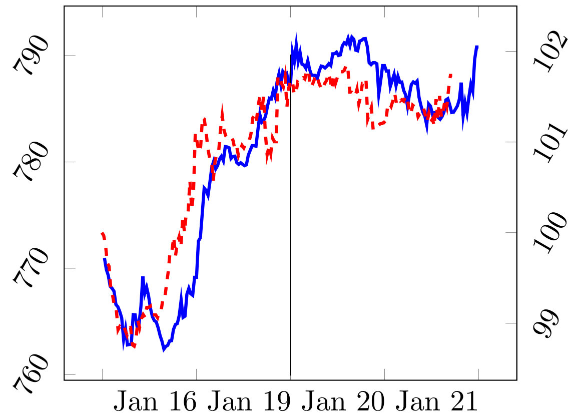
(a) December 18, 2014

(b) January 15, 2015

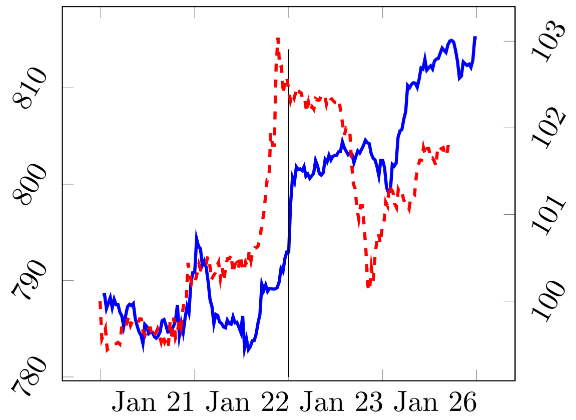
Figure 8: **Reaction to DNB Negative Rate Cuts**



