EFFECTS OF DEPOSIT FACILITY RATE ON BANKS' ASSET ALLOCATION IN THE EUROZONE

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ABSTRACT

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Abstract As one of characteristics reflecting the exceptionally easing monetary policy of the ECB since the financial crisis of 2008, the deposit facility rate (DFR) was first pushed down to the zero-lower bound. Then, it entered the negative zone in June 2014. To investigate the pass-through of this policy rate to the banking markets, I use a data set of 19 eurozone countries from 2009-2019 to examine whether the DFR successfully lowers bank reserves, conditional on their business model being proxied by net interest margin and wholesale funding ratio. If bank reserves decline in response to the DFR reduction, it is important to reveal whether the banks use this additional liquidity for lending expansion or investments on higher-yield liquid assets. I find that banks withhold more reserves in response to a decrease of DFR and even behave more aggressively under the negative era after 2014, which is a plausible reaction under the high overall uncertainty, that has resulted from the negative interest rate policy and low-for-long period. Although bank lending has increased after 2014, it seems to have been caused more by unconventional tools other than the negative interest rate policy or main refinancing operations. Additionally, the country effect creates heterogeneity on loan supply changes as a response to the DFR change. Banks in the stressed countries generally have more incentives towards increasing lending, while banks in the non-stressed countries show a preference in liquidity withholding.	
Key words Deposit facility rate, bank reserves, negative interest rate policy.	
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1 INTRODUCTION

Since the outbreak of the financial crisis in 2008, the euro area aggregate economic performance has been suffering due to some challenging issues. In 2011, the sovereign debt crisis emerged, resulting in increasing segmentation and the banks in the stressed countries almost lost access to the interbank markets. With the large liquidity injected into the banking system through open market operations and asset purchase programs, it was expected that banks would use such liquidity to increase lending and investments. However, due to the low-for-long period - a result of recession and ECB's aggressive cutting policy rates - banks withhold liquidity by increasing reserves at the central banks because investment opportunities become too risky. Under the pressure of further decrease in the nominal rate to recover the economy while the deposit facility rate had already reached the zero-lower bound, in 2014 the ECB decided to let the policy rate enter the negative zone despite its incomplete theoretical basis and many concerns about the real economic effects of negative rates.

The rise of excess reserves in the eurozone banking system has obviously damaged the transmission of the ECB's monetary policy to the real economy because of the lending contraction. Thus, the deposit facility rate (DFR) has become a potential candidate to deal with this problem as it directly raises the cost of holding reserves and forces banks to reallocate such liquidity to lending. Notably, the role of the deposit facility rate as a monetary policy tool is just pronounced under the contemporary abnormal situation of high excess reserves and extremely low interest rates. However, the efficiency of the negative interest rate policy is still debatable.

From the supporter's side point of view, many agree that it successfully reduces banks' reserves, but often through an interaction effect with bank-specific factors. For example, Buchholz et al. (2020) find a positive relationship between the deposit facility rate and banks' reserves at the central banks. This effect varies across banks with different degrees of interest sensitivity measured by the Net Interest Margin (NIM). In another study, Altavilla, Burlon, et al. (2019) also argue for the pass-through of negative interest rate policy on the real output, conditional on the soundness of banks. They explain that sound banks can pass the negative rates to corporate depositors and then can decrease the cost of lending. Meanwhile, the firms having a high proportion of current assets and being charged negative interest rates on deposits are likely to reallocate from cash holdings to asset investments, and thus increase the demand for credit.

In contrast, Heider et al. (2018) state that the negative interest rate policy causes a squeeze on net worth, thus leading to less lending and more risk-taking of the banks with greater deposit dependence. The reason lies in the banks' reluctance to pass the negative rate to customers due to the fear of deposit outflow, and it is especially true for the banks having more reliance on deposit funding. Another growing concern is related to the financial stability caused by the search-for-yield incentive and transmission to a greater interest-insensitive business model in the banking system under the low-for-long and negative interest rates (Chen, Katagiri & Surti 2018, Adrian 2020).

Inspired by these new events and bank market developments, I use bank-specific data on 19 eurozone countries over 11 years (2009-2019) to examine the effect of changes in the deposit facility rate on three main asset portfolio items of the banking system, that is, reserves at the central banks, liquid assets, and lending. Among those, the first one is my primary concern while the other two provide an understanding of how banks reallocate their liquidity to the higher-yield assets from a reserve reduction (if any) in response to a change in the deposit facility rate.

The baseline regression set of variables closely follows the Buchholz et al. (2020) study with the utility of net interest margin representing the interest sensitivity of the bank business model. Accordingly, the effect of the deposit facility rate is considered through its interaction with the net interest margin. The regression model also controls for some standard bank-specific characteristics (profitability, capitalization, deposit reliance, and size) and for the possible effects related to the main refinancing operations. However, different from Buchholz et al. (2020), I apply both random effects and fixed effects models in my analyses. In addition, as a new approach to their study, apart from the baseline regression, I further conduct two more regressions. The first one includes a dummy variable named GIIPS to investigate the heterogeneity in bank behaviours between the stressed and non-stressed countries, while the second one inserts the After2014 dummy variable to capture the differences between the times before and after the introduction of negative interest rate policy. Furthermore, as the net interest margin is a common measurement of bank profitability, the use of net interest margin in this study as a proxy for interest sensitivity may receive some criticism. Therefore, in the later phase, I replace the net interest margin with the wholesale funding ratio and conduct similar analyses to the previous analyses with the net interest margin. Using the two proxies will make my findings in this study stronger and more accountable for the asset allocation effects controlling for the role of the bank business model. It is also expected to result in a broader picture about the effects of the deposit facility rate on banks' portfolio components.

This master's thesis will be divided into four sections. First, in chapter 2 there is the theoretical framework where I will review some main discussions in the previous literature. Next, the data and methodology are explained in chapter 3. Then, I will discuss the main results in chapter 4, and finally, the conclusion will be given in chapter 5.

2 THEORETICAL IDEAS AND PREVIOUS LITERATURE

The Global Financial Crisis of 2007-2008 and especially the collapse of Lehman Brothers had damaged the asset values in the banking sector and turned the European financial markets and real economy into recession. The situation got worse with the explosion of the sovereign debt crisis in 2011-2012, which made the Eurozone fragmented, and the stressed banks suffered from a severe liquidity shortage. Not surprisingly, the banking system has been the main concern of both public discussions and academic research related to this situation because the ECB monetary policies are obviously designed to affect the real economy through the banking system. Therefore, the bank behaviour not only plays the main role in the monetary policy transmission mechanism but also has an effect on the continuity and future prospects of this special monetary and economic union.

In response to the crises, ECB implemented a number of policies to rescue the economy, mainly aiming to quickly cut interest rates and provide liquidity to the banks. Initially, fixed-rate full allotment (since 15th October 2008) going along with the extensions in refinancing operations and aggressive reductions in the policy rates were conducted just after the Global Crisis 2008. In the next phase, during the sovereign debt crisis, ECB started to carry out the Securities Markets Programme from 10th May 2010. Under the escalating situation of market malfunctioning, ECB further applied a reduction of required reserves from 2% to 1% and launched two three-year refinancing operations on 8th December 2011, followed by the Outright Monetary Transactions (OMT) announcement on 6th September 2012. However, the EU economy still suffered and faced an exceptional "Low-for-long" period, that is, the prolonged period of low inflation and low-interest rates. [1]

Meanwhile, an abnormal phenomenon was observed during this period – an increasing level of excess reserves in the European banking system. Prior to 2008, banks mainly kept their reserves at central banks as the minimum required reserves. However, this situation changed after the crisis because of the banks' incentives to secure their liquidity by increasing their cash holdings. To illustrate the evolution of excess reserves in the euro area, Buchholz et al. (2020) plotted the reserves holdings (per total assets) of banks from Jan 2005 to Apr 2016, showing great volatility in excess reserves since 2008 and reaching the peak in 2012 (Figure 1). There are two main reasons for it: the fear of liquidity risk and the malfunction of the interbank market. Frutos et al. (2016) argue that the asymmetric information issues and the counterparty risk caused the interbank market malfunction, then putting more pressure on stressed

[1] Information of the monetary policies are retrieved from the official website of the ECB (https://www.ecb.europa.eu/home/html/index.en.html)

banks' funding while encouraging the liquidity suppliers to either hold the liquidity or liquidate other assets. Moreover, Frutos et al. (2016) find that banks even borrowed at higher rates than the Marginal Lending Rate, and the euro area money market got fragmented with fewer cross-border transactions. In line with it, Altavilla, Burlon, et al. (2019) noticed the heterogeneity of the average lending rate that emerged after 2008 and became considerable from July 2011 to May 2014. This was caused by the failure of the median lending rate in following the policy rate changes as previously, and it was more pronounced in stressed countries including Greece, Ireland, Italy, Portugal, and Spain (GIIPS). Subsequently, the lending supply was inevitably contracted. Rostagno et al. (2019) give more explanation to this phenomenon. According to their argumentation, because only sound banks could borrow in the interbank markets, conditional on the liquidity by ECB's full allotment, the Euro Overnight Index Average (EONIA) reflecting the main money market reference rate, was forced down towards the DFR. At the same time, the distressed banks had to borrow directly from ECB at or even above the Main Refinancing Operations (MRO) rate.

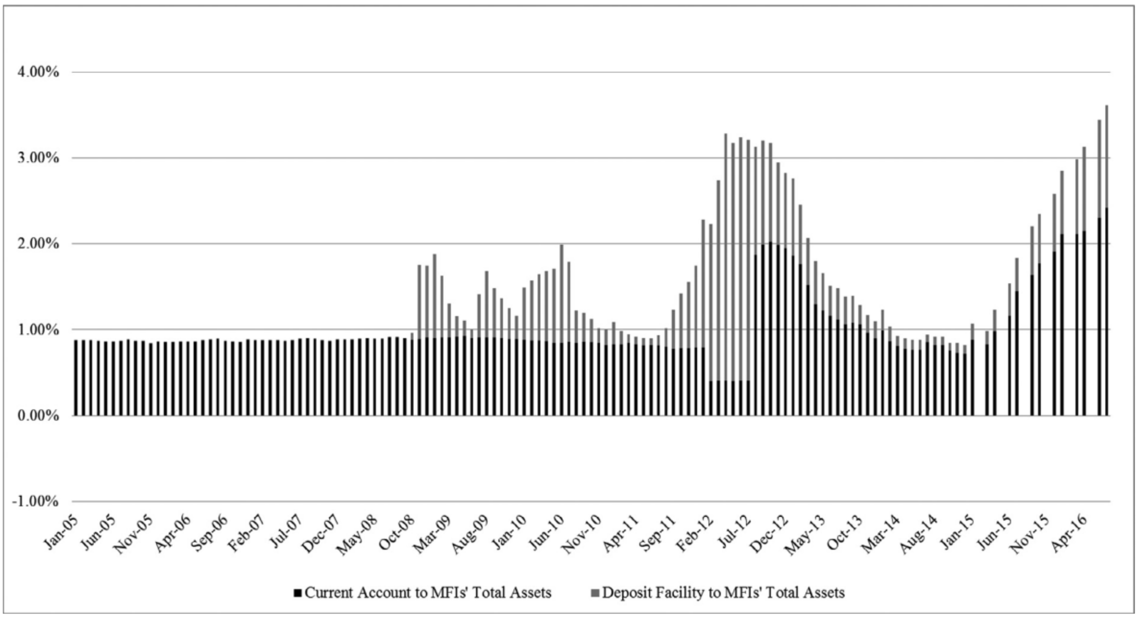

FIGURE 1. Bank reserve holdings in the euro area
This graph shows the rise of excess reserves of monetary financial institutions since late 2008 (scaled in the percentage of total assets). Bank reserves comprise of the current account holdings located at the national central banks (depicted in black bars) and the deposit facility holdings controlled by the ECB (depicted in gray bars). *Source*: Buchholz et al. (2020) with data extracted from Datastream.

