Banks' Liquidity Demands under Unconventional Monetary Policies in Japan*

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Abstract

This paper empirically examines the impacts of unconventional monetary policies and the soundness of Japanese regional banks on their excess reserve accumulating behavior.

In the 21st century, developed countries have experienced the massive accumulation of reserves at central banks by their deposit institutions. The biggest question raised by the massive accumulation is why individual profit-maximizing banks held large excess reserves. Although some previous literatures tackled this question, there are still missing pieces of the puzzles. This paper is what fills in the missing piece.

This is the first study that specifically examines the effects of the so-called unconventional monetary policies on the reserve-accumulation in Japan. The Bank of Japan conducted six different types of unconventional policies for two decades, but there were no research which focused on these differences. Using the annual panel data of Japanese regional banks from Mar. 1999 to Mar. 2018, this paper investigates the impacts of unconventional monetary policies and Japanese banks' soundness and their interactions with three different models: Pooled-ols, fixed-effects model and panel-probit.

There are some findings in this paper: It found that regional banks with higher capital adequacy ratio, higher return on asset ratio and lower non-performing loan ratio tend to hold fewer excess reserves. It also found that call rate (short-term policy rate) has a negative relationship but most of the past or currently unconventional monetary policies have positive relationships with excess reserve holding.

By marginal analysis, this paper found that under the influence of certain practices of unconventional monetary policy, the level of non-performing loan ratio did not have strong impact to excess reserves. These findings allowed us to rethink how to evaluate and adjust monetary policies in the economies with similar problem of massive excess reserves.

Keywords: Excess Reserves, Unconventional Monetary Policies, Japanese Regional Banks

JEL Classification: C23, E51, G21

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1. Introduction

In this 21st century, developed countries experienced the massive accumulation of reserves at central banks by their deposit institutions. Japanese economy is the first one which faced this phenomenon in this century, and since the end of the 20th century, the massive accumulation has continued for more than 20 years. Especially, after the *Abenomics*[5], the accumulation increased much faster than before. While this phenomenon was only seen in Japan before the Global Financial Crisis, since the crisis, US and EU countries also faced this phenomenon under their economic recovery policies.

The biggest question raised by the massive accumulation is why individual profit-maximizing banks held large excess reserves. Although some previous literatures tackled this question, there are still missing pieces of the puzzles. This paper is what fills in the missing piece. There are a variety of literatures that have addressed the reasons for excess reserve accumulation. Chang et al. (2014) examined the situation in the US that was in the peak of the financial crisis during 2008 to 2010. They argued that rapidly increasing aggregate levels of reserve could be explained by three motives: (1) precautionary motives according to the nonperforming loan, (2) concerns about the penalty rate lacking short-term liquidity, and (3) opportunity costs, which means potential profitability in the lending environment. Likewise, Ogawa (2007) examined the case of Japan during 1991-2002 when Japan was still suffering from the recession or so-called the "Lost Decade"[6]. His study pointed out similar factors suggested by Chang et al. (2014) to explain the phenomenon that the Japanese commercial banks held excess reserves chronically due to the concern of opportunity costs and precautionary motives. Hoffmann & Sigaux (2020) examined the determinants of excess reserve accumulation in EU in the context of the ECB's public sector purchase program by testing hypotheses concerning the roles of risk-taking, investment opportunities, and market structure. They find that excess reserves systematically accrue on the balance sheets of banks with a low share of customer deposits, low opportunity costs, and high payments settlement activity. These studies explained precisely the possible factors causing the banks to accumulate huge amounts of excess reserves during financial crisis.

Even after these central banks' policy shifts from quantitative easing (QE) to quantitative tightening (QT), some studies have estimated the demand function for reserves from the perspective of the debate over the process of quantitative tightening: Shiratsuka (2025) examines Japanese case, Lopez-Salido and Vissing-Jorgensen (2024) for US, and Brandao-Marques and Ratnovski (2024) is for EU. In addition, the US financial markets in September 2019 and March 2023 let researchers to focus on

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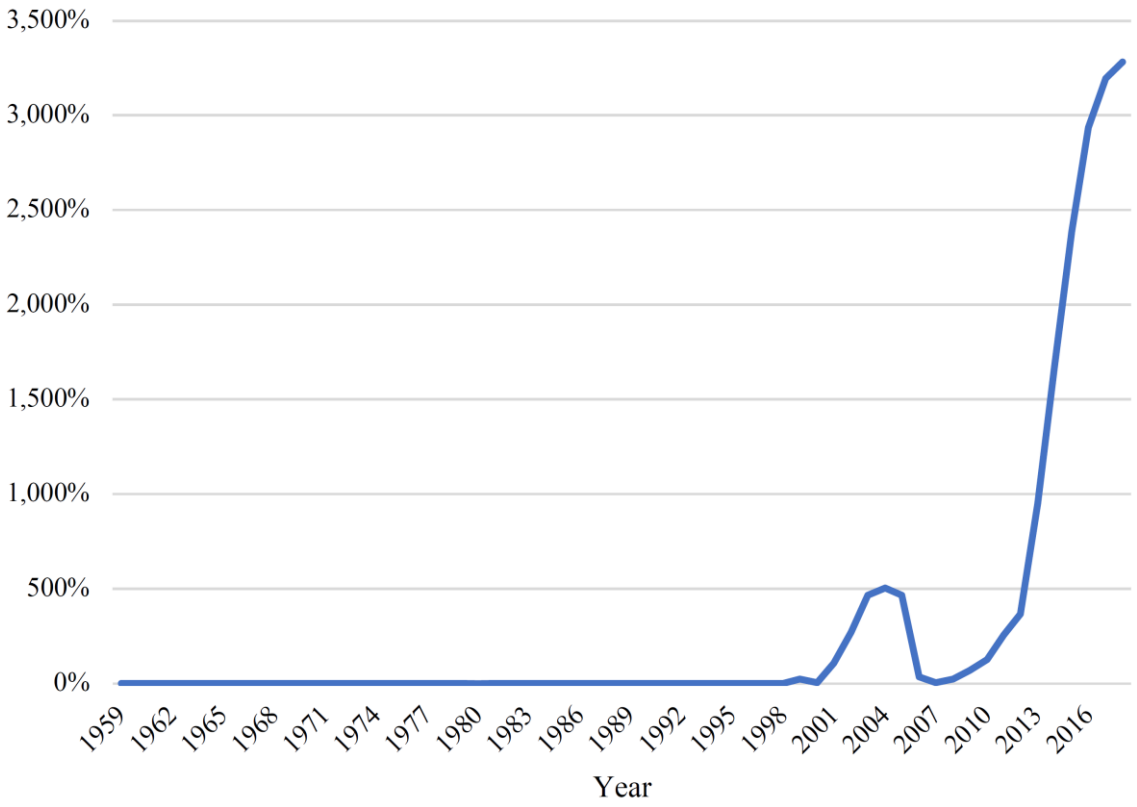
[5] "'Abenomics' refers to the new economic policy regime advocated by the Prime Minister of Japan, Shinzo Abe. It is a set of policy measures meant to resolve Japan's macroeconomic problems. It consists of three arrows: unconventional monetary policy (the first arrow), expansionary fiscal policy (the second arrow), and economic growth strategies to encourage private investment (the third arrow). Through the three arrows, the Japanese government tried to revive its economy through implementing bold economic policies that will pull its economy out of prolonged deflation, depreciate Japanese yen, and induce CPI inflation rate of 2% per year." (Fukuda, 2015)