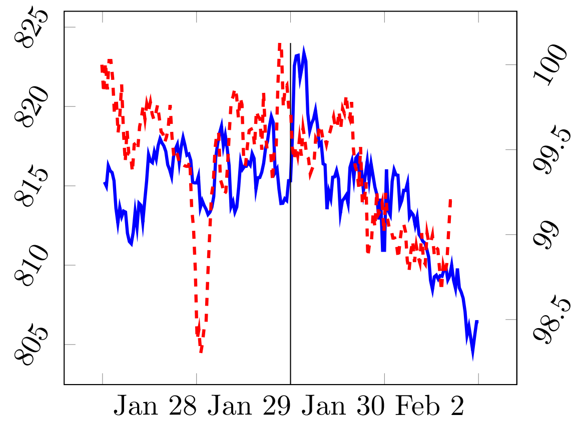
(a) September 4, 2014



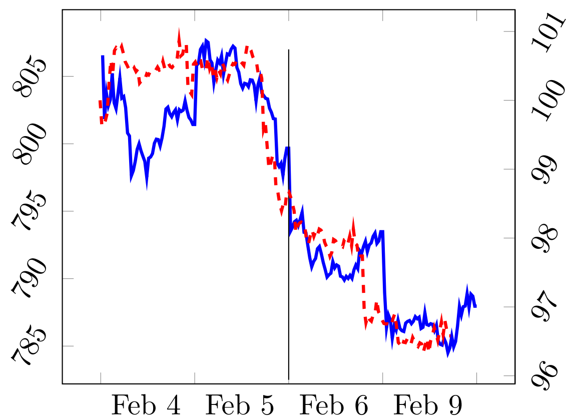
(b) January 19, 2015



(c) January 22, 2015

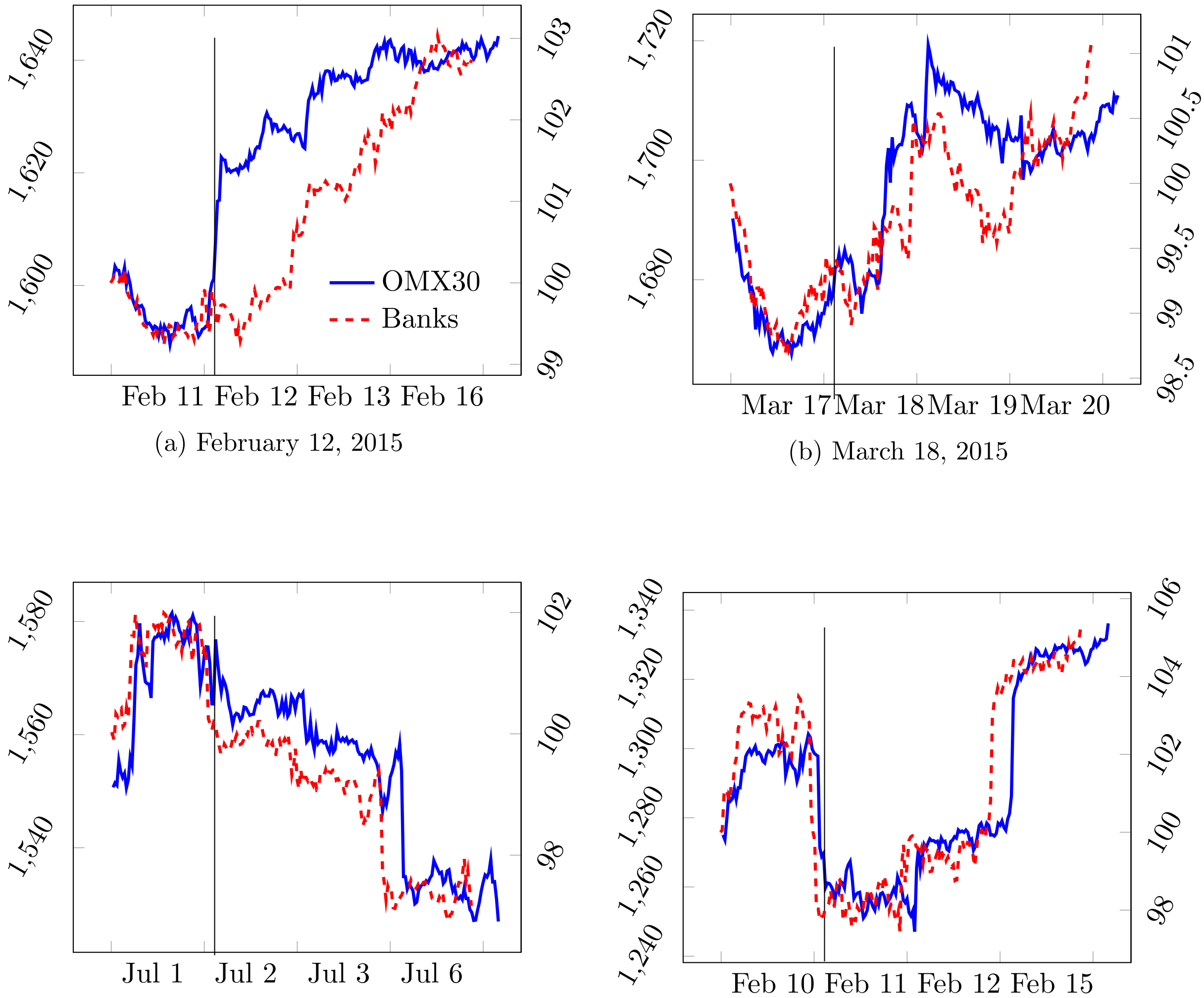


(d) January 29, 2015



(e) February 5, 2016

Figure 9: **Reaction to Riksbank Negative Rate Cuts**



(a) February 12, 2015

(b) March 18, 2015

(c) July 2, 2015

(d) February 11, 2016

Figure 10: **Central Bank Assets Minus Capital and Currency as a Percent of Banking System Assets**