To stimulate bank lending and push the inflation rate up, ECB needs to reduce the policy rate according to the conventional practice. However, the policy rates were already very low, and the DFR finally reached zero in 2013. This circumstance is the so-called zero-lower bound of the nominal interest rate, which is rooted in a fundamental that cash with no interest rate will become preferable to money if the interest rate on deposits turns negative (Rogoff 2017a).

Despite the above uncertainty, the ECB made a striking decision with the introduction of the negative interest rate policy (NIRP) for the first time in June 2014. This negative policy rate combines with the other three tools (the targeted longer-term refinancing operations (TLTROs), asset purchase program (APP), and forward guidance (FG)) that are together considered as the unconventional monetary package of the ECB. The TLTROs are similar to the conventional LTROs but with much longer maturity (up to four years). The main purposes of this package are to overcome the crisis and zero-lower bound constraint by providing huge amounts of liquidity into the economy and directing such liquidity into bank lending.

Prior to ECB, the Swedish and Danish central banks were the first two to apply negative interest rates on banks' central bank deposits in July 2009 and July 2012, respectively (Mishkin 2019). Although the euro area is not the first one that entered the negative zone of interest rates, this move has caught a lot of attention as it contributes significantly to the growing interests of the zero-lower bound as the ECB is not only a special central bank but also one of the largest central banks in the world.

Compared to the TLTROs and APP, the negative DFR plays a quite different role. While the other two focus on improving the liquidity of the banking system, the DFR channel directs such liquidity towards desired effects by attempting to reduce the excess reserves and pushing lending, when the policy rate is lowered. Noticeably, the role of DFR as a monetary policy tool is pronounced just under special situations such as ZLB in which the interest rates are low while the excess reserves are high. The reason is that DFR’s impact comes along with the existence of banks’ excess reserves which probably appears only during the periods of high uncertainty when banks prefer withholding money from investing and lending.

The DFR has influences on bank’s behaviour based on three channels. First, it sets up an opportunity cost on bank reserves, thus discouraging banks to withhold money. Indeed, when DFR turns negative, such cost realizes. Lee (2016) states that banks have fewer incentives to keep reserves when DFR decreases. Similarly, Buchholz et al. (2020) also agree that banks probably shift liquidity into higher-yielding assets in response to a reduction in DFR. This effect is in connection to the portfolio rebalancing channel of the transmission, specifically, that banks reallocate their reserves to more profitable assets.

Second, DFR sets the floor of the interbank market rate and affects the borrowing cost of banks. The importance of the interbank market is transparent as it provides the primary funds for banking activities, and the contraction in this market can damage the banking system. There are two policy rates set by the ECB in the interbank market: Marginal Lending Facility (MLF) and Deposit Facility Rate (DFR). Theoretically, the banks with excess reserves are motivated to lend in the interbank market at a rate higher than DFR which is what they can earn from the deposits at the central bank. Meanwhile, the banks with liquidity needs will not borrow in the interbank market at a rate higher than the one with which they can borrow directly from the central bank (MLF). Thus, these two policy rates establish the desired corridor of the EONIA movement in the interbank market (Mishkin 2019, Rostagno et al. 2019).

Finally, DFR has a direct impact on banks' profitability. This is not a new concept in the literature. However, many researchers have gained more interest in this topic very recently due to the concerns of the ZLB and the negative interest rate situation. Borio et al. (2017) analyzed the impact of the policy rate on bank profitability and concluded that a decrease in either interest rate or the slope of the yield curve results in lower bank profitability in general. They emphasize that such a relationship is non-linear and gets stronger under the lower interest rate level. A similar finding is also found by Claessens et al. (2018), especially when the interest rate is lower for a longer period of time. This is explained by the fact that banks' lending rates are more sensitive than banks' deposit rates, in which case banks have to decrease the lending rates due to the competition and contractual duties while they often hesitate to decrease the deposit rate in the fear of losing deposit funding. Indeed, Claessens et al. (2018) propose that although banks can adjust operations such as cost-cutting and shifting to non-interest income to keep profitability, such adjustments take time to conduct and bank profitability still gets hurt at least in the short term.

To put it short, we can say that the DFR affects the banks mainly through the determinants of their profit, i.e., costs of funding and interest rate spread. Given their incentive to profit maximization, banks have to make decisions on their portfolio composition based on contemporary circumstances. As specified above, banks should increase their positions in higher-yield assets such as liquid assets and lending rather than hoarding reserves when DFR reduces. However, in practice, this is not always the case as some factors affect this relationship, and the bank characteristics also have decisive influences on how banks react to the DFR change.

The bank business model is a typical bank-specific factor as it generally expresses how banks acquire their funding, as well as the channels that banks focus on to generate profits (Köhler 2015). Thus, the chosen business model also implies the degree of the bank's sensitivity to interest rate risks. In their study of banks' profitability concerning the prolonged period of low-interest rates and the business model, Chen et al. (2018) argue that the decline in banks' profitability under the low-for-long era depends on their engagement in maturity transformation and deposit funding. Under the ZLB and negative interest rate policy (NIRP), banks often fail to transmit fully the negative rates to depositors, especially the retail ones, causing banks to decrease lending and increase their fee-based activities. Empirically, they find that more wholesale-funded banks are less affected by the monetary policy during the low-for-long period. Buchholz et al. (2020) also agree that banks having a higher share of loans and deposits are more sensitive to policy rate changes. Using the net interest margin (NIM) as a measure of interest-sensitive business model, they find that banks with more interest-sensitive business model react more actively to a drop in DFR and use such liquidity to increase lending rather than invest in other assets. Yet, this result is just statistically significant in non-stressed countries, implying a weaker effect of DFR during a crisis in those countries.

Soundness of the bank also plays a vital role in the bank's behaviour. This is supported by Altavilla, Canova, et al. (2019) who find a lower pass-through of the conventional policy rate on lending at banks with weak capitalization measured by the Tier 1 capital ratio. Moreover, they suggest a higher possibility of sound banks being able to pass the negative DFR through to their corporate customers. However, most banks remain cautious to do the same with the retail customers who have a looser connection to banks compared to the corporations and always have an option of hoarding cash if needed (Chen, Katagiri & Surti 2018). Thus, the soundness can change the banks' reaction to the policy rate and stimulate the real output.

Furthermore, Molyneux et al. (2019) examine the OECD countries and conclude that the NIRP erodes the bank margins and profitability in the countries implementing NIRP. In turn, the squeeze in margins and profitability limits banks' lending capacity and increases risk-taking behaviour. Notably, they also propose that both bank-specific and country-specific characteristics have significant influences on NIRP transmission; in particular, the NIRP has more severe impacts on small banks and in countries with high competition and floating interest rate schemes. This bank size effect can be explained by the ability of large banks to overcome constraints of funding and NIRP by diversifying their activities and geographical operations (Chen, Katagiri & Surti 2018).

Heider et al. (2018) propose another bank-specific factor – deposit reliance - when they study how the NIRP affects banks' behaviours. They find that the banks with higher deposit dependence (proxied by the deposit ratios) suffered more from the increased funding costs and reducing net worth when the policy rate entered the negative zone in 2014. Thus, these banks more likely lowered lending and were more committed to search-for-yield activities.

It should be noticed that the ECB has combined simultaneously different instruments to achieve the expected effects of conventional and unconventional actions on the banking system. Therefore, it is hard to separate the effects of each policy instrument on the economy and bank behaviour, as a combination of joint consequences of multiple tools. Altavilla, Canova, et al. (2019) investigate the lending rates of banks to non-financial customers over time under the ECB policies. They demonstrate that in normal times the small, distressed banks respond more actively to the monetary policies because the large, sound banks have more advantages in externalities and easily overcome those policy-based constraints. During the "Low for long" era the small, distressed banks are bounded by the liquidity pressure, so their lending rates also fail to follow the policy-aimed direction. Altavilla, Canova, et al. (2019)

specify that before 2014, the median lending rates of banks in the Eurozone were almost unchanged since the early 2000s, nevertheless, there was a wider gap between the stressed and non-stressed banks' lending rates. Hence, the former ones were unable to keep their rates as low as the latter ones under the ZLB because of the funding cost contraction. Their findings show that the combination of different unconventional monetary policies successfully makes the lending gap smaller by improving the vulnerable banks' situation through three channels. Firstly, the banks received huge liquidity through TLTROs and APP at a low rate and with a longer duration. Moreover, the negative DFR also provides them with lower-cost funding from the interbank markets. Secondly, thanks to the APP and NIRP, the financial asset value was appreciated with the spillover effects on other assets ineligible to the APP as well. This helped the collateral value increase and solidated the banks' network and lending capacity. Lastly, the forward guidance keeps the expected interest rates low, and combined with NIRP, encourages credit demand for investments and spendings.

In this paper, I will follow the study of Buchholz et al. (2020) to investigate how the DFR affects banks' balance sheet decisions and whether banks in GIIPS behave differently from those in non-GIIPS countries. More specifically, I will examine how banks' reserve levels change against the DFR movement based on their characteristics. Furthermore, when banks reduce their excess reserves, I will analyze whether they increase lending or just reallocate their asset portfolio to other liquid assets. In addition, I am also interested in the investigation of the heterogeneities of banks under the NIRP compared to the previous.