[6] At the beginning of this 21st century, the low growth economic situation since the beginning of 1990s was referred as "Lost Decade". However, the low growth has continued for more than 30 years, which is often referred as "Lost Decades" or "Lost 30 Years".

banks' liquidity risk management (Acharya and Rajan, 2024; Ugai and Osada, 2025). These studies share our motivation in terms of studying the liquidity demands of the banking industry.

Fig. 1 shows that Japanese banks are incessantly accumulating excess reserves in an exponential growth rate, which shows the accumulation occurs not only during crisis periods but also recovery periods. Osada (2017) examined the case of Japan during 1998-2007. The sample of study covered both crisis and recovery periods. It provided evidence that precautionary demand in terms of capital adequacy ratio or Tier 1 ratio has significant negative effect to excess reserve accumulation regardless the period of recession or convalescence.

Figure 1 Excess reserves ratio of Japanese banks (1959-2017)



Source: Author's calculation based on data : Bank of Japan. (2019). BOJ Time-Series Data Search. Retrieved June 26, 2019

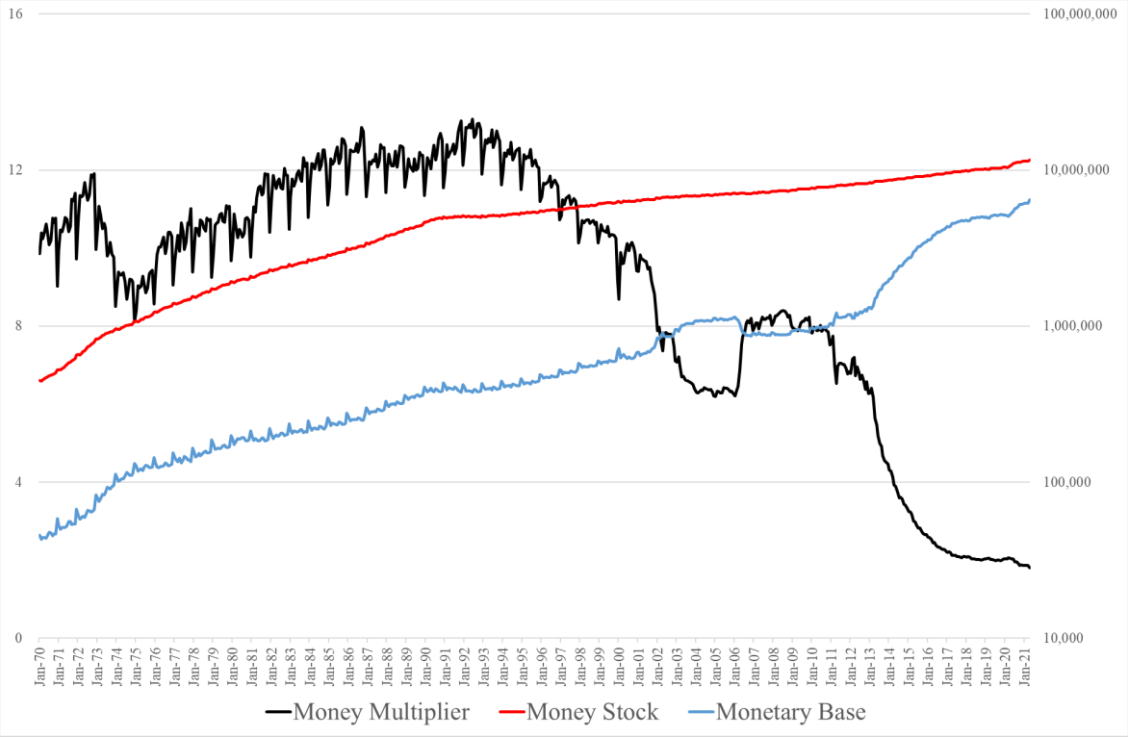
Note: Excess reserves ratio is defined as excess reserves divided by required reserve.

Meanwhile, the Bank of Japan (BOJ) adopted various unconventional monetary policies, which is said that these monetary policies were one of the major factors of the excess reserve accumulation. No previous research, however, directly examined the effects of these unconventional monetary policies on excess reserve accumulations. Since Feb. 1999, Japanese economy experienced several types of unconventional monetary policy frameworks: "Zero interest rate policy", Quantitative easing,"

"Quantitative and qualitative easing," "Negative interest rate policy," and so on. Kuroda (2016), the current Governor of the BOJ explained that because the banking sector plays a key role in the transmission of monetary policies, the BOJ had launched some unprecedented policies to inject liquidity into the banking sector as a downward pressure on interest rate, aiming at a conversion of people's deflationary mindset and anchoring the inflation target.

It is expected that the excess reserves would gradually reflect the recovery period of Japanese economy as well as the effects of the BOJ's monetary policy initiative. However, it seems that there are still other factors in which some commercial banks' concerns are even beyond the periods of financial crisis or recession. As a result, the amount of excess reserves soars significantly, and more importantly, the money supply is only slightly increasing although the monetary base is increasing sharply, which let the money multiplier significantly decrease from 12 to 2 for 30 years (Fig. 2).