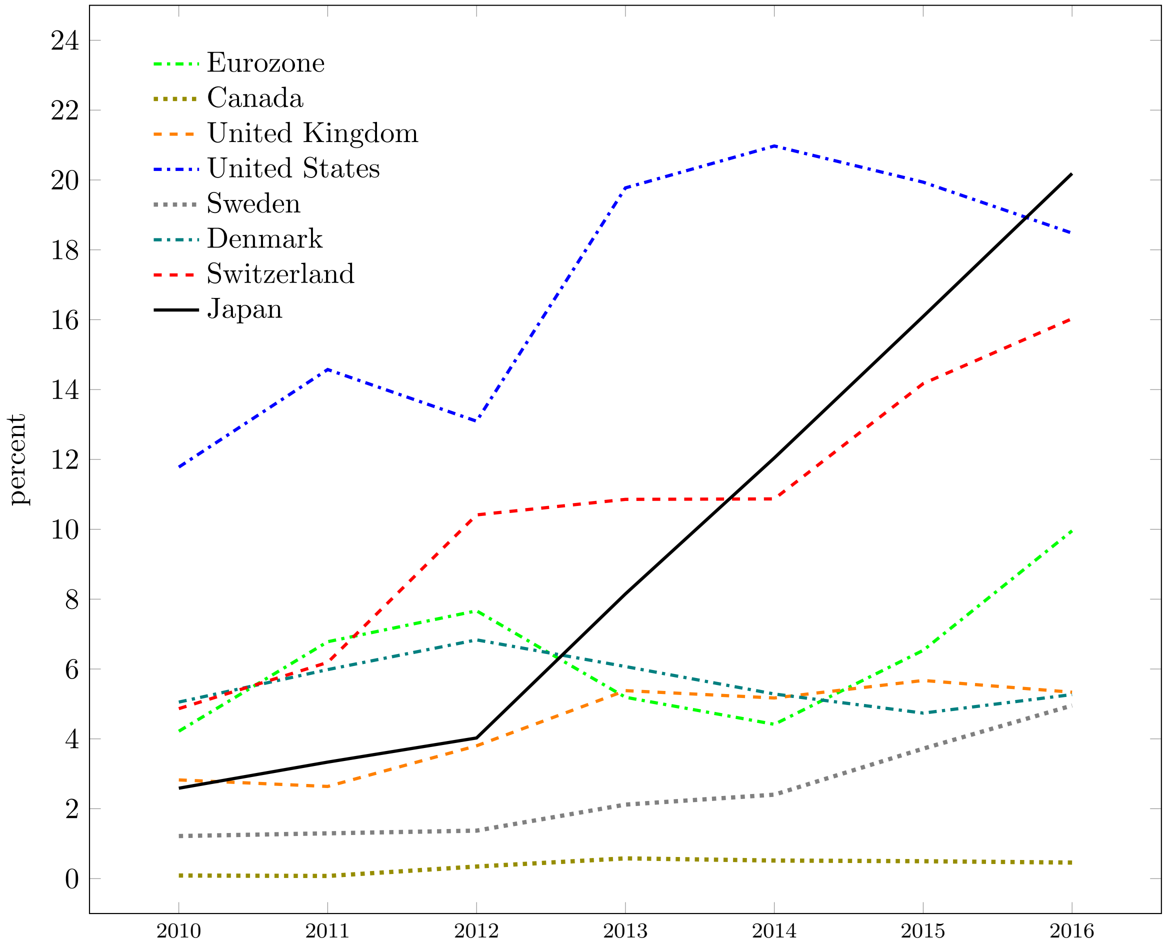
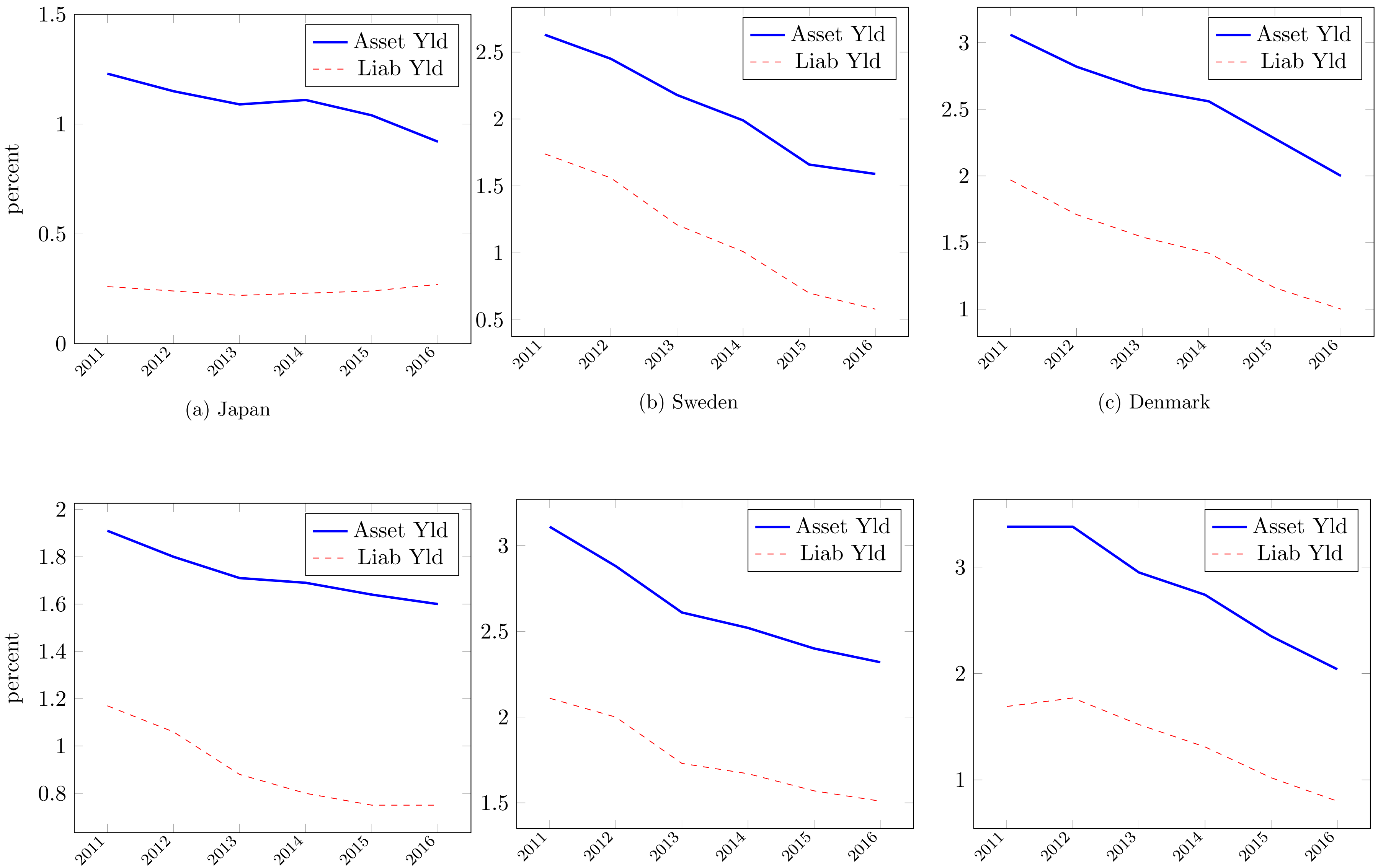