This study will firstly contribute to the literature on unconventional policy with the focus on the Eurozone system. Unlike other nations applying the nonconventional policy such as Japan and the U.S, the Eurozone system consists of different countries, and ECB is regarded as the most independent and decentralized central bank in the world (Mishkin 2019). As mentioned above, the implementation of negative interest rates put doubts on the traditional theory of financial transmission mechanisms which is based on the assumptions of positive interest rates. Optimally, the new era requires finding a new theory to explain such abnormality, to figure out its effects, and to develop the future monetary policy. Currently, we still do not know for sure when the interest rates can turn positive again in the Eurozone. Especially the global spread of the COVID-19 pandemic has put more pressure on the policies enhancing economic recovery and strengthened the "Low-for-Long" period in advanced countries.

Next, the study of NIRP's effects contributes to policy makers' decisions. If the ECB decides to dive further into the negative zone, the question will be to which effective level the ECB could reach to achieve its monetary purposes. Related to this issue, Altavilla, Burlon et al. (2019) propose that the ECB has not met the effective lower bound yet, but they fail to identify such limiting level of nominal interest rates. Agarwal & Kimball (2019) also argue that the central banks are able to use the negative interest rates to deal with the recession within a short window, and they also discuss some approaches to preserve the monetary policy power under the NIRP while still minimize costs and other side effects. Alternatively, some discussions are reasoning the possibility of other measures apart from the current unconventional tools, for instance, raising the inflation target to 4% (Ball 2014) instead of the current level of 2%. Nevertheless, Rogoff (2017b, 2017a) argues that the central banks should move deeper into the negative territory, rather than raise the inflation target, to deal with the long-lasting low real activity situation. In his work, Rogoff (2017a) discusses in more detail the preconditions for effective lower bound and suggests removing the ZLB out of the path of interest rate movement completely.

Finally, the observations on banks' behaviour against DFR policy in this paper support the current literature on risk-taking and financial stability. There is a growing concern about financial stability among central banks in many countries with more macroprudential tool applications (Adrian 2020). Recently, Xu et al. (2019) have developed a theoretical framework to illustrate the effect of bank profitability on financial stability. Combining empirical evidence from data on many advanced countries from 2004 to 2017, they find a negative relationship between the bank profitability and both system and idiosyncratic risks. Remarkably, from their findings, the source of income is an important factor in this connection. An interest-insensitive model (e.g., wholesale, fee-based activities) makes individual banks and financial systems more vulnerable. As discussed above, under the ZLB and NIRP, it seems that banks will gradually increase the share of non-interest income to save their profitability, so this will inevitably destabilize the financial system more at the aggregate level. Similarly, Demirgüç-Kunt and Huizinga (2010) also find that banks that focus more on non-interest income and funding become riskier and more fragile. However, according to Savov et al. (2018), banks do not face the interest rate risk which is considered as a nature of maturity mismatch. They use the "deposit franchise" to explain this idea based on two characteristics of deposit funding costs: i) insensitivity of deposit rates to short-term rates due to the banks' market power over retail depositors, and ii) fixed costs for deposit franchise operations such as branches and salaries. They argue that these two factors convert the short-term deposit costs to an identical form of long-term fixed-rate debt. Therefore, banks' profits are no longer sensitive to interest rate volatility. Obviously, this requires further research and consideration to reach a common conclusion.

3 DATA AND METHODOLOGY

3.1 Data

This study uses a bank-level data set from the Moody's Bureau van Dijk BankFocus database on 19 countries in the Eurozone. The policy rates of ECB, including DFR and MRO, are acquired from the ECB's database (https://sdw.ecb.europa.eu).

The sample period is from 2009 to 2019. The starting point of this time frame follows the initiation of Buchholz et al. (2020) analysis which considers the change in the MRO scheme to a fixed-rate full allotment policy in 2008. However, the data set in this paper is extended until 2019 to capture much more profoundly the effect of DFR after the negative rate implementation since 2014.

As Latvia and Lithuania recently joined the Eurozone (in 2014 and 2015, respectively), only observations *after* the participation year for the part of these two countries are included. There are 415 banks in total, after excluding missing values and outliers (the outlier treatment is explained in the Appendix). In line with Buchholz et al. (2020), my data set contains bank holding companies, commercial banks, cooperative banks, and savings banks. The banks with observations from less than three years are also excluded. Due to the data availability, all variables are given at the annual frequency. Accordingly, the DFR and MRO are annualized, using the average rates (360-day basis) weighted on the number of applicable days.

3.2 Regression model

The empirical model in this paper follows closely that of Buchholz et al. (2020), specified as:

$$\frac{\Delta Balance\ Sheet\ Position_{ijt}}{Total\ Assets_{ijt-1}} = \alpha_1 \Delta DFR_t \times NIM_{ijt-1} + \alpha_2 Bank\ Controls_{ijt-1} + \varepsilon_{ijt}$$

where the ε_{ijt} refers to the error term from a panel data regression for the observations from bank (*i*) in country (*j*) at time *t*. While Buchholz et al. (2020) only utilize the fixed effect model in their study, I use both the random effects and fixed effects models in my analysis. More specifically, the random-effects model is used for the regression on the reserve ratio changes, and the fixed effects model is used for the regressions on the changes in liquid assets and loans. The chosen models are recommended by the Hausman test results. Indeed, the use of the random-effects model for the main observed variable (reserve ratio change) has some advantages. First, because my data set is smaller with 415 banks on the annual basis in comparison with the 516 banks of Buchholz et al. (2020), the application of the fixed-effect model will further reduce the degrees of freedom in comparison with the random-effects model. Second, I want to scrutinize the effect of DFR on the European banking system as a whole, rather than on any specific bank, so the use of the random effects model is more reasonable. An important assumption related to the random-effects model is that the unobserved individual effects are normally distributed and uncorrelated with the independent variables (Brooks 2019).

The analyzed vector of relevant dependent variables for bank's asset allocation decisions consist of three balance sheet position factors relative to the balance sheet size in the previous period ($Total\ Assets_{t-1}$), including changes in Bank Reserve ($\Delta Reserve$), changes in Liquid Assets ($\Delta Liquid\ Assets$), and changes in Loans ($\Delta Loans$). Each of these balance sheet items will be examined separately to see how banks in the euro area distribute their liquidity in response to the changes in the ECB's policy rate. We need to consider the balance sheet position changes in relation to the total assets because of two reasons. First, it allows the variables to be comparable among different entities. Second, it translates the variables into a percentage scale which corresponds to the units of measurement for the policy interest rates and other control variables.

Reserves and liquid assets are taken from the "Cash & Balances with central banks" and "Liquid assets", respectively, from the annual financial statements reported in the BankFocus. On the other hand, Loans include "Net loans &Advances to customers" accounts.

The independent variable is an interaction between the change in DFR and the variable that proxies the interest-sensitive business model. The latter variable is lagged one period to capture the fact that banks' decisions related to their portfolio are made based on the figures in the report of the preceding period. Following Buchholz et al. (2020), I firstly use NIM as the interest-sensitive business model in the interaction term of the independent variable ($\Delta DFR_t \times NIM_{ijt-1}$). NIM is defined as the ratio of net interest income on average earning assets, so it clearly illustrates the profitability of banks from interest-bearing activities. As discussed in Section 2, it is expected that a higher NIM bank will react more actively to the DFR change than the banks with lower NIM. The arguments for using NIM are based on its three characteristics. First, NIM illustrates bank profitability on average interest-earning assets. Because lending rates are more elastic than deposit rates, NIM also causes heterogenous replies to DFR change. Second, there is some evidence in the literature showing the negative relationship between NIM and non-interest income. Third, NIM also captures the bank's exposure to interest rate risk and thus implicitly reflects the efficiency of the maturity structure of the bank. (Buchholz, Schmidt & Tonzer 2020).

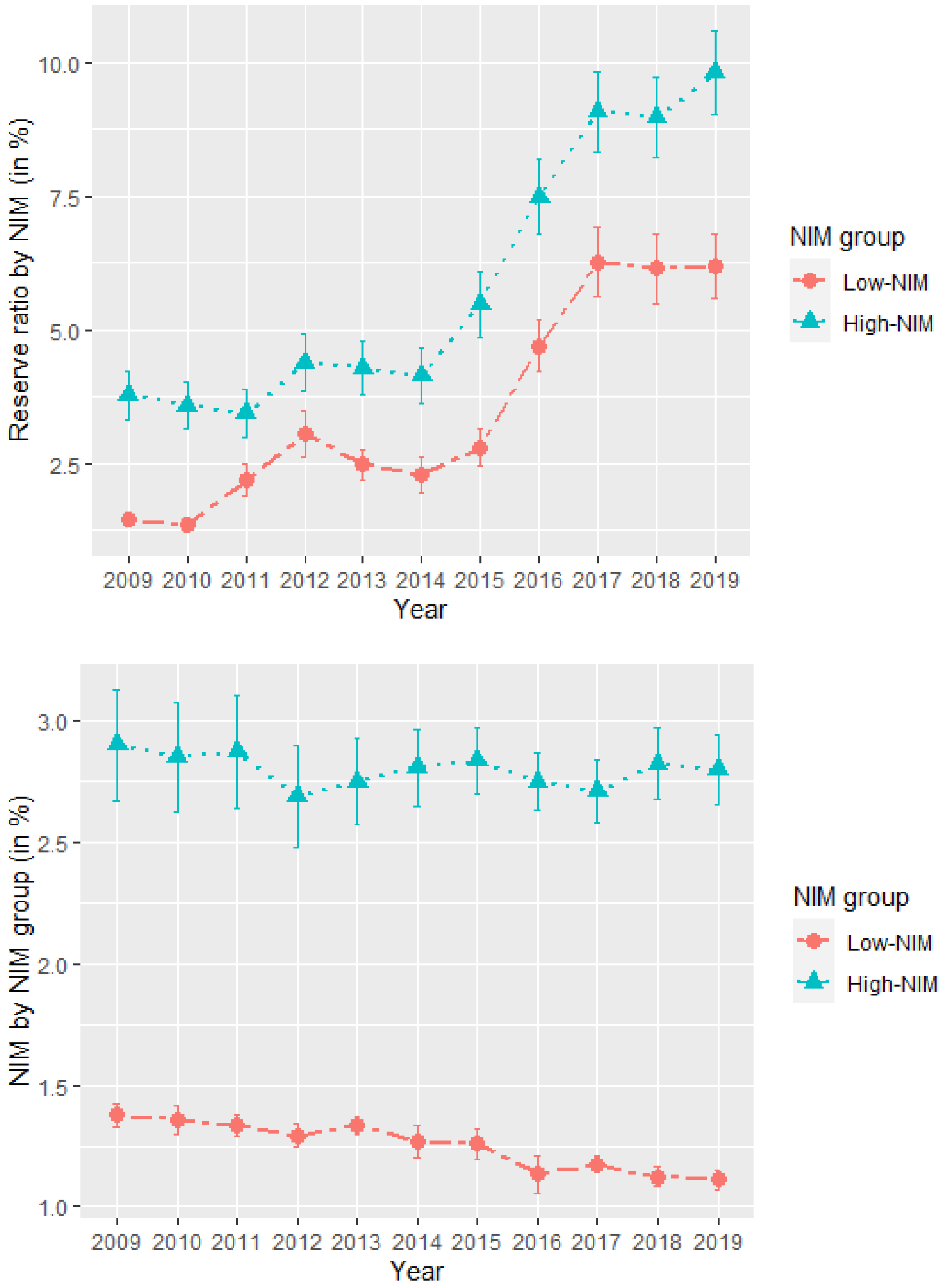

FIGURE 2. Evolution of reserve ratio and NIM of High-NIM and Low-NIM banks.
The graphs illustrate the average changes in reserve ratio and NIM over the period 2009-2019 across the low-NIM banks (red, dashed line with points) and high-NIM banks (green, dotted line with triangles).