Figure 2 Money Multiplier



Note: Monetary Base (Monthly Average): data series "Monetary Base/Average Amounts Outstanding" [Data code: MD01'MABS1AN11] Money Stock (Monthly Average) is what the following three different series are connected as one series: as Money Stock of 1970-1998 we use the series "M2+CDs/Average Amounts Outstanding/ Money Stock (Based on excluding Foreign Banks in Japan, etc., through March 1999)" [data code: MD02'MAMS1ANM2C]; as 1999-2003, "M2+CDs/Average Amounts Outstanding/ Money Stock (from April 1998 to April 2008)" [MD02'MAMS3ANM2C]; after 2004-, "M2/Average Amounts Outstanding/Money Stock" [MD02'MAM1NAM2M2MO]

Ogawa (2007), Chang et al. (2014) and Osada (2017) have shown in their studies that even the banks under the same macroeconomic environment could act differently in terms of holding excess reserves. The soundness of each bank is the possible major factor.

Private banks in Japan can be classified into two categories city banks(≒international banks) and regional banks (≒domestic banks) and it is often shown that these two groups' economic behavior are different with each other[8,9]. Therefore, by narrowing the target to only regional banks (focusing on homogeneous group), we empirically examine whether their difference in soundness affects on their excess reserve accumulating behavior.

This paper reports the empirical examination of two factors --- precautionary motives and opportunity cost towards the effects on excess reserves by using a panel data set and several regression models. Excess reserves in the BOJ divided by total amount of deposits is the dependent variable of the examination. As the required reserves of each bank are not publicly disclosed, we use the amount of deposit from each bank to calculate an approximation (See Section 3). By comparing the estimated amount to the outstanding reserve in the BOJ, we can calculate the excess reserves. The capital adequacy ratio (CAR), return on assets (ROA) and non-performing loan ratio (NPL) capture the banks' soundness while uncollateralized overnight call rate (Call) captures the opportunity cost. In our hypotheses, (1) a bank with high CAR, high ROA or low NPL has fewer precautionary motives to hold excess reserves, (2) a bank in a high overnight call rate environment faces higher opportunity cost for holding excess reserves, (3) under different periods of unconventional monetary policies, the motives to hold excess reserve change even if the aforementioned ratios remain unchanged. To check if the unconventional monetary policy also significantly affects regional banks' decisions, we use dummy variables to classify the panel data in six periods of time. There are different hypotheses under different periods, all of which shall be explained thoroughly in Section 2. The uncollateralized overnight call rate and periodic dummy variables together can represent macroeconomic factors in the models. We would like to investigate whether macroeconomic factors or the soundness of banks dominate regional banks' decisions on excess reserve accumulation during different periods of time. We examine the panel data from FY1998 to FY2017 to analyze the behavior of banking sectors from the very beginning of unconventional monetary policy as well as the upcoming transformation. With a longer timeframe comparing to previous literatures, we examine the banks under the latest "QQE with a negative rate" policy which had not been examined by other scholars.

This paper is organized as follows. Apart from this introductory section, Section 2 explains

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[8] We have 136 commercial banks in Japan as of 2019: 5 city banks, 102 regional banks, 14 trust banks and 15 other banks. City banks', with a very large scale, headquarters are located in major cities such as Tokyo and Osaka, and have branches across the whole country and even overseas. They are the main players in Japanese economy so previous literatures usually included them in the examination. Although regional banks have a rather smaller scale compared to city banks, they are usually the largest financial institutions in the prefectures, excluding the big cities.

[9] Kinai & Osada (2019) focus on the different business model and historical backgrounds among two groups and showed the different determinants of their capital structure.

thoroughly on the evolution of unconventional momentary policy and expected corresponding effect on excess reserves. Sections 3 examines the calculation of bank's excess reserves and the reserve deposit requirement system in Japan. Section 4 depicts the data set and model that to be used to test the hypotheses. Section 5 estimates the results. Finally, Section 6 is the conclusion of the paper.

2. Unconventional Monetary Policies in Japan

Smaghi (2009) explained that unconventional monetary policies are policies that directly target the cost and availability of external finance to banks, households and non-financial companies. Forms of central bank liquidity, loans, fixed-income securities or equity can be the sources of these external finance. Generally, they are used in the situations where the interest rate is already close to zero or in severe economic distress beyond three main traditional tools, namely open market operations (OMO), reserve requirement, and discount rate. Quantitative easing (QE) is one of the most well-known examples. In comparison to the conventional OMO, QE is its extension. First, the scale of QE is much larger. Second, OMO does not focus on the overall amount of reserves but the interest rate (uncollateralized overnight call rate). In contrast, the QE program mainly focuses on market liquidity and injects a massive amount of reserves into banking system.

In this section, we give a thorough explanation about the unconventional monetary policies that Japan has adopted since the late 1990s. There are six periods of Japanese unconventional monetary policy:

(1) Zero interest rate policy(1999Feb-2001Feb)

Starting from 1990s, Japan has been suffering from deflation and prolonged recession due to the burst of the bubble economy at the end of 1980s. The BOJ adopted the "zero interest policy" from February 2nd, 1999 to combat deflation and boost the economy by guiding the overnight money market rate close to zero percent. The BOJ provided ample funds which exceeded required reserves by ¥1 trillion to meet the short-term credit demand and drive the short-term interest rate to zero.

Under the zero-interest policy, the overnight money market rate was pushed to be almost zero percent. Because excess reserves are close substitutes to call loans, it is expected that the bank would hold more excess reserves as there was almost no incentive for banks to creative more loans during such a low interest rate environment.

In April of 1999, the BOJ announced that the zero-interest policy would continue until deflationary threats were dispelled. Finally, the policy was rescinded on August 11th, 2000 as the economy showed a sign of gradual recovery. It is predictable that the excess reserves would decrease back to similar level to the time before the zero interest policy.

In February of 2001, the BOJ introduced "the Complementary Lending Facility," a lending facility that the BOJ could extend loans at the request of its counterparties based on pre-specified conditions. The amount of the loans should not have exceeded the total value of collateral submitted by

counterparties. When money market interest rates became higher than the basic loan rate of this facility, financial institutions were expected to use it. As a result, a ceiling was set on the basic loan rate and money market rates would not rise. It is expected that the ceiling on loan rates would lower the incentive of the financial institution to make loans. Therefore, the level of excess reserves would increase.