Figure 11: **Components of Net Interest Margins by Country**



(a) Japan

(b) Sweden

(c) Denmark

(d) Switzerland

(e) France

(f) Italy

Figure 12: **Topix and Topix Bank Index (December 2008)**

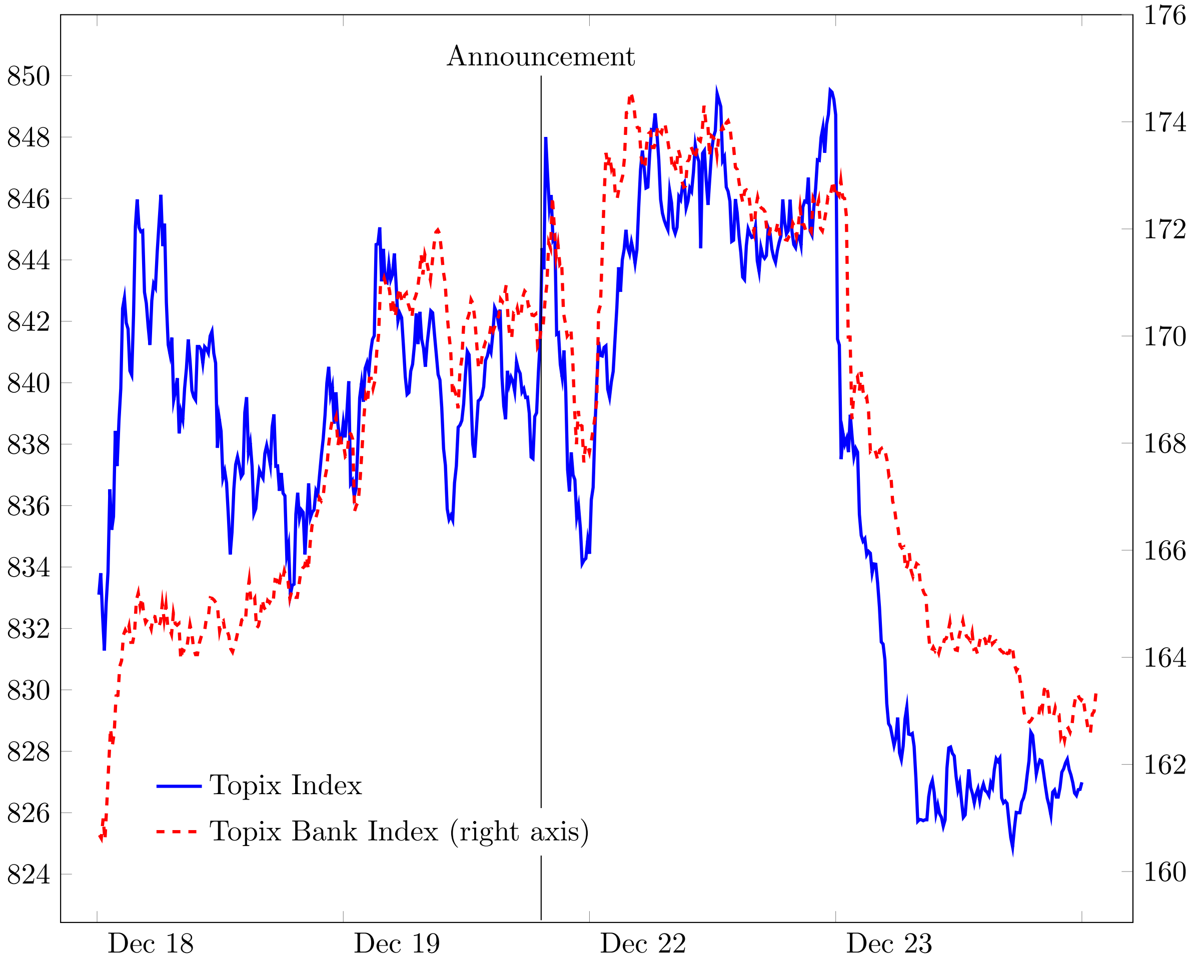


Figure 13: **Topix and Topix Bank Index (October 2010)**

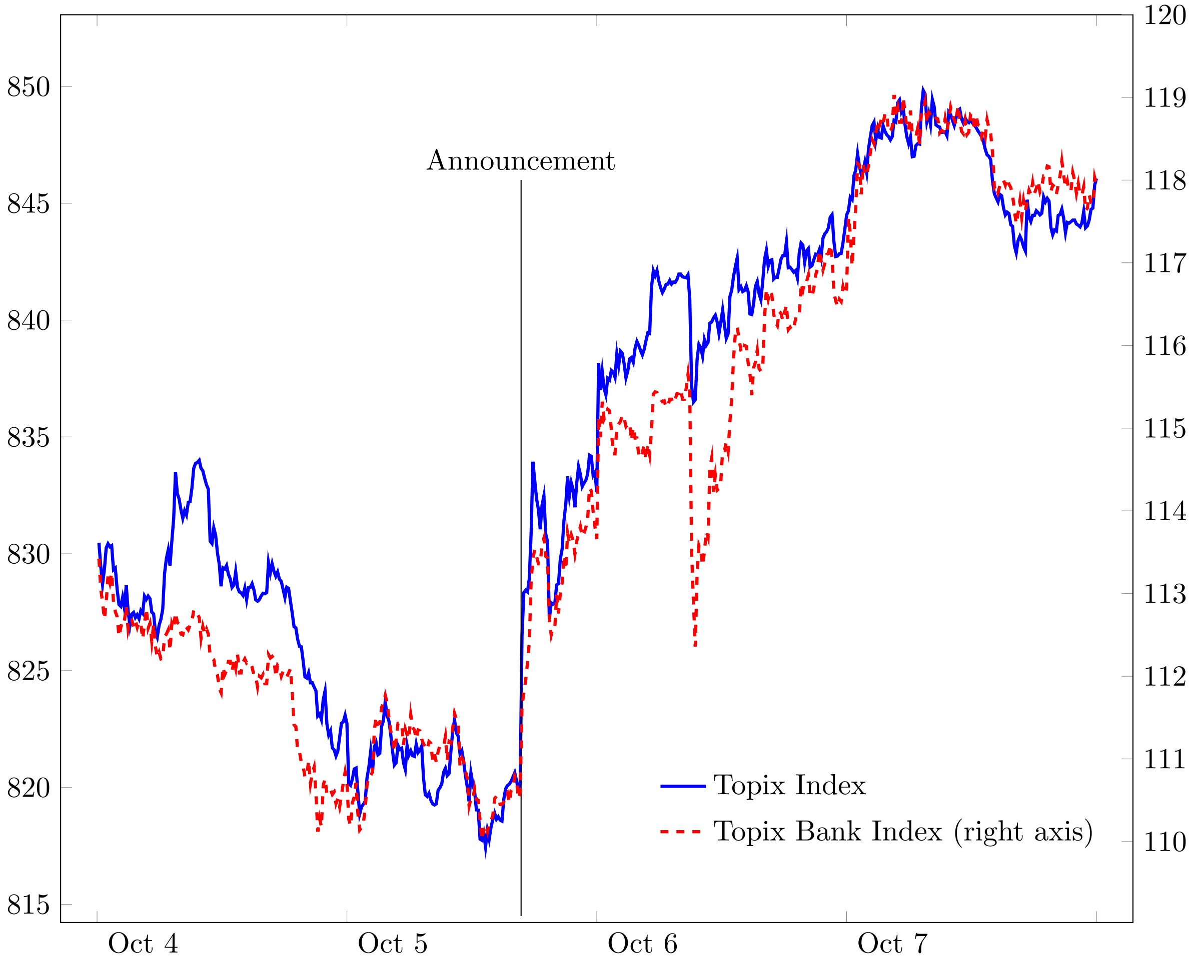


Table 1: Determinants of Stock Price Changes Around NIRP Announcement

	ΔPrice$_{40min}$			ΔPrice$_{2\ day}$		
	(1)	(2)	(3)	(1)	(2)	(3)
Reserves	-0.15***	-0.16**	0.02	-0.21**	-0.22**	0.11
	(0.05)	(0.07)	(0.08)	(0.09)	(0.11)	(0.11)
Wholesale Time Deposits		0.15***	0.14***		0.21***	0.23***
		(0.03)	(0.03)		(0.05)	(0.05)
ROA			-1.42			-3.52
			(1.72)			(2.66)
Dividend Yield			0.47**			0.60
			(0.21)			(0.39)
Risk-Weighted Assets			-0.04			-0.07
			(0.05)			(0.09)
Capital			-0.44**			-1.23***
			(0.22)			(0.41)
Assets			-0.15***			-0.29***
			(0.00)			(0.09)
Assets^2			0.50***			0.87***
			(0.15)			(0.27)
Industry Loan Shares	–	–	✓	–	–	✓
Adj. R^2	0.09	0.32	0.65	0.06	0.20	0.65
Number of observations	77	74	74	77	74	74

Notes: This table reports determinants regressions for bank stock price changes around the announcement of NIRP. All windows used to calculated stock price changes begin approximately five