To illustrate the overview of heterogeneity of banks with different NIM levels, I create a variable called *HighNIM*. Therefore, I first calculate the NIM averages of each bank over the whole period and that of all banks as well. The HighNIM dummy variable takes the value of 1 if the bank's NIM average is higher than the sample average; otherwise, HighNIM is zero. This method follows Buchholz et al. (2020), but because the data coverage in this paper is very different, also the resulting series behave very differently. While the evolution of the reserve ratio of Buchholz et al. (2020) has only a small variation of around 2%, Figure 2 shows a constant increase of about 8% in reserve ratio in both groups of high NIM and low NIM over the whole observed period on this study. On the other hand, the high-NIM banks (referring to a more interest-sensitive business model) generally have a higher reserve ratio than the low-NIM banks. Additionally, Figure 2 shows the gap of NIM between the high-NIM and low-NIM groups.

Nevertheless, there is no empirical study other than Buchholz et al. (2020) using NIM as the measure of interest sensitivity. In the literature, many other studies consider NIM as a representative of bank profitability (see Junttila, Perttunen & Raatikainen (2021), Molyneux et al. (2019), Detragiache, Tressel, and Turk-Ariss (2018)), so the use of NIM in this study is not free of critique. The wholesale funding ratio (WSF), on the other hand, is used more commonly as a proxy of the business model such as in Demirgüç-Kunt and Huizinga (2010) and Junttila, Perttunen & Raatikainen (2021). The relationship between wholesale funding and bank interest insensitivity can be explained through the simultaneous determination of bank activities and bank funding, often referred to as the so-called asset-liability matching problem. It is a frequent observation in which traditional lending and deposit-taking services are provided within the same firm, resulting in a positive correlation between interest income generation and deposit funding. In turn, such a positive correlation implicitly explains the positive correlation between their complementaries, i.e. non-interest income generation and wholesale funding, if the given resources are allocated to interest and non-interest operations (Demirgüç-Kunt & Huizinga 2010). Additionally, Demirgüç-Kunt & Huizinga (2010) argue that the connection between the non-interest income and wholesale funding arises from the similar inputs in which banks have to keep close relationships with non-retail entities.

Hence, in a later stage, I replace NIM with the WSF variable as the proxy of bank interest sensitivity and rerun the regressions with the dependent interaction term of $\Delta DFR_t \times WSF_{ijt-1}$ to study deeper the impacts of DFR on the European banking system. The WSF variable is the ratio of wholesale funding to total assets, in which, the wholesale funding provided by the BankFocus includes the borrowings from the wholesale market other than customer deposits (i.e., interbank and wholesale deposits, securities financing transactions, and borrowings including short-term, long-term, liabilities at fair value and subordinated borrowings). By using an alternative proxy, I can compare the differences between the two proxies and strengthen my analysis and findings. Noticeably, because of the positive correlation between the WSF and non-interest income that we discussed above, the higher WSF means the lower interest sensitivity. As a result, it is expected that the impacts of the WSF variable will be opposite to those of the NIM variable.

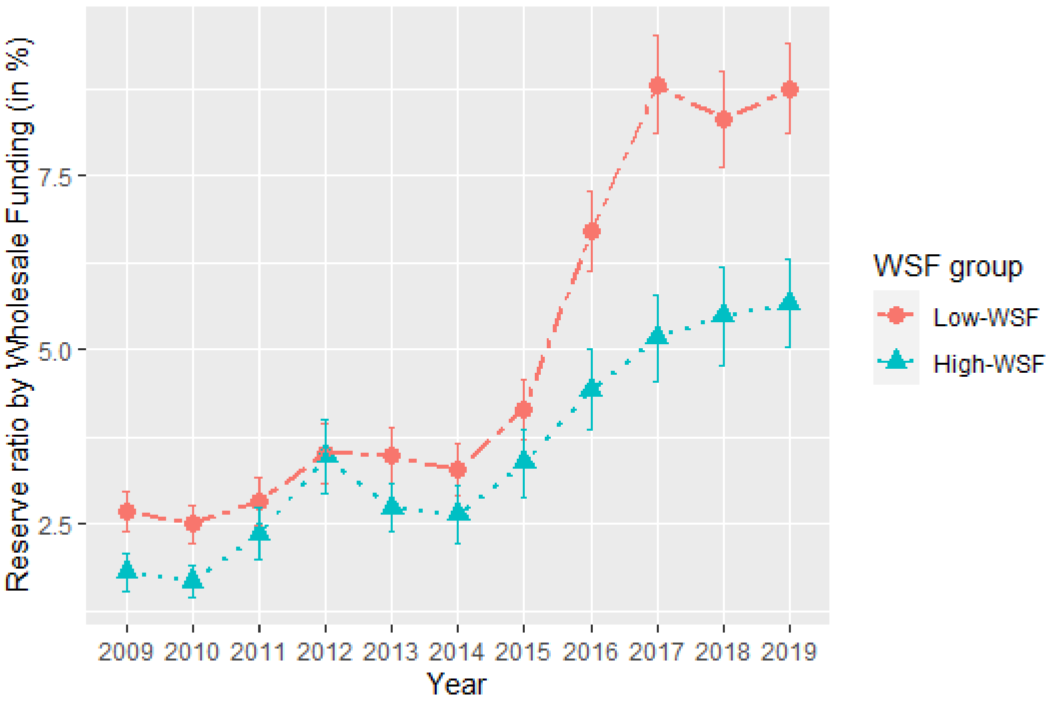

FIGURE 3. Evolution of reserve ratio of High-WSF and Low-WSF banks
The graph illustrates the average change in reserve ratio over the period 2009-2019 across the low-WSF banks (red, dashed line with points) and high-WSF banks (green, dotted line with triangles).

Once again, I created a dummy variable of *HighWSF* with the same method as the HighNIM variable to show the differences in the reserve ratio movement between the banks with greater reliance and those banks with less reliance on non-interest activities. From Figure 3, we can see that banks with high WSF constantly had lower reserve ratios (except 2012), and this gap has even widened after 2015. This implies that WSF also influences the way banks react to the monetary policies under the NIRP.

To examine the heterogeneity of banks in GIIPS from those in non-GIIPS countries, I further add a dummy variable of *GIIPS* into the regression. The GIIPS variable takes the value of 1 when the observations are from Greece, Ireland, Italy, Portugal, or Spain. Figure 4 below illustrates the movement in average reserve ratio in these two groups of countries. The evolution of reserve ratio in GIIPS and non-GIIPS countries in this paper are quite different from those in Buchholz et al. (2020) who show that the non-GIIPS banks' ratio is consistently higher than that of banks in GIIPS and the gap between the two groups is stable. With my data set, we see another picture. Prior to the sovereign debt crisis, banks in both groups had a similar reserve ratio (GIIPS countries even had a bit higher reserve ratio), but the ratio movements differed after 2011. While non-GIIPS banks kept raising their reserve ratio from 2.5% to 8% in 2019, banks in GIIPS experienced a decline and they almost retained the ratio at the required reserve ratio of 1% until 2015, and then, increased it again to over 5% in 2019. This may infer the liquidity shortage that GIIPS banks suffered before the implementation of NIPR combined with other easing policies. The unconventional monetary package could improve the pass-through and affect the heterogeneity in the reserve ratio change between the banks in GIIPS and non-GIIPS.

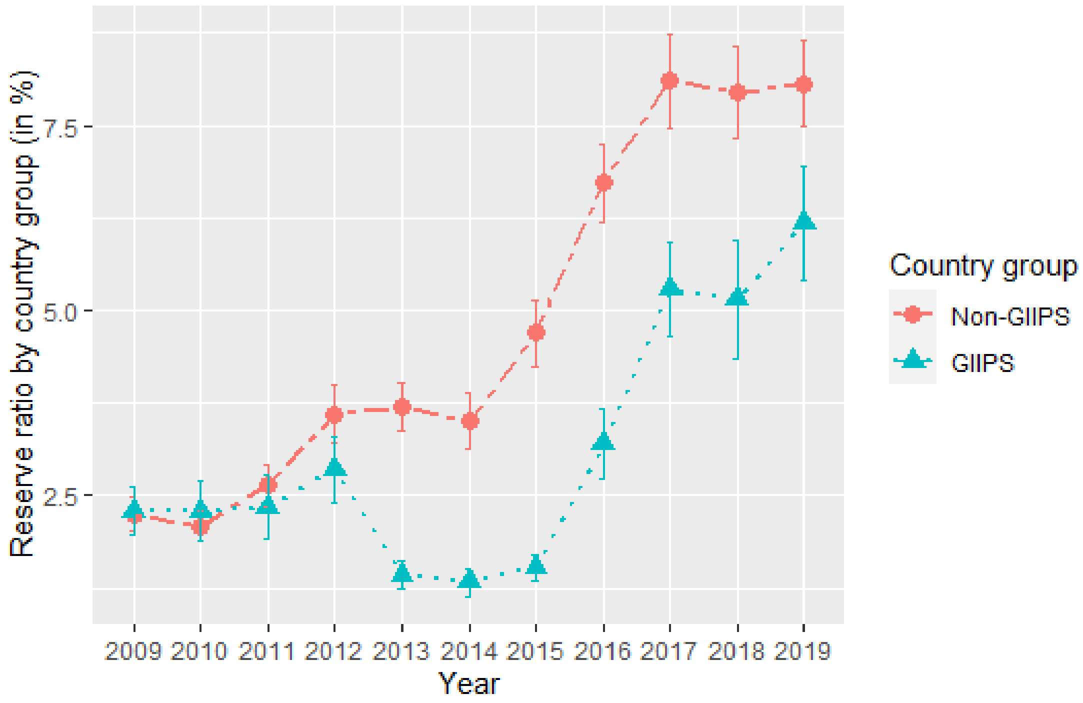

FIGURE 4. Evolution of reserve ratio of GIIPS and non-GIIPS.
The graph illustrates the average change in reserve ratio over the period 2009-2019 across the banks in the non-GIIPS countries (red, dashed line with points) and banks in the GIIPS countries (green, dotted line with triangles).