(2) Zero interest rate policy and Quantitative easing (2001Mar-2006Mar)

Unfortunately, the recovery did not last long. In 2001, the inflation rate was still negative and the real GDP growth rate was close to zero . The BOJ switched its operating target in 2001 from overnight money markets to current account balances held by financial institutions at the BOJ. This was a new monetary policy--- the first attempt of quantitative easing ever. The BOJ purchased a net ¥37 trillion of securities and expanded its balance sheet from ¥115.3 trillion yen to ¥152.3 trillion. This consisted of Japanese government bonds (JGBs) and short-dated financing bills or promissory notes.

Along with the QE program, the BOJ introduced again the zero-interest rate policy until 2006. From the effect of the zero-interest policy, it is expected that financial institutions would make fewer loans and hold more excess reserves because of low market interest rates like the period around 1999. In the QE program, because the BOJ injected a massive amount of liquidity into the banking system, it would surely increase the excess reserves. Combining the consequences of both policies, the excess reserves would increase.

(3) Exiting QE and Zero interest policy (2006Mar-2010Sep)

As there were signs that deflation dispelled in 2006, the BOJ announced to exit the QE policy on 9th March, 2006. On July 16th, 2006, the BOJ announced that the uncollateralized overnight call rate would increase back to 2.5% which meant the zero-interest rate policy would be stopped temporarily. The excess reserves are expected to decrease back to the level before the zero-interest policy was launched.

However, between 2007 and 2008, there was a financial crisis that occurred globally, originating from the subprime problems and the Lehman shock. Massive amounts of capital flowed into the Japanese financial market, resulting in the rapid appreciation of Japanese Yen. It critically affected exports and stock price. Unfortunately, the Japanese economy fell back into negative territory.

“The Complementary Deposit Facility” was introduced by the BOJ in 2008. The BOJ applied an interest rate to financial institutions’ excess reserves. There was a high incentive to hold more excess reserves because of the fluctuation of financial markets during the crisis between 2007 and 2008. On the other hand, the interest on excess reserves was expected to be a high incentive to hold more excess reserves. However, the interest on excess reserves was adjusted to be the same as the call rate 0.1%. It is predicted that the effect would be offset, and there would not be a significant change in excess

reserves because of this policy.

(4) Comprehensive monetary easing (2010Oct-2013Mar)

In October of 2010, the BOJ introduced another policy called the "Comprehensive monetary easing'. Under this program, the BOJ purchased large amounts JGBs, especially those maturities up to three years to push down the interest rate close to zero percent. Moreover, the BOJ also purchased private-sector debt such as corporate bonds and commercial paper, as well as equity financial products such as exchange-traded funds (ETFs) and real estate investment trust (REITs) to reduce risk premiums. In addition, the BOJ introduced a special long-term lending facility with a relatively low interest rate to encourage lending and investment by financial institutions.

Similar to the zero-interest rates in QE policy periods, it was anticipated that both policies would make the excess reserves remain in a high level due to the lacking profitable investment opportunity in such low interest rate environments and the large amount of liquidity injected. In addition, the Complementary Deposit Facility, which was still paying interest on excess reserves, would possibly make the scenario worse as there was no profitable investment opportunity in the zero-interest rate environment. The financial institutions are predicted to put the excess reserves in the deposit facility rather than lending it out to the public.

(5) Quantitative and qualitative monetary easing in Abenomics (2013Apr-2016Jan)

The government started to think about a stronger monetary easing tool to let Japan dispose of the deflation nightmare. In December of 2012, the newly elected prime minister Abe Shinzo launched "Abenomics" with the well-known "three arrows" strategy. They were proactive monetary policies, a flexible fiscal policy and a growth strategy to promote private investment. In 2013, the BOJ announced a 2% inflation target and bold monetary policy "quantitative and qualitative monetary easing (QQE)". There were two main elements: raising inflation expectations among the public, and putting downward pressure not only on short-term interest rate but the entire yield curve. The intimate target was to lower short-term as well as long-term real interest rate to reach the inflation target.

Instead of focusing on how massive the amount of the QE program was, the QQE also focused on the quality of the purchased asset. At that time the BOJ purchased JGBs with maturities of up to 40 years, the longest maturity in Japan. The remaining maturities of JGBs purchased by the BOJ were extended from less than three years to about seven years. The BOJ also purchased REITs and ETFs with a larger scale than the comprehensive monetary easing in 2010.

The entire yield curve was further pushed down. Because long-term loans were not a close substitute for excess reserves and the utility of public investors and banks might have indirectly influenced the change of excess reserves, the effect would be ambiguous and unpredictable. However, as the zero interest-rate policy continued and there was a larger amount of capital injected, the excess reserves are

expected to increase as there was no profitable investment opportunity in zero interest-rate environment.

(6) QQE with Negative interest rate (2016Jan- 2024Mar)

Although the monetary base continuously increased from 2010 until now, the inflation target was still remotely far while the growth rate of export and lending kept downward. On January 29th, 2016, the BOJ introduced a surprising initiative: "QQE with Negative interest rate" in order to reach the 2% inflation target as soon as possible. While adopting the QQE, a three-tier system of interest rate would be applied to the current accounts of the financial institution in the BOJ. (A) For the current excess reserves under the Complementary Deposit Facility, 0.1% interest would be applied to prevent the profit of bank decreasing in a large extent. (B) For the required reserve, there would be no interest. (C) For the outstanding balance other than (A) and (B), a negative 0.1% would be applied as a "punishment" to encourage financial institutions keep lending money.

Under the QQE program, the excess reserves are expected to increase due to the large amount of money injected by the BOJ into the banking system. However, under the negative rate punishment, if the call rate is greater, a strong incentive is expected for financial institutions to hold fewer excess reserves. It is conceivable that the banks might make more loans and investments in order to avoid the punishment. In contrast, if the call rate is same as or lower than negative 0.1%, the excess reserves might increase by the QQE program but not decrease by the negative rate.

3. Reserve deposit requirement system in Japan

As seen in Introduction, because the required reserves of each bank are not publicly disclosed, we need to calculate an approximation of excess reserves for empirical analysis. This section aims to discuss the reserve deposit requirement system in Japan and depicts the method to calculate the approximate amount of excess reserves from the data of Japanese banks at the end of financial year.