minutes before the announcement. The 2 day change ends on the close of trading two days after the announcement. All covariates except for assets are normalized by total assets. A constant (not shown) is included in all specifications. The coefficients on assets and assets^2 are multiplied by 10^6 and 10^{15}, respectively. Robust standard errors are reported in parentheses. Statistical significance: $^{***}p < 0.01$;$^{**}p < 0.05$;$^{*}p < 0.10$.

Table 2: Currency-to-GDP and Bank Deposit Funding Ratios

	$\frac{\text{Currency}}{\text{GDP}}$		$\frac{\text{Deposits}}{\text{Liabilities}}$	
	2011	2015	2011	2015
Japan	0.18	0.20	0.80	0.78
Germany	0.09[†]	0.11[†]	0.46	0.55
Italy	0.09[†]	0.11[†]	0.46	0.56
United Kingdom	0.03	0.03	0.44	0.55
Canada	0.03	0.04	0.68	0.72
France	0.09[†]	0.11[†]	0.32	0.38
United States	0.07	0.08	0.76	0.79
Sweden	0.03	0.02	0.32	0.34
Denmark	0.03	0.03	0.24	0.25
Switzerland	0.09	0.12	0.45	0.61

Notes: This figure shows country-level currency-to-GDP ratios and the banking sectors' aggregate deposits-to-liability ratio. Currency in circulation and capital for each country is provided in Annual Reports. GDP, deposits, and bank liabilities for each country reported by S&P Global Market Intelligence. [†] denotes Eurozone value.