The main refinancing operation rate (MRO) is also added to control for the possible effect on banks' behaviour conditional on the main funding cost. In line with Buchholz et al. (2020), MRO is used instead of the marginal lending facility because the European banks are more likely to borrow liquidity through the main refinancing operations than through other channels. As MRO sets up the main funding cost and affects the interest spread that determines part of bank profitability, it inevitably has a certain influence on banks' portfolio allocation decisions. Moreover, the change in DFR has often coincided with the announcements of refinancing operations. For example, the reduction to zero interest rate in mid-2012 happened just before the OMT announcements and came after the launching of two three-year refinancing operations (one in December 2011 and another in February 2012). Also, the NIRP was announced together with the TLTROs in June 2014. Thus, the inclusion of MRO in the regression model specification is plausible.

When considering the bank-specific characteristics which may have an impact on the behaviour of banks against the DFR change, there are four bank control factors in the estimated regressions, and their first lagged values are used to account for the delay of their effects on banks' behaviour. More specifically, the control variables are the logarithm of total assets (for the bank size), deposit ratio (reflecting the role of the most standard source of funding), return on averaged asset ratio (ROA) for the bank profitability, and equity to total asset ratio (for capital adequacy).

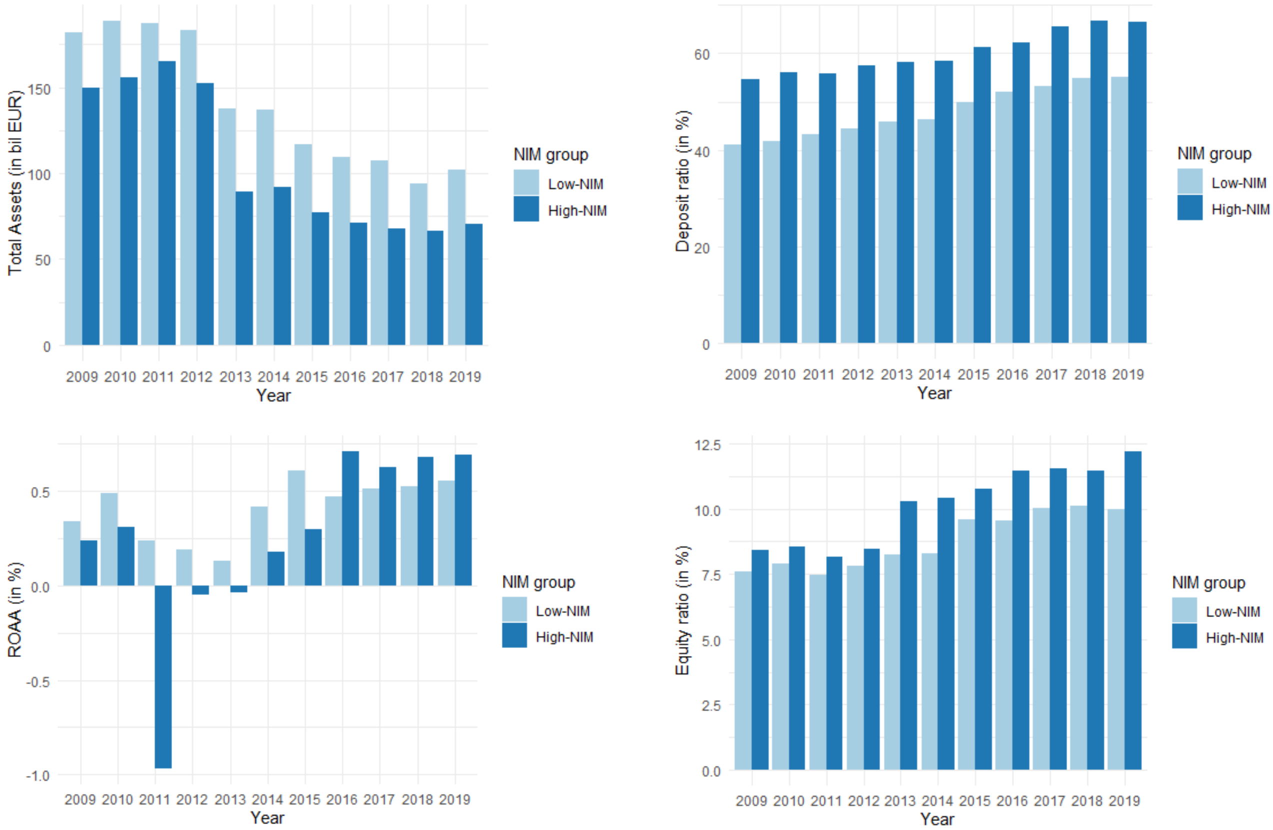

FIGURE 5. Banks' characteristics between High NIM and Low NIM groups of banks.

Figure 5 gives an overview of the differences in the control factors conditioned on NIM as a proxy of the business model. The interest-sensitive banks generally had lower assets throughout the period and suffered more damage in total assets since 2011. In addition, the high-NIM banks were highly unprofitable during 2011-2013, but they improved their profitability again since 2014. However, this interest-sensitive group comprises more sound banks with a higher equity ratio than the others.

Analogously, Figure 6 shows the comparisons of control factors but conditioned on another proxy of bank business model – WSF. Although the two groups of banks shared similar capitalization levels measured by the equity ratio, they differed greatly in terms of total assets and deposit ratio. It is reasonable for banks with greater dependence on wholesale funding to have a significantly lower deposit ratio. Consistent with what we observed in Figure 5, banks with high WSF (less interest sensitivity) were bigger and did not experience any loss compared to the considerable losses in 2011 and 2013 of the low-WSF banks. In addition, the profitability of high-WSF banks was much better than that of low-WSF banks prior to 2014, but their profitability was nearly similar to each other under the negative era.

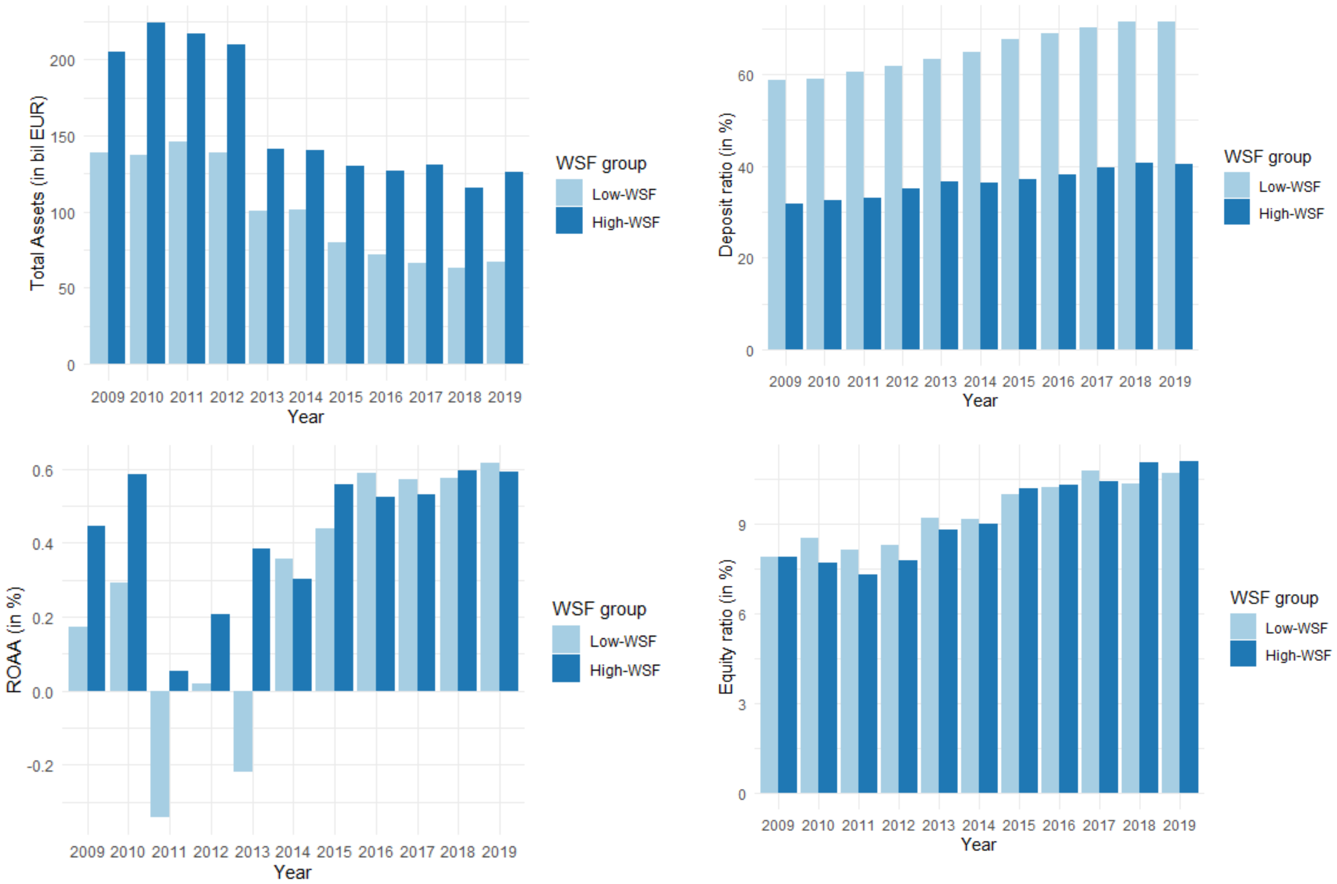

FIGURE 6. Banks' characteristics between High-WSF and Low-WSF groups of banks.

Figures 7 and 8 demonstrate the changes in portfolio composition between the NIM groups and WSF groups, respectively. Both figures show an upward trend in the reserve ratio in all banks. The high-NIM banks increased reserves to a greater extent than the low-NIM banks, mostly by decreasing liquid assets in their portfolio, while loans took a relatively stable proportion in the portfolio in both high-NIM and low-NIM groups over time. Consistently, the comparison between the WSF groups also shows that more interest-sensitive banks (low WSF) raised their reserve more aggressively through a cut in the liquid assets as a proportion in the total assets.