The timeframe of calculation is from March of 1999 to March of 2018, a total of 19 years[10]. Osada (2018) showed how the reserve deposit requirement system works in Japan as in Fig. 3. We use ① to represent the daily fluctuation of all deposit accounts' total balance in Bank A from 1st of March (beginning of month) to 31st of March (end of month). We can calculate the required reserve ③ by required reserve ratio multiplied by the average value of ① (＝②). Additionally, ④ represents the reserves belonging of Bank A from 16th of March to 15th of April and ⑤ is its average value. Under the reserve deposit requirement system, it is required for all banks to ensure ⑤ ≥③. In other words, Bank A only needs to ensure the average amount of reserve from the 16th of this month to the 15th of next month higher than the required reserve calculated from the average amount of all deposit accounts'

[10] All the Japanese banks's fiscal year ends on March: e.g. March of 2018 is the fiscal year end of FY2017.

total balance in the last month multiplied by the required reserve ratio. Therefore, it is possible to have cases in which the daily reserve amount is lower than the required reserve (it is not necessary to keep ④ ≥③) and as a result, end up with some negative digits in our approximate excess reserves.

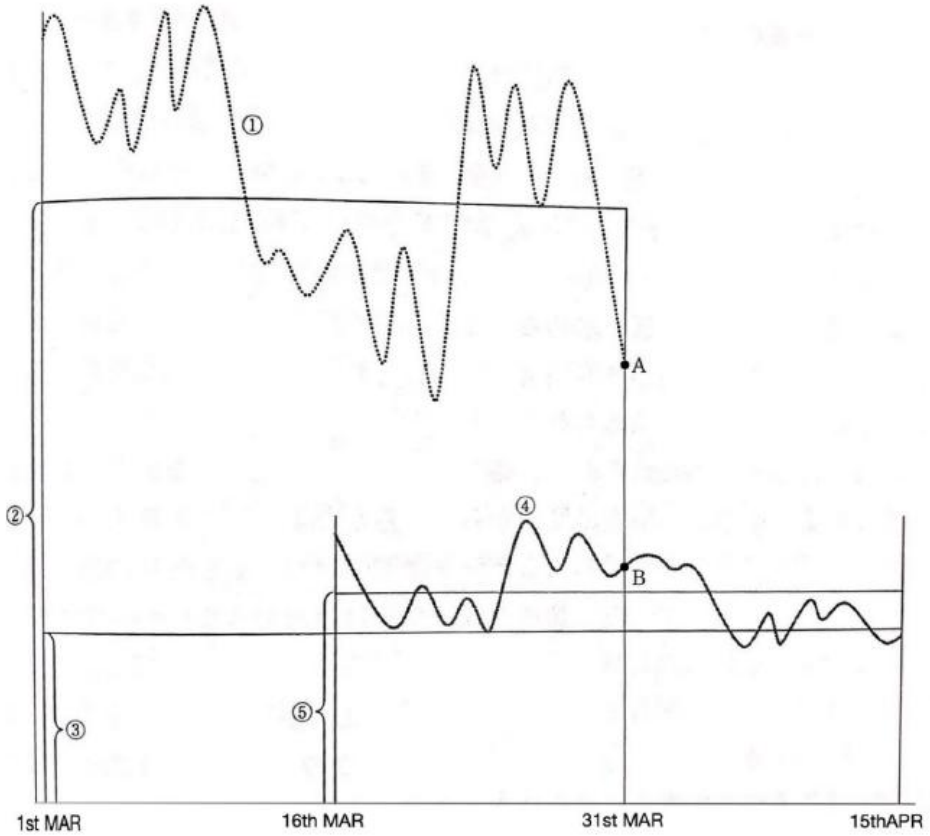
The progressive reserve deposit requirement system has been adopted since July of 1986. In this system, there are different classifications by amount of designated accounts as shown in Table 1. For deposits except debentures, the higher amount of classification will have a higher required reserve ratio, but debentures will have an equal rate no matter how much the amount is.

For example, if one bank has 4 trillion JPY time deposit in March of 2017 on a daily average, it needs to reserve 30.275 billion JPY by the following calculations:

30.275 billion = (4 trillion—2.5 trillion) ×1.2%
+(2.5-1.2 trillion) ×0.9%
+(1.2-0.5 trillion) ×0.05%
+(0.5-0.05 trillion) ×0.05%

In this case, this bank needs to reserve on average more than this amount between16th March 2017 and 15th April, 2017.

Figure 3 Reserve deposit requirement system in Japan



Source: Osada (2018)

Table 1 The progressive reserve deposit requirement system of Japan

<table>
<tr><th>Outstanding deposit of</th><th>Time deposits (including certificates of deposits)</th><th>Other deposits</th><th>Debentures</th></tr>
<tr><td>More than 2.5 trillion JPY</td><td>1.2%</td><td rowspan="2">1.3%</td><td rowspan="4">0.1%</td></tr>
<tr><td>Between more than 1.2 trillion yen and 2.5 trillion JPY or less</td><td>0.9%</td></tr>
<tr><td>Between more than 500 trillion yen and 1.2 trillion JPY or less</td><td rowspan="2">0.05%</td><td>0.8%</td></tr>
<tr><td>Between more than 50 trillion and 500 trillion JPY or less</td><td>0.1%</td></tr>
</table>

Source: Bank of Japan. https://www.boj.or.jp/en/statistics/boj/other/reservereq/junbi.htm/

4. The Methodology and Models

We examine the fiscal year end panel data of regional banks from FY1998 to FY2017 with three different models.

The first one is pooled ordinary least squares (Pooled-OLS) model.

$$A.\ \frac{ER_{it}}{D_{it}} = \alpha + \beta_1 Ratio_{it} + \beta_2 Call_t + \varepsilon_{it}$$

$$B.\ \frac{ER_{it}}{D_{it}} = \alpha + \beta_1 Ratio_{it} + \beta_2 Call_t + \gamma_2 Period_2 + \cdots + \gamma_6 Period_6 + \varepsilon_{it}$$

ER_{it} and D_{it} are excess reserves in the BOJ and total deposits of bank *i* in FY *t*. $Ratio_{it}$ is the corresponding CAR, NPL and ROA of bank *i* in FY *t* while $call_t$ is the overnight call rate at the end of FY *t*. In Japan, CAR has both Basel and Japanese standards. Most of the regional banks in Japan do not have overseas branches so they are only required to follow the Japanese standard. Yajima (2009) explained the differences between the two standards in table 2.