Table 3: Summary Statistics

	Full Sample		Highest Tercile		Lowest Tercile	
	2015	2016	2015	2016	2015	2016
Net Interest Margin (%)	1.10	1.06	1.17	1.09	1.11	1.05
	(0.31)	(0.35)	(0.16)	(0.16)	(0.43)	(0.50)
Return on Avg. Assets (%)	0.72	0.55	0.86	0.59	0.61	0.43
	(1.19)	(0.81)	(1.25)	(0.79)	(0.75)	(0.48)
Dividend Yield (%)	2.26	2.31	2.96	2.94	1.99	2.16
	(1.07)	(1.29)	(1.20)	(1.17)	(0.75)	(0.79)
Loan Share of Assets (%)	58.8	58.4	62.7	62.9	58.8	57.4
	(12.5)	(12.7)	(7.73)	(8.04)	(9.67)	(9.88)
Assets (¥Trillion)	16.6	15.6	2.15	1.87	31.9	32.3
	(48.5)	(47.5)	(1.27)	(1.44)	(68.7)	(69.8)
Loan Portfolio Yield (%)	1.58	1.49	1.46	1.34	1.41	1.35
	(1.61)	(1.64)	(0.22)	(0.20)	(0.55)	(0.61)
Loan Share >10 years (%)	17.8	18.2	19.5	20.2	17.7	17.6
	(10.0)	(10.4)	(10.9)	(11.2)	(8.94)	(9.32)
Capital-Asset Ratio (%)	6.11	10.1	5.06	11.7	6.23	9.92
	(2.58)	(14.6)	(0.91)	(16.5)	(1.33)	(15.8)
Z-score	102.9	101.2	76.8	76.1	123.4	119.2
	(101.7)	(98.7)	(74.5)	(70.9)	(126.7)	(122.9)
σ_{return} (%)	1.89	2.49	1.75	2.20	2.00	2.78
	(0.33)	(0.45)	(0.39)	(0.50)	(0.19)	(0.26)
Distance to Default	6.90	5.26	7.21	5.83	6.59	4.49
	(2.93)	(2.79)	(3.96)	(3.96)	(1.94)	(1.70)
5-year Default Prob. (%)	1.48	1.64	1.84	1.34	1.31	1.95
	(1.07)	(1.30)	(1.09)	(1.20)	(1.05)	(1.30)

Notes: This table reports year-end means and standard deviations (in parentheses) for key outcome and control variables in our sample. The highest tercile banks correspond to the 33% of banks that witnessed the smallest decline in their stock prices in the 40 minute window around the NIRP announcement. The lowest tercile banks witnessed the largest declines in their stock prices after the NIRP announcement.

Table 4: NIM and Profit Growth Under NIRP

	NIM (% Δ)				EPS (% Δ)				Net Income (% Δ)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
$\Delta \text{Price}_{40\text{min}}$	-0.08	–	0.53	–	-0.83	–	-2.25	–	-2.05	–	-1.66	–
	(0.33)	–	(0.39)	–	(1.62)	–	(2.96)	–	(1.34)	–	(1.54)	–
$\Delta \text{Price}_{40\text{min}} \times D_{\text{NIRP}}$	–	0.18	–	0.79	–	-0.06	–	-0.47	–	-0.87	–	0.28
	–	(0.44)	–	(0.58)	–	(0.98)	–	(1.69)	–	(1.24)	–	(1.45)
Bank Controls	–	–	✓	✓	–	–	✓	✓	–	–	✓	✓
Adj. R^2	0.00	0.87	0.67	0.93	0.00	0.91	0.28	0.95	0.04	0.95	0.16	0.98
Number of observations	79	241	78	238	82	246	80	240	93	278	80	240

Notes: This table reports the relationship between bank stock price changes and future profit growth. Columns 1 and 3 correspond to cross-sectional regressions using 2015 and 2016 values. Columns 2 and 4 correspond to DiD regressions in levels when (Δ) is indicated, or log levels when (% Δ) is indicated. All DiD regressions include year time and bank fixed effects. Bank controls include return on assets, dividend yield, the loan-to-assets ratio, the risk-weighted-assets-to-assets ratio, the capital-to-assets ratio, assets, assets squared, and industry loan shares. A constant (not shown) is included in all specifications. Robust standard errors are reported in parentheses. Statistical significance: $^{***}p < 0.01$;$^{**}p < 0.05$;$^{*}p < 0.10$.

Table 5: Changes in Standard Deviation of Returns, Distance to Default, and Default Probability Under NIRP

	σ_{return} (Δ)				Dist-to-Default (Δ)				5yr Pr(Default) (% Δ)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
$\Delta \text{Price}_{40\text{min}}$	-0.06***	–	-0.06***	–	0.13***	–	0.14***	–	-13.1***	–	-13.5***	–
	(0.01)	–	(0.01)	–	(0.03)	–	(0.04)	–	(3.60)	–	(4.79)	–
$\Delta \text{Price}_{40\text{min}} \times D_{\text{NIRP}}$	–	-0.09***	–	-0.07***	–	0.09***	–	0.09***	–	-14.6***	–	-16.8***
	–	(0.02)	–	(0.01)	–	(0.02)	–	(0.04)	–	(3.95)	–	(6.25)
Bank Controls	–	–	✓	✓	–	–	✓	✓	–	–	✓	✓
Adj. R^2	0.21	0.61	0.56	0.88	0.14	0.96	0.39	0.96	0.16	0.69	0.61	0.74
Number of observations	93	278	80	239	90	270	79	237	86	259	74	223