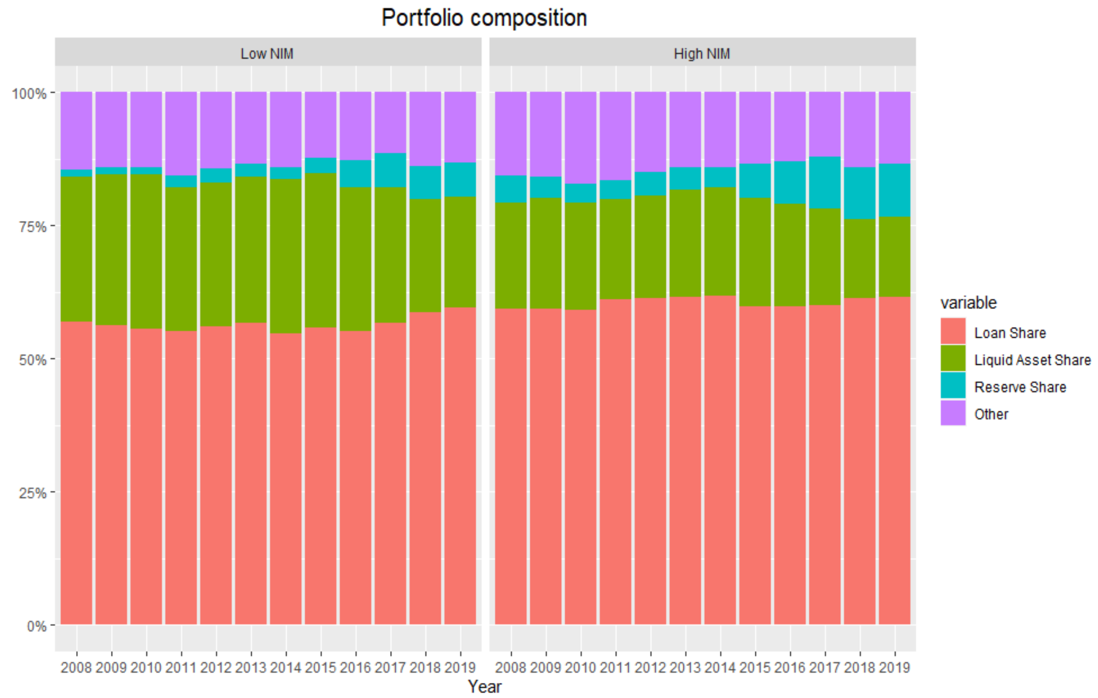

FIGURE 7. Portfolio composition between High-NIM and Low-NIM groups of banks.

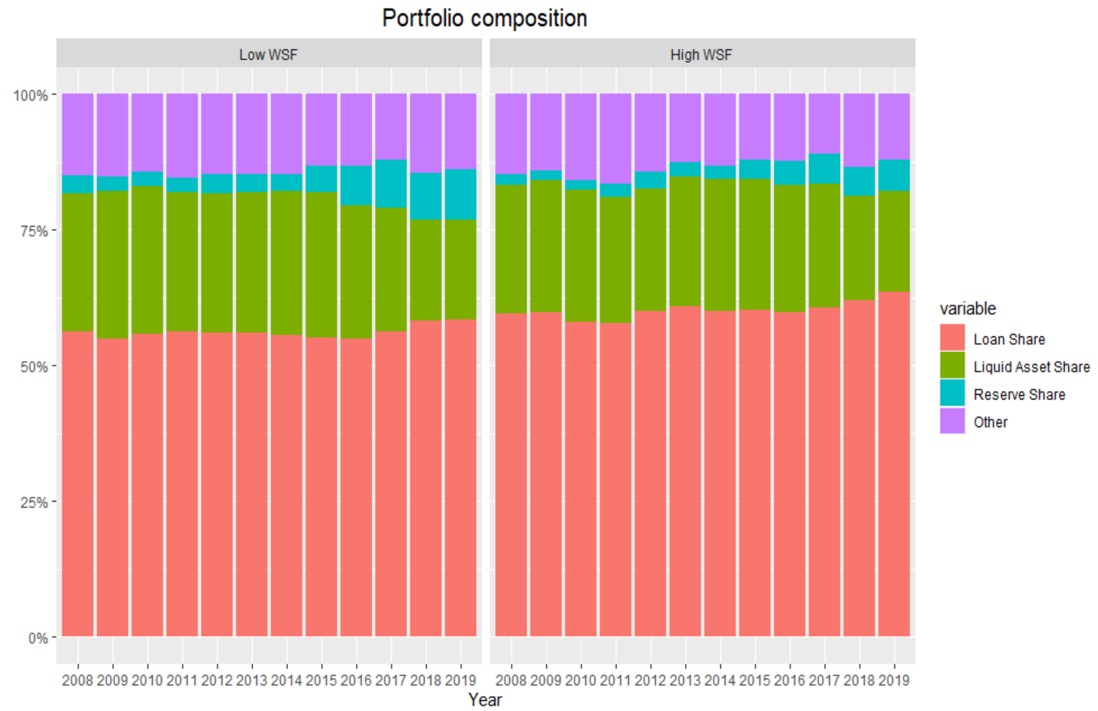

FIGURE 8. Portfolio composition between High-WSF and Low-WSF groups of banks.

3.3 Descriptive statistics

The descriptive statistics of all variables used in the regressions for the whole data set from 2009-2019 are reported in Table 1. Although I excluded some outliers in the bank control variables to reduce their variation and adjusted their distribution closer to the normal distribution, the variations of variables in this paper are relatively larger than the corresponding variations in the study of Buchholz et al. (2020). Moreover, I still include the relatively large extreme values due to the obviously aggressive cut in both DFR and MRO rates in 2009 because these rates are the main observed variables, and such outliers simply reflect the economic situation and responses of ECB and banking system to the global financial crisis.

TABLE 1. Descriptive statistics for the whole data set (2009- 2019)

Descriptive Statistics

	N	Mean	Std. dev.	Min.	25 %	Median	75 %	Max.
RES_Change	2,956	0.684	3.848	-26.110	-0.183	0.038	1.104	28.860
LIQ_Change	2,956	-0.260	8.648	-51.480	-2.837	-0.044	2.511	59.074
LOA_Change	2,956	2.380	9.045	-90.396	-0.598	2.037	4.602	133.896
DepositRatio	2,956	53.983	22.148	0.000	36.437	58.386	70.684	94.941
WSFRatio	2,956	28.612	18.960	0.000	14.847	25.703	39.777	94.348
lnAsset	2,956	9.757	1.977	2.492	8.585	9.611	10.836	14.772
DFRchange	2,956	-0.216	0.565	-2.876	-0.173	-0.086	-0.021	0.248
MROchange	2,956	-0.254	0.618	-3.155	-0.326	-0.039	0.000	0.248
NIM	2,956	1.800	1.359	-14.365	1.190	1.591	2.137	15.458
ROA	2,956	0.412	1.549	-25.885	0.216	0.440	0.734	19.978
EQU	2,956	9.666	6.602	-3.931	6.198	8.493	11.820	98.860

NOTES: From top to bottom, the abbreviations respectively stand for RES_Change - changes in Bank Reserve ($\Delta Reserve$), LIQ_Change - changes in Liquid Assets ($\Delta Liquid\ Assets$), LOA_Change - changes in Loans ($\Delta Loans$), Deposit ratio – Ratio of total customer deposits to total assets, Wholesale funding ratio (WSF), (Natural) Logarithm of total assets (lnAsset), Changes in DFR (ΔDFR), Changes in MRO (ΔMRO), Net interest margin (NIM), Return on average assets (ROA), Equity ratio - Ratio of total equity to total assets (EQU).

Because I will run a regression on a subsample over the period 2009-2014 to be able to compare the results against the results obtained in Buchholz et al.

(2020), I also include here the descriptive statistics for the 2009-2014 subsample (see Table 2 below). Compared to the data set of Buchholz et al. (2020) which has 516 banks and a total of 1978 observations, my subsample is smaller with 278 banks and 1,174 observations. This is due to fewer data available from BankFocus compared to BankScope with the same bank types that are used by Buchholz et al. (2020). Apart from the greater variations of my variables, another noticeable difference between our data sets is in the mean values of the balance sheet positions. While all these variables have negative means in the study of Buchholz et al. (2020), they are positive in my data set. Notably, the number of banks in the subsample is also smaller than the whole data set because of limited data on some banks in the earlier years.

TABLE 2. Descriptive statistics for the subsample (2009- 2014)

Descriptive Statistics

	N	Mean	Std. dev.	Min.	25 %	Median	75 %	Max.
RES_Change	1,174	0.154	2.860	-19.755	-0.319	0.009	0.515	28.206
LIQ_Change	1,174	0.694	8.365	-51.053	-2.675	0.331	3.170	57.793
LOA_Change	1,174	1.213	8.781	-90.396	-1.561	1.013	3.502	133.896
DepositRatio	1,174	48.672	20.791	0.000	30.763	51.179	63.445	94.606
WSFRatio	1,174	33.648	17.948	0.035	21.871	31.312	44.974	94.348
lnAsset	1,174	10.198	1.837	2.492	9.087	9.806	11.293	14.772
DFRchange	1,174	-0.440	0.844	-2.876	-0.365	-0.133	-0.086	0.248
MROchange	1,174	-0.591	0.878	-3.155	-0.392	-0.365	-0.288	0.248
NIM	1,174	1.837	1.292	-8.578	1.269	1.649	2.154	15.458
ROA	1,174	0.185	1.803	-25.885	0.138	0.368	0.669	6.415
EQU	1,174	8.422	5.445	-3.931	5.114	7.412	10.805	66.310

According to the Spearman correlations in Table 3 below, DFR has a positive correlation with reserves and loans while it correlates negatively with liquid assets, and especially the correlations with liquid assets and loans are statistically significant at below 1% risk level. The correlations of MRO with these three balance sheet positions are of the same sign as in the case of DFR correlations, and all of them are significant as well. However, the correlations between the two policy rates with liquid assets are not strongly significant subject to the Pearson method.

In general, both DFR and MRO are significantly correlated with the other variables except NIM and ROA (based on the inference from either the Spearman or Pearson correlation comparisons). Meanwhile, NIM and ROA have a significantly positive correlation based on both methods. This is inevitable as both the NIM and ROA are indicators of profitability and NIM is also a component in the calculation of ROA.