However, some banks might have overseas branches so in previous years they have just provided the

CAR data Basel standard. Although the Basel standard is stricter, there is not a big difference in the calculations. We use the CAR in Basel standard as a supplementary of missing data of CAR in Japanese standard, and then took an average of the banks provided for both. For NPL, we use "bankrupt and substantially bankrupt claims", "doubtful claims" and "substandard claims" under financial reconstruction law to calculate. For ROA, we use ordinary revenue divided by the total asset that are declared in bank's income statement and balance sheets. For uncollateralized overnight call rate, the monthly average data in March when the end of the fiscal year is used. Periods 2 to 6 are dummy variables that capture different effects during different states of unconventional monetary policy mentioned in section 2. When all dummy variables are equal to zero, it represents the case of period 1. The data is categorized as shown in table 3.

Table 2 Comparison of CAR standards

	Basel (international) standard	**Japanese (domestic) standard**
Regulated target	Banks with overseas branches	Banks without any overseas branches
Required CAR	8%	4%
Adjusting the value of other securities	Valuation gain: Including 45% of the gain into Tier 2 Valuation loss: Deducting 60% of that loss from Tier 1	Valuation gain : no adjustment Valuation loss: Deducting 60% of that loss from Tier 1
Arrangement from Dec of 2008 to Mar of 2012	No adjustment for sovereign bonds. Others' bonds are adjusted as above	No adjustment for raising nor reducing value
Counting market risk into adjusted asset	Yes	No

Source: Yajima (2009)

Table 3 Dummy variables' classifications by financial year

Period	FY
$Period_1$	1998-1999
$Period_2$	2000-2004
$Period_3$	2005-2009
$Period_4$	2010-2012
$Period_5$	2013-2014
$Period_6$	2015-2017

The first factor effect of "Precautionary demand for reserves" can be captured by β_1 and second factor effect of "Opportunity cost" can be captured by β_2. Equation B is examined with dummy variables, but equation A is examined without them. The macroeconomic effect is examined together by β_2 and γ_2 to γ_6 while the effect from the soundness of banks can be examined by β_1.

The second model is a two-way fixed-effects model.

$$C.\ \frac{ER_{it}}{D_{it}} = \alpha + \beta_1 Ratio_{it} + \gamma_2 Period_2 + \cdots + \gamma_6 Period_6 + \mu_t + \mu_i + v_{it}$$

μ_t *and* μ_i capture the time effect and individual effect respectively. And, the third model is the Probit model.

$$D.\ Y_{it} = \alpha + \beta_1 Ratio_{it} + v_{it}$$

$$C.\ Y_{it} = \alpha + \beta_1 Ratio_{it} + \gamma_2 Period_2 + \cdots + \gamma_6 Period_6 + v_{it}$$

$$s.t.\ Y_{it} = \begin{cases} 1, & \frac{ER_{it}}{D_{it}} \geq \left(\frac{ER_{it}}{D_{it}}\right)_{60} \\ 0, & \frac{ER_{it}}{D_{it}} \leq \left(\frac{ER_{it}}{D_{it}}\right)_{40} \end{cases}$$

where $\left(\frac{ER_{it}}{D_{it}}\right)_{60}$ represents the 60th percentile point of $\frac{ER_{it}}{D_{it}}$, *and* $\left(\frac{ER_{it}}{D_{it}}\right)_{40}$ represents the 40th percentile point of $\frac{ER_{it}}{D_{it}}$ respectively.

These five equations are estimated by using 19 years of data from Japanese regional banks. The banks' accounting data and ratio are from Nikkei NEEDS Financial Quest at the end of each fiscal year

FY1998 to FY2017. The overnight call rates are the monthly average rate of March from the BOJ.

5 Estimation Results & Analysis

Table 4 shows the results of Pooled OLS model with $\frac{ER_{it}}{D_{it}}$ in which columns 1-3 are results of equation A and columns 4-6 are results of equation B. For ratios which capture the banks' soundness level, the coefficient of ROA is significantly negative without examining dummy variables of monetary policy periods, while in another case, NPL is significantly positive. Surprisingly, CAR has no significant effect to excess reserve holding in both cases as we can see in previous literatures. One of the reasons might be because the regional banks tend to rely on the bad loan ratio like NPL or profitability ratios like ROA rather than CAR, which supposedly represents the self-confidence level of banks to make decisions. For the macroeconomic effect, call rate has significantly negative effects in all the cases using equations A and B. It can prove that the opportunity cost is a big concern among regional banks. With a higher interest rate environment, regional banks may properly have a higher opportunity cost to be considered for holding excess reserves. All the dummy variables in the 6 different periods show significantly positive relationships with excess reserves[11]. In other words, while the BOJ continues using different kinds of unconventional tools to stimulate the economy, the policies may be the direct or indirect reasons to induce regional banks holding more excess reserves. Comparing the coefficients, it is shown that in some periods the effects from the policies are even stronger than those from call rate or the ratio of banks' soundness. From fifth column, we can see in the early stages such as periods 1 through 4, NPL has a higher influence on banks' decision. However, from period 5 the dummy variables show a stronger effect. This may give us some enlightenments on how regional banks make decisions by considering both macroeconomic factors and their level of bank soundness.

[11] Please note that constants in the model represent dummy variables of period 1.

Table 4 Estimation results of equations A & B: Pooled-OLS

Dep. Variable	*Excess-Reserve/Deposit*					
Equation	A			B		
CAR	-0.0001			-0.0001		
	(-1.31)			(-1.19)		
NPL		0.012			0.042 **	
		(0.69)			(2.33)	
ROA			-0.182 ***			-0.012
			(-2.96)			(-0.20)
Call Rate	-0.029 ***	-0.026 ***	-0.025 ***	-0.020 ***	-0.020 ***	-0.020 ***
	(-7.01)	(-6.25)	(-6.31)	(-4.17)	(-4.14)	(-4.32)
Period2				0.010 ***	0.012 ***	0.014 ***
				(3.77)	(5.73)	(7.53)
Period3				0.005 *	0.010 ***	0.010 ***
				(1.92)	(3.88)	(4.53)
Period4				0.009 ***	0.014 ***	0.013 ***
				(3.31)	(5.49)	(6.15)
Period5				0.073 ***	0.078 ***	0.078 ***
				(10.06)	(10.94)	(11.24)
Period6				0.104 ***	0.109 ***	0.109 ***
				(13.23)	(14.15)	(14.50)
Constant	0.024 ***	0.021 ***	0.026 ***	0.015 ***	0.007 ***	0.009 ***
	(18.29)	(15.80)	(14.95)	(5.84)	(3.25)	(3.87)
No. Obs	1539	1578	1670	1539	1578	1670
Adj. R2	0.031	0.025	0.028	0.173	0.181	0.187

t statistics in parentheses. *, **, *** denote statistical significance at the 10%, 5% and 1% respectively.