Notes: This table reports the relationship between bank stock price changes and changes in market-based measures of bank riskiness. Columns 1 and 3 correspond to cross-sectional regressions using 2015 and 2016 values. Columns 2 and 4 correspond to DiD regressions in levels when (Δ) is indicated, or log levels when (% Δ) is indicated. All DiD regressions include year time and bank fixed effects. Bank controls include return on assets, dividend yield, the loan-to-assets ratio, the risk-weighted-assets-to-assets ratio, the capital-to-assets ratio, assets, and assets squared. A constant (not shown) is included in all specifications. Robust standard errors are reported in parentheses. Statistical significance: $^{***}p < 0.01$;$^{**}p < 0.05$;$^{*}p < 0.10$.

Table 6: Changes in Z-score, Assets, and Leverage Under NIRP

	Z-score (% Δ)				Assets (% Δ)				Capital-to-Asset Ratio (% Δ)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
$\Delta\text{Price}_{40\text{min}}$	0.46**	–	0.21	–	-1.41	–	-2.91	–	0.51*	–	0.33	–
	(0.24)	–	(0.28)	–	(0.91)	–	(2.26)	–	(0.30)	–	(0.37)	–
$\Delta\text{Price}_{40\text{min}} \times D_{\text{NIRP}}$	–	0.53**	–	0.74**	–	-1.15**	–	-1.87*	–	0.61**	–	0.50
	–	(0.27)	–	(0.32)	–	(0.53)	–	(1.03)	–	(0.31)	–	(0.35)
Bank Controls	–	–	✓	✓	–	–	✓	✓	–	–	✓	✓
Adj. R^2	0.05	0.99	0.33	0.99	0.04	0.99	0.18	0.99	0.05	0.99	0.31	0.97
Number of observations	93	279	80	240	81	255	79	239	81	255	79	239

Notes: This table reports the relationship between bank stock price changes and changes in measures of bank risk taking from banks' balance sheets. Columns 1 and 3 correspond to cross-sectional regressions using 2015 and 2016 values. Columns 2 and 4 correspond to DiD regressions in levels when (Δ) is indicated, or log levels when (% Δ) is indicated. All DiD regressions include year time and bank fixed effects. Bank controls include return on assets, dividend yield, the loan-to-assets ratio, the risk-weighted-assets-to-assets ratio, the capital-to-assets ratio, assets, and assets squared. A constant (not shown) is included in all specifications. Robust standard errors are reported in parentheses. Statistical significance: $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.10$.

Table 7: Interest Rate and Maturity Changes on Loan Portfolio Under NIRP

	Loan Portfolio Interest Rate (Δ)				Loans >10 Yr Maturity (% Δ)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
$\Delta\text{Price}_{40\text{min}}$	-1.09***	–	-0.63**	–	-0.27	–	-0.46*	–
	(0.39)	–	(0.29)	–	(0.19)	–	(0.25)	–
$\Delta\text{Price}_{40\text{min}} \times D_{\text{NIRP}}$	–	-1.07***	–	-0.60**	–	-0.21	–	-0.59**
	–	(0.34)	–	(0.30)	–	(0.21)	–	(0.29)
Bank Controls	–	–	✓	✓	–	–	✓	✓
Adj. R^2	0.11	0.99	0.66	0.99	0.01	0.99	0.48	0.99
Number of observations	78	238	78	238	93	257	80	231

Notes: This table reports the relationship between bank stock price changes and changes in characteristics of banks' loan portfolios. Columns 1 and 3 correspond to cross-sectional regressions using 2015 and 2016 values. Columns 2 and 4 correspond to DiD regressions in levels when (Δ) is indicated, or log levels when (% Δ) is indicated. All DiD regressions include year time and bank fixed effects. Bank controls include the 2015 loan portfolio yield, the lagged return on assets, dividend yield, the loan-to-assets ratio, the risk-weighted-assets-to-assets ratio, the capital-to-assets ratio, assets, assets squared, and industry loan shares. A constant (not shown) is included in all specifications. Robust standard errors are reported in parentheses. Statistical significance: $^{***}p < 0.01; ^{**}p < 0.05; ^{*}p < 0.10$.

Table 8: Loan Supply Growth Under NIRP

	Industry Lending Volume (% Δ)			
	(1)	(2)	(3)	(4)
$\Delta\text{Price}_{40\text{min}}$	-0.46*	–	-0.54**	–
	(0.26)	–	(0.26)	–
$\Delta\text{Price}_{40\text{min}} \times D_{\text{NIRP}}$	–	-1.31**	–	-2.87**
	–	(0.60)	–	(1.37)
Bank Controls	–	–	✓	✓
Industry Fixed Effects	✓	–	✓	–
Industry-Time Fixed Effects	–	✓	–	✓
Adj. R^2	0.09	0.82	0.10	0.82
Number of observations	940	3,028	940	3,028

Notes: This table reports the relationship between bank stock price changes and changes in loan supply. Columns 1 and 3 correspond to cross-sectional regressions using 2015 and 2016 values to compute changes. Columns 2 and 4 correspond to DiD regressions in the log-level of bank loans. Bank controls include the 2015 loan portfolio yield, the lagged return on assets, dividend yield, the loan-to-assets ratio, the risk-weighted-assets-to-assets ratio, the capital-to-assets ratio, assets, and assets squared. A constant (not shown) is included in all specifications. Standard errors clustered at the bank level are reported in parentheses. Statistical significance: $^{***}p < 0.01; ^{**}p < 0.05; ^{*}p < 0.10$.