TABLE 3. Correlation matrix (whole data set)

	A	B	C	D	E	F	G	H	I	J	K
A: RES_Change		**-0.18**	**0.07**	0.04	-0.05	**-0.07**	**0.05**	**0.07**	-0.03	0.03	0.02
B: LIQ_Change	**-0.12**		0.05	0.01	0.02	0.02	-0.03	-0.05	0.05	**0.09**	-0.02
C: LOA_Change	**0.06**	0.04		**0.09**	-0.02	**-0.09**	**0.05**	**0.06**	**0.12**	**0.19**	-0.02
D: DepositRatio	**0.07**	-0.05	**0.13**		**-0.86**	**-0.30**	**0.09**	**0.11**	**0.17**	-0.04	**-0.19**
E: WSFRatio	**-0.07**	**0.07**	-0.05	**-0.88**		**0.24**	**-0.11**	**-0.13**	**-0.16**	-0.01	**-0.07**
F: lnAsset	-0.04	-0.01	**-0.15**	**-0.35**	**0.31**		**-0.08**	**-0.09**	**-0.12**	-0.03	**-0.42**
G: DFRchange	0.03	**-0.09**	**0.14**	**0.13**	**-0.14**	**-0.07**		**0.98**	-0.02	0.01	**0.07**
H: MROchange	**0.08**	**-0.10**	**0.20**	**0.16**	**-0.18**	**-0.09**	**0.78**		-0.02	0.02	**0.08**
I: NIM	0.01	0.04	0.02	**0.28**	**-0.25**	**-0.18**	-0.05	**-0.07**		**0.10**	**0.13**
J: ROA	**0.06**	**0.08**	**0.33**	-0.02	-0.01	**-0.22**	**0.07**	**0.09**	**0.24**		**0.16**
K: EQU	0.01	**0.07**	**0.11**	-0.02	**-0.05**	**-0.48**	**0.10**	**0.12**	**0.22**	**0.45**	

This table reports Pearson correlations above and Spearman correlations below the diagonal. Number of observations: 2956. Correlations with significance levels below 1% appear in bold print.

NIM and WSF have a negative correlation and this relationship is statistically significant below 1% risk level. This supports the use of these two variables as the measures of interest rate sensitivity and business model form. Furthermore, the highly negative correlation between WSF and deposit ratio is reasonable as the wholesale and deposit fundings are the two main liquidity sources of the banks and they are used as the alternative source of funding. In other words, as the deposit funding ratio increases, the WSF decreases, and vice versa.

4 EMPIRICAL RESULTS AND ANALYSIS

This section will be divided into two main parts, in which, the former utilizes NIM as the measure of bank interest sensitivity and the latter is based on WSF measure.

4.1 NIM as a proxy of business model

In this part, I will first conduct the comparison with Buchholz et al. (2020) by using the subsample 2009-2014. After that, the whole data set (2009-2019) will be utilized for the baseline regressions to investigate the DFR effect on three balance sheet position indicators, that is, for the Reserve changes, Liquid asset changes, and Loan changes. Subsequently, there will be two further discussions on the results when adding a dummy variable, GIIPS and After2014, respectively, into the baseline regressions to capture the heterogeneities between banks in relation to their location and the negative interest rate policy implementation.

4.1.1 Comparison to Buchholz et al. (2020)

Results in Table 4 show both some similarities and differences in comparison with the results of Buchholz et al. (2020). Noticeably, the effects of the two policy rates in this study are separated into two parts, individual effects and heterogeneous effects, conditional on the interest-sensitive business model (NIM), while Buchholz et al. (2020) only report the interaction terms of the policy rates with NIM.

TABLE 4. Results for the subsample (2009-2014)

	Dependent variable:		
	Δ Reserves$_t$/ Assets $_{t-1}$	Δ Liquid Assets$_t$/ Assets $_{t-1}$	Δ Loans$_t$/ Assets $_{t-1}$
	(1)	(2)	(3)
Δ DFR$_t$	-2.993**	1.126	5.391
	(1.284)	(3.523)	(3.754)
NIM$_{t-1}$	-0.126	0.027	0.740**
	(0.103)	(0.326)	(0.329)
Deposit Ratio $_{t-1}$	0.008*	0.017	0.017
	(0.005)	(0.015)	(0.015)
Ln Asset $_{t-1}$	0.088	-0.479**	-0.532***
	(0.058)	(0.208)	(0.199)

Equity Ratio $_{t-1}$	0.069***	0.075	0.078
	(0.020)	(0.063)	(0.064)
ROA $_{t-1}$	-0.005	0.193	0.586***
	(0.049)	(0.146)	(0.152)
Δ MRO$_t$	3.067**	-1.451	-5.109
	(1.234)	(3.383)	(3.605)
Δ DFR$_t$ × NIM $_{t-1}$	0.503	-0.015	-4.056**
	(0.571)	(1.557)	(1.662)
Δ MRO$_t$ × NIM $_{t-1}$	-0.463	0.151	4.011**
	(0.547)	(1.493)	(1.594)
Constant	-1.068	3.887	4.134
	(0.823)	(2.806)	(2.745)
Observations	1,173	1,173	1,173
R^2	0.022	0.017	0.037
Adjusted R^2	0.014	0.010	0.030
F Statistic	26.037***	19.295**	43.809***

NOTES: ***, **, * indicate significance at the 1%, 5%, and 10% risk levels, respectively. The random-effects model is applied in this table as this model has some advantages over the fixed-effects model (as discussed in Section 3.2) and the results from the random-effects model are also more economically meaningful.

While Buchholz et al. (2020) find significant influences of both DFR and MRO on changes in reserve ratios conditional on the bank sensitivity model, I fail to do so due to the insignificant coefficients of the two interaction terms. However, the individual effects of these two policy rates are significant. Therefore, this finding argues against the heterogenous reactions of banks with different degrees of interest sensitivity to the policy rate changes. In other words, DFR and MRO generally have the same impact on bank reserve ratios regardless of bank-specific characteristics in the preceding period. In addition, the soundness (equity ratio) and reliance on deposit funding (deposit ratio) significantly affect changes in reserve ratio in the later period. This is different from Buchholz et al. (2020) as they find the effects of size (ln assets) and profitability (ROA) on the reserve ratio change next period.

The negative relationship between the DFR and reserve ratio is quite surprising as it contradicts what we should have expected based on the fundamental theory that banks would decrease their reserve ratios as a result of DFR reduction due to the higher opportunity costs of holding liquidity. More specifically, I find that banks increase their reserve ratios by 3% if the DFR reduces by 1%. Nevertheless, this finding retains its economic meaning by focusing on the fear of banks under the high uncertainties regarding the market development. As we already know, the global financial crisis followed by the sovereign debt crisis forced the European banks to struggle in maintaining their profitability due to the malfunction of interbank markets, slow economic recovery, and high amounts of non-performing loans. Molyneux et al. (2019) state that when the bank profits are squeezed, their capitalization is also eroded, thus limiting their lending ability. Because the low-for-long interest rate period reduces the bank profitability, this effect is even more pronounced when the interest rates approach zero (Borio, Gambacorta & Hofmann 2017, Claessens, Coleman & Donnelly 2018), and banks have to increase their reserves to improve liquidity and leverage buffers against the capital reduction.

In addition, under abnormally low rates, the market expectations of the policy rate reduction may be different compared to the expectations in normal times. Policy rates at the negative zone are considered to be less accommodative (Heider, Saidi & Schepens 2018) and they have also not been widely used on a global scale. Apart from the fear of cash hoarding under the negative rates, many believe that the low-for-long and NIRP cause increasing financial instability as there is some evidence showing the trade-off between the short-term easing monetary policy and medium-term financial system vulnerabilities (Rogoff 2017b, Adrian 2020, Xu, Kun & Das 2019).

Regarding the effects on loan changes (reported in column 3), in line with Buchholz et al. (2020), I find a similar effect of both DFR and MRO on loan changes conditional on NIM, although the regression coefficients in my results (-4.056 and 4.011, respectively) illustrate somewhat stronger effects than what Buchholz et al. (2020) find. These effects are statistically significant. Additionally, the individual effects of both policy rates may lessen the interaction effects, but the coefficients of these individual effects are insignificant. As a result, the finding suggests an increase in loans in response to a reduction in DFR. However, if the refinancing operations' effects take place simultaneously with the DFR change effects, the opposite directions of the two rates may result in neutrality with very little changes in bank lending (Buchholz, Schmidt & Tonzer 2020). In terms of control variables, this study once again confirms the effects of size and profitability, but not for the part of deposit ratio.

Like Buchholz et al. (2020), in these results changes in DFR and MRO have no significant effect on changes in liquid assets. Nevertheless, Buchholz et al. (2020) do find that bank control variables influence changes in liquid assets, and especially the size of banks has a highly negative relationship with the coefficient of -13.513. Related to bank-specific variables, the results in Table 4 only confirm the effects of size on liquid asset changes, but with a relatively much smaller scale (-0.479)

4.1.2 Baseline regressions with NIM

The baseline results for the whole data set covering the period 2009-2019 are presented in Table 5 below. Generally, the effects of DFR are statistically significant on the reserve and loan changes only, while its effect on the changes in liquid assets remains unclear. Indeed, NIM has a significant role when banks adjust their loan portfolio as a response to a DFR change in the next period, while it has no significant impact on the changes in bank reserves.

In column (1), the coefficients on both the DFR and MRO are significant but with opposite signs. When the DFR reduces by 100 basis points, the bank's reserve ratio increases by 5.19%. In contrast, a reduction of 100 basis points in MRO lowers the reserve ratio by 5.05%. Similar to the results in section 4.1.1, these effects come from the individual effects only, while the effects conditioned on the bank interest sensitivity proxied by NIM are relatively small and insignificant as well. In other words, NIM does not create any significant heterogeneity in bank behaviour, and this seems to hold even in the negative interest rate period.

TABLE 5. Baseline results with NIM as the business model variable (whole data set)

	Dependent variable:		
	Δ $Reserves_t$/ Assets $_{t-1}$	Δ Liquid $Assets_t$/ Assets $_{t-1}$	Δ $Loans_t$/ Assets $_{t-1}$
	(1)	(2)	(3)
Δ DFR_t	-5.194***	13.679	9.779
	(1.125)	(14.838)	(13.962)
NIM_{t-1}	-0.022	0.057	-0.346*
	(0.059)	(0.221)	(0.208)
Deposit Ratio $_{t-1}$	0.001	0.004	0.025*
	(0.004)	(0.014)	(0.014)
Ln Asset $_{t-1}$	-0.118**	-3.129***	-4.359***
	(0.046)	(0.556)	(0.523)
Equity Ratio $_{t-1}$	0.010	0.169***	0.100**
	(0.013)	(0.045)	(0.042)
ROA $_{t-1}$	0.053	-0.138	0.071
	(0.047)	(0.134)	(0.126)
Δ MRO_t	5.054***	-10.070	-18.543
	(1.027)	(13.229)	(12.448)
Δ DFR_t × NIM $_{t-1}$	0.812	-0.753	-2.026*
	(0.505)	(1.172)	(1.103)
Δ MRO_t × NIM $_{t-1}$	-0.706	0.659	2.151**
	(0.458)	(1.067)	(1.004)
Observations	2,955	2,955	2,955
R^2	0.024	0.052	0.068
Adjusted R^2	0.021	-0.111	-0.092
F Statistic	70.583***	7.230***	9.686***

NOTES: ***, **, * indicate significance at the 1%, 5%, and 10% risk levels, respectively.