Table 5 shows the results of the two-way fixed effect model that has been previously defined as equation C. ROA and NPL have a significantly negative and positive relationship respectively with excess reserves, which is in accordance with our hypotheses. Similarly, almost all the dummy variables reflect significantly positive relationships with excess reserves. Likewise, the coefficients of period 6 in both Pooled OLS and fixed effect models are highest within all dummy variables. This violates our hypotheses that the punitive negative interest rate may encourage regional banks to make new loans rather that accumulating more profitless excess reserves. The coefficient of period 3 does not have a strong significant result like other dummy variables. It is properly due to the Complementary Deposit Facility we have mentioned before. Although the interest on excess reserves is a reasonable incentive to hold more excess reserves, the adjusted interest rate that is close to the market rate seems to offset the effect and it has not brought strong consequences to regional banks' decisions. From third column, we can see ROA has a rather big number of the coefficient. It seems to be an important indicator for banks' decisions on excess reserves.

Table 5 Estimation results of equation C: Two-way fixed-Effects Model

Dep. Variable	*Excess-Reserve/Deposit*		
Equation	C		
CAR	0.0001		
	(1.20)		
NPL		0.062 **	
		(2.18)	
ROA			-0.558 ***
			(-3.33)
Period2	0.010 ***	0.011 ***	0.011 ***
	(4.47)	(5.93)	(6.03)
Period3	0.000	0.004 *	0.001
	(-0.01)	(1.84)	(0.63)
Period4	0.007 ***	0.011 ***	0.006 **
	(2.95)	(5.07)	(2.21)
Period5	0.055 ***	0.059 ***	0.053 ***
	(8.34)	(9.15)	(8.04)
Period6	0.086 ***	0.090 ***	0.083 ***
	(11.74)	(12.50)	(11.34)
Constant	0.012 ***	0.007 ***	0.026 ***
	(5.38)	(3.04)	(4.86)
No. Obs	1539	1578	1670
Adj. R2	0.068	0.077	0.098

t statistics in parentheses.
*, **, *** denote statistical significance at the 10%, 5% and 1%

Table 6 shows the results of Probit model that known as equation D in columns 1 through 3 and equation E in columns 4 through 6. CAR show a significantly negative relationship for the first time among 5 equations. We highly doubt that CAR may not be strong enough to reflect the precautionary motives or soundness of regional banks. In equation D, ROA shows again a strong impact to excess reserves although it does not have a significant result in equation E. NPL shows consistent results in 4 out of 5 equations (except equation A). From the 5 equations, we can conclude that NPL is the best ratio indicating the precautionary motives of regional banks among the 3 ratios we have used.

Interestingly enough, we have a slightly different result from Pooled OLS and fixed effect model. The constants have significantly negative relationship with excess reserves which represent period one policies. This is discrepant with what we have expected at the beginning; the zero-interest rate policy may have properly created a low opportunity cost environment and enhance the activity of accumulating extra reserve. Bernanke and Reinhart (2004) justified that one of the possible

transmission channels of monetary policies stimulating the economy during very low or even zero policy rate environment is that influencing market expectations about future trend of policy rates by an explicit act of setting conditional policy commitments. For example, the BOJ has announced the zero interest rate policy that would continue until deflationary was gone. The stimulus towards economic activities can be strengthened by announcing various forms of verbal commitment to the public to keep the low policy rate for a longer period than everyone expected. Therefore, the unprecedented zero interest rate policy in Japanese history at that time might provide a signal to the public about the BOJ's potential attitude towards low interest rate policies and stimulate the lending activities. Also, using 60 percentile point as a benchmark in Probit model may be also another reason for different results from equations A to C.

In addition, all data in period 6 is larger or equal to 60 percentile point which equals to 1 in equation E. This is a limitation of data so the regression model has dropped the observations automatically for period 6. More data from period 6 is required for further analysis.

However, by comparing the results of period dummy variables among 5 equations, we wonder if the adopted or currently adopting policies can provide an environment that encourages banking sector to conduct more lending activities and create a larger money supply from the large monetary base.