Table 9: Robustness to Longer Horizons and Abnormal Returns

Dependent Variable:	Abnormal Returns		Longer Event Window	
	$\Delta\text{Price}_{40\text{min}}$	$\Delta\text{Price}_{40\text{min}} \times D_{\text{NIRP}}$	$\widehat{\Delta\text{Price}}_{2\text{ day}}$	$\widehat{\Delta\text{Price}}_{2\text{ day}} \times D_{\text{NIRP}}$
NIM (% Δ)	0.54	0.71	0.34	0.88*
	(0.40)	(0.58)	(0.23)	(0.43)
EPS (% Δ)	-2.81	-0.64	0.14	0.50
	(3.25)	(1.78)	(0.89)	(0.89)
Net Income (% Δ)	-2.06	0.00	0.10	0.78
	(1.65)	(1.51)	(0.60)	(0.79)
σ_{return} (Δ)	-0.06***	-0.06***	-0.03***	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)
Dist-to-Default (Δ)	0.14***	0.09***	0.06***	0.04*
	(0.04)	(0.04)	(0.02)	(0.02)
5yr Pr(Default) (% Δ)	-12.9***	-16.3***	-5.26**	-8.38***
	(4.95)	(6.26)	(2.55)	(3.79)
Z-score (% Δ)	0.22	0.79**	0.00	0.22
	(0.30)	(0.34)	(0.15)	(0.20)
Assets (% Δ)	-3.19	-2.02*	-1.16	-0.75**
	(2.52)	(1.15)	(0.96)	(0.31)
Capital-to-Asset Ratio (% Δ)	0.29	0.46	0.16	0.15
	(0.40)	(0.38)	(0.21)	(0.18)
Loan Interest Rate (Δ)	-0.63**	-0.63**	-0.10	-0.09
	(0.31)	(0.32)	(0.16)	(0.18)
Loans >10 Yrs. (% Δ)	-0.46*	-0.58**	-0.28*	-0.29
	(0.26)	(0.30)	(0.14)	(0.22)

Notes: This table reports robustness checks of the regressions reported in Tables 4 through 8. Each coefficient in the table reflects the outcome of a separate regression, with the dependent variable reported to the left. The coefficients reported in the leftmost columns use the abnormal returns (i.e. accounting for the effects of market-wide movements in stock prices, bonds, and currency markets). The coefficients reported in the rightmost columns use a longer event window than that in the main analysis. The specifications correspond to columns 3 (for the cross sectional specifications, ΔPrice) or 4 (for the DiD specifications, $\Delta\text{Price} \times D_{\text{NIRP}}$) of the relevant tables, including the full set of controls with sample sizes identical to those reported in the prior tables. Statistical significance: $^{***}p < 0.01$;$^{**}p < 0.05$;$^{*}p < 0.10$.

Table 10: Determinants of Stock Price Changes Around Previous Rate Cuts

Panel A: December 19, 2008 Interest Rate Cut

	$\Delta Price_{40min}$			$\Delta Price_{2\ day}$		
	(1)	(2)	(3)	(1)	(2)	(3)
Reserves	0.15**	0.06	0.05	-0.13	-0.09	-0.14
	(0.06)	(0.07)	(0.11)	(0.16)	(0.19)	(0.26)
Wholesale Time Deposits		0.04**	0.00		-0.01	-0.02
		(0.02)	(0.01)		(0.03)	(0.03)
Other Controls	–	–	✓	–	–	✓
Adj. R^2	0.05	0.17	0.36	0.01	0.01	0.05
Number of observations	64	64	64	64	64	64

Panel B: October 5, 2010 Interest Rate Cut

	$\Delta Price_{40min}$			$\Delta Price_{2\ day}$		
	(1)	(2)	(3)	(1)	(2)	(3)
Reserves	-0.06	-0.08	-0.05	-1.89	-1.52	0.34
	(0.06)	(0.05)	(0.04)	(1.91)	(1.61)	(1.63)
Wholesale Time Deposits		0.03**	0.01		-0.48	-1.53
		(0.01)	(0.02)		(0.52)	(1.71)
Other Controls	–	–	✓	–	–	✓
Adj. R^2	0.02	0.09	0.14	0.00	0.00	0.02
Number of observations	68	68	68	68	68	68

Notes: This table reports determinants regressions for bank stock price changes around the two rate cuts prior to NIRP. All windows used to calculated stock price changes begin approximately five minutes before the announcement. The 2 day change ends on the close of trading for the day after the announcement. Other controls match those reported in Table 1. Robust standard errors are reported in parentheses. Statistical significance: $^{***}p < 0.01$;$^{**}p < 0.05$;$^{*}p < 0.10$.