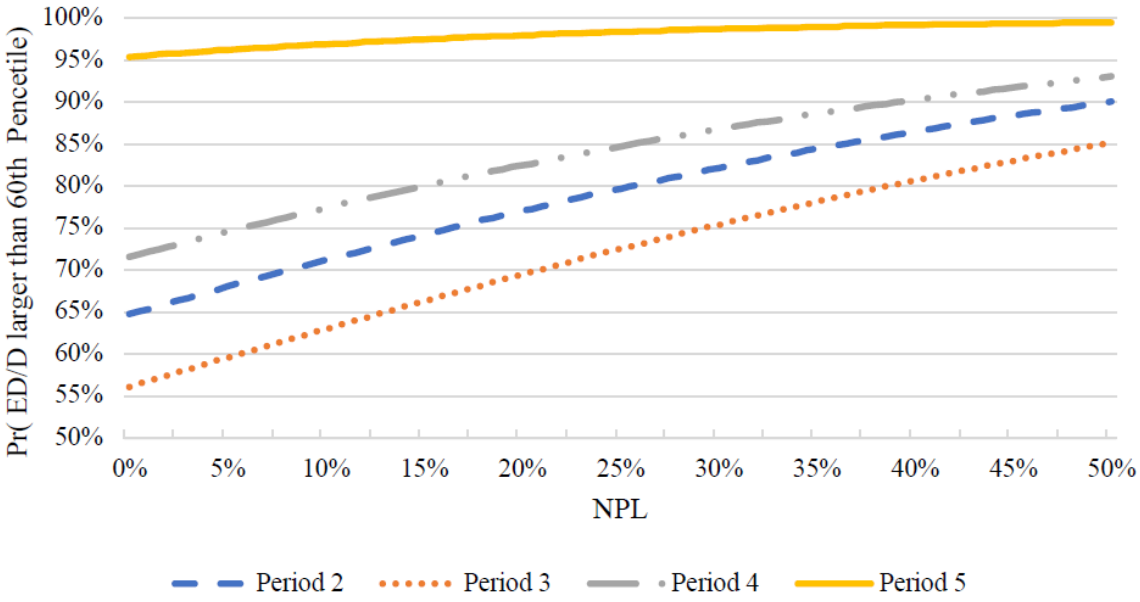
As the NPL is a stable indicator among 3 ratios, we used it for our marginal analysis to calculate the probabilities of regional banks to accumulate more excess reserves than the 60th percentile if the NPL increases within certain periods of monetary policies. Fig. 4. shows our results. The later the period is, the higher the probability is even though the NPL is as low as zero. Period 3 is an exceptional case that has the lowest probability whatever the NPL is. From periods 2 through 4, if a regional bank has lower NPL ratio, it is less likely to accumulate more excess reserves than the 60th percentile among the whole regional banking sector. In other words, a sound bank can still be a channel for transferring the liquidity from the BOJ to the public, especially in period 3. In period 5, the asymptote approaches 100% of probability, meaning the concerns about macroeconomic environment are highly dominating the reserve holding decisions comparing with those ratio indicators of banks' performance. This is the period of Abenomics when the BOJ first attempted quantitative and qualitative monetary easing. If we interpret from the figure, the policies are one of the main factors to boost excess reserve accumulation. It will be interesting to look at the prediction of period 6 as it is the negative rate period. Unfortunately, more data is required for Probit regression and marginal analysis.

Table 6 Estimation results of equations D & E: Probit Model

Equation	D			E		
CAR	-0.009 **			-0.008 *		
	(-2.20)			(-1.77)		
NPL		1.789 **			1.869 **	
		(2.29)			(2.10)	
ROA			-13.703 ***			-4.859
			(-3.67)			(-1.46)
Period2				0.231 *	0.547 ***	0.748 ***
				(1.78)	(4.91)	(7.42)
Period3				-0.214	0.174	0.291 ***
				(-1.64)	(1.51)	(2.88)
Period4				0.293 **	0.675 ***	0.772 ***
				(2.11)	(5.32)	(6.66)
Period5				1.323 **	1.704 ***	1.809 ***
				(2.52)	(3.27)	(3.47)
Constant	0.277 ***	0.054	0.438 ***	0.178	-0.351 ***	-0.289 **
	(5.09)	(0.99)	(4.50)	(1.44)	(-3.00)	(-2.20)
No. Obs	1539	1578	1670	1528	1567	1659
Pseudo R2	0.002	0.002	0.007	0.028	0.033	0.046

z statistics in parentheses. *, **, *** denote statistical significance at the 10%, 5% and 1% respectively.
note: As all samples in period 6 equal to 1 (Yit=1), the system dropped all of Period6 automatically.

Figure 4 Predictive margins of excess reserve holding more than 60th percentile



6 Conclusion

Excess Reserve Accumulation does not exist only in Japan. Countries like the US and EU countries where they adopted unconventional monetary policies have faced similar problems of excess reserves. This is no longer for banks just dealing with financial crises or short-term liquidity needs. A healthy bank during period of economic recovery also has the potential to accumulate greater excess reserves. Also, it is not just about ratios representing the banks' soundness, the macroeconomic factors like call rates or momentary policies also have remarkable influence on banks' behaviors. It is essential to discover how regional banks in Japan make decisions in both macroeconomic factors and the soundness level of themselves. The previous literatures found out that precautionary motives and opportunity costs are the core reasons that Japanese banks hold excess reserves. In this research we have narrowed our focus on the regional banks and put more concern on monetary policies' effects to see the interaction of bank performance, economic environment, and excess reserves.

We have examined regional banks in Japan during FY 1999 through 2018 by precautionary motives, opportunity cost, and periods of unconventional monetary policies. Not only CAR and NPL represent the soundness of banks like previous researches either, we have added ROA to see if it can also be a significant proxy for banks' performance. While CAR merged by Basel and Japanese standards is not a strong indicator, ROA and NPL are the favorable ratios in our research. We have examined 3 different models: Pooled OLS, Fixed effect, and Probit model, as well as 5 equations. Almost all the results agree with our hypotheses: a bank with high CAR, high ROA or low NPL have fewer precautionary motives to hold excess reserves; banks in a high overnight call rate environment face higher opportunity cost in excess reserves holding. We have made various predictions in every periods of monetary policies to calculate the possible economic outcome from the policies towards excess reserves and compared it with the data from reality. Almost all the results show that the policies may be a reason to provoke the regional banks to accumulate more excess reserves. From a marginal analysis with NPL, we have discovered under certain monetary policies a regional bank with lower NPL is more likely to have fewer excess reserves in most cases. In contrast, under certain monetary policies like quantitative and qualitative monetary easing during April of 2013 through January of 2016, even a bank with low NPL may still have high probability to accumulate excess reserves more than the 60th percentile in a regional bank sector. Concerning the latest negative interest rate period, which has yet to be examined by pervious literatures, both Pooled OLS and the fixed effect model show that it has a significantly positive relationship with excess reserves. This is inconsistent with our theoretical prediction. Unfortunately, more data is required from period 6 to conduct Probit regression.

These findings can be implicated as a review of unconventional monetary policies. Policies that can encourage regional banks to maintain high CAR, ROA or low NPL may be a useful way to revive the economy while injecting tons of liquidity into banking sectors in such low interest environments. Especially NPL, it is an important indicator for soundness of banks. However, the policies do not

always work. During certain periods of unconventional monetary policies, even banks with low NPL ratios are still not likely to involve more in lending activities but prefer holding more reserve. Therefore, a regular inspection is important to see whether the ratios representing the soundness level of banks or macroeconomic factors that are affecting the whole economy will be the regional banks' main concern. A more precise investigation on the mechanism of interaction between monetary policies, banks' performance, and interest rate is needed to fully understand which is the most efficient way from the BOJ to stimulate the whole economy. Also, these factors are what needs to be closely monitored in liquidity risk management during conventional monetary policy and quantitative tightening policy phases.

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