The results in the first column are based on the random-effects model, while the results in the other columns are based on the fixed-effects model. The choices of the model are supported by Hausman Test. Time effects are included in the fixed-effects model but not reported. The constant term of the random model is not reported either.

Consistently, Buchholz et al. (2020) find an insignificant influence of policy rates on liquid assets, and they confirm the effect on loans conditional on NIM. The results in columns (2) and (3) support their findings. The significantly negative coefficient of the interaction term between DFR and NIM points out that banks with previously one percentage point higher NIM are likely to increase their lending by 2.03% when DFR drops by 100 basis points. Meanwhile, the effect of MRO on lending is in the opposite direction with the DFR's, reflected by the significant positive coefficients of the MRO interaction term with NIM (2.151). It implies that the effects of the two policy rates on bank lending are not the same from banks to banks, and the way a particular bank reacts to the policy rates significantly depends on its NIM in the previous period.

An interesting and new finding from these results is the change in the sign of the NIM coefficient. While NIM has a positive effect on loans on the subsample (see Table 4), it turns to negative when the whole data set is included. It refers to the possibility that the banks with higher previous NIM are more active in lending before the NIRP only, and they have become more hesitant in lending under the negative interest rates.

The remarkable effect of bank size is worth to be discussed further too. All three regressions in Table 5 confirm the significant impact of bank size in the prior period on the bank's asset reallocation. The negative coefficient implies that the larger banks in the previous period seem to experience greater changes in their asset portfolio, and this bank size effect is clearly stronger for liquid assets and loans (in terms of absolute values of the coefficients). Thus, the large banks may conduct the cuts in loans and liquid assets more aggressively than the small banks. This finding is probable evidence for the transmission to the non-interest activities to compensate the losses of interest activities due to the Low-for-long era that some previous studies have suggested (see e.g. Molyneux, Reghezza & Xie (2019); Chen, Katagiri & Surti (2018)).

Although capitalization (or the soundness) measured by equity ratio has an ambiguous influence on the reserve ratio changes, it causes some changes in both liquid assets and loans to a small but statistically significant extent. In particular, banks with a higher equity ratio of 1% may increase their liquid assets and loans by approximately 0.1% for each type of asset. It is consistent with Altavilla, Canova, et al. (2019), supporting the idea that high-capitalized banks are able to pass through the policy rates to the real output, even under the NIRP when they can still pass the negative rates to their corporate customers and increase lending. Much evidence in the literature has confirmed the role of capitalization on bank behaviour, too (see e.g. Altavilla et al. 2019, Jiménez et al. 2012, Dell'Ariccia, Laeven & Suarez 2016).

Additionally, the deposit ratio also seems to have a positive relationship to the lending activity changes of the banks, but at a relatively small scale with the coefficients of 0.025. While Heider et al. (2018) conclude that the high-deposit ratio banks reduce lending (under the negative interest rate), my finding confirms a positive correlation between the deposit ratio and loans. Because Heider et al. (2018) examined this relationship within a short window of three years (2013-2015), their finding may reflect the short-term behaviour around the event of negative rates' introduction only. As they also stated that during the normal times, the high-deposit banks are often more active in lending, the results in my study imply that this idea still holds in general and also in the longer-term observations after the banks have overcome the truncation effects of ZLB and adapted to the negative environment.

4.1.3 Heterogeneity between stressed and non-stressed countries

Table 6 below illustrates the results from the baseline regressions adding the dummy variable *GIIPS* to examine whether the banks in non-stressed countries behaved differently compared to those in stressed (GIIPS) countries.

TABLE 6. Results when controlling for the difference in results for the part of GIIPS countries (using the NIM as the business model variable)

	Dependent variable:		
	Δ $Reserves_t$/ $Assets_{t-1}$	Δ Liquid $Assets_t$/ $Assets_{t-1}$	Δ $Loans_t$/ $Assets_{t-1}$
	(1)	(2)	(3)
Δ DFR_t	-5.246***	12.262	7.509
	(1.137)	(14.905)	(14.036)
NIM_{t-1}	-0.039	-0.235	-0.412*
	(0.069)	(0.258)	(0.243)
GIIPS	-0.257	-	-
	(0.317)		
Deposit Ratio $_{t-1}$	0.001	0.005	0.026*
	(0.004)	(0.014)	(0.014)
Ln Asset $_{t-1}$	-0.118**	-3.160***	-4.285***
	(0.046)	(0.560)	(0.527)
Equity Ratio $_{t-1}$	0.010	0.160***	0.104**
	(0.013)	(0.045)	(0.042)
ROA $_{t-1}$	0.049	-0.156	0.069
	(0.048)	(0.134)	(0.127)
Δ MRO_t	5.130***	-7.722	-17.444
	(1.037)	(13.269)	(12.495)

Δ DFR$_t$ × NIM $_{t-1}$	0.845*	-0.563	-2.169*
	(0.512)	(1.175)	(1.106)
Δ DFR$_t$ × GIIPS	-0.163	-0.902	-2.875**
	(0.631)	(1.542)	(1.452)
NIM $_{t-1}$ × GIIPS	0.072	1.072**	0.414
	(0.143)	(0.503)	(0.474)
NIM $_{t-1}$ × Δ MRO$_t$	-0.747	0.448	2.130**
	(0.465)	(1.069)	(1.007)
Δ DFR$_t$ × NIM $_{t-1}$ × GIIPS	0.065	-0.315	1.708**
	(0.342)	(0.867)	(0.816)
Observations	2,955	2,955	2,955
R^2	0.024	0.055	0.070
Adjusted R^2	0.020	-0.109	-0.091
F Statistic	71.175***	6.638***	8.576***

NOTES: ***, **, * indicate significance at the 1%, 5%, and 10% risk levels, respectively.
Dummy variable *GIIPS* takes value 1 if the observations are from Greece, Italy, Ireland, Portugal, or Spain; otherwise, its value is 0.
The results in the first column are based on the random-effects model, while the results in the other columns are based on the fixed-effects model. The choices of the model are supported by Hausman Test. Time effects are included in the fixed-effects model but not reported. The constant term of the random model is not reported either.

The regression results in column (1) are not able to identify statistically significant effects for the part of GIIPS countries on the pass-through of the DFR to reserve ratio and liquid assets. Therefore, banks in the sound countries and stressed countries seem to adjust their reserves and liquid assets in a similar way against the DFR change. Nevertheless, it should be noticed that the banks with higher NIM in stressed countries probably raise their liquid assets in the asset portfolio as the interaction of NIM and GIIPS in column (2) is statistically significant at the 10% level.

On the other hand, the new country factor creates a statistically significant heterogeneity in bank lending responses to a change in DFR. In particular, banks in GIIPS countries build up about 2.875% more loans relative to assets than the banks in non-GIIPS when DFR drops by one percentage point. However, when recognizing that if the banks in GIIPS countries have 1% NIM higher than average, their increases in loans are just 1.17% (=2.875-1.708) higher than the banks' in non-GIIPS countries. This is evidenced by the statistically significant coefficients of GIIPS in interaction with the previous NIM and DFR change, indicating that the location of the bank also has an effect on the pass-through of DFR conditional on NIM. For the other factors, based on these results there is no major difference from the baseline results reported in section 4.1.2.

A possible explanation for the above findings may lie in the liquidity shortage of banks in stressed countries during the crises and the low-for-long period. As shown in Figure 3, the GIIPS banks already have had lower reserve ratios than the non-GIIPS banks and they actually seem to have kept their reserve ratio at the minimum required level in 2013 and 2014. It implies that the banks in stressed countries have held less funding for lending activities, but the reduction of policy rates over the sample period probably has succeeded in helping the banks in the stressed countries to improve their funding possibilities, and thus, ability to increase lending. But if banks in the GIIPS countries previously have had higher NIM which stands for the interest sensitivity in my model, they may be more cautious to expose further risk in the later period due to their current high interest-rate risk. This may be the reason why they increased their lending less aggressively than the banks with lower NIM. Besides, NIM also measures the bank profitability specifically related to the interest-bearing activities, so banks may prefer preserving their previous profitability by decreasing their risk exposure, especially under the high real economic uncertainty observed during the low-for-long era and NIRP.

This finding partly supports the findings in Altavilla, Canova, et al. (2019) and Buchholz et al. (2020). Although Altavilla, Canova, et al. (2019) agree about the irrelevance of operating location in the bank heterogeneities in response to the conventional monetary policy, they find that the banks located in GIIPS have been more affected by the unconventional policies. Nevertheless, they believe the quantitative easing and credit easing policies contribute to such heterogeneities, while the effect of DFR is quite limited. Buchholz et al. (2020) also find that banks in GIIPS countries behave differently from those in non-GIIPS countries although their conclusions related to the DFR effects on banks' asset reallocation contradict mine, as discussed in the baseline results (see section 4.1.2).

4.1.4 Effect of negative interest rate policy

In this section, the dummy variable *GIIPS* in the previous section is replaced by *After2014* to investigate the differences in the results before and after the implementation of negative interest rates in the euro area. The results are shown in Table 7.

TABLE 7. Results when controlling for the effects of negative interest rate era (using the NIM as the business model variable)

	Dependent variable:		
	Δ Reserves$_t$/ Assets $_{t-1}$	Δ Liquid Assets$_t$/ Assets $_{t-1}$	Δ Loans$_t$/ Assets $_{t-1}$
	(1)	(2)	(3)
Δ DFR$_t$	-3.818**	12.689	12.926
	(1.539)	(14.912)	(14.012)

NIM_{t-1}	-0.065	-0.249	0.204
	(0.121)	(0.321)	(0.302)
After2014	-0.227	-6.669	28.996***
	(0.354)	(5.060)	(4.755)
Deposit Ratio $_{t-1}$	0.002	0.004	0.026*
	(0.004)	(0.014)	(0.014)
Ln Asset $_{t-1}$	-0.111**	-3.176***	-4.297***
	(0.046)	(0.556)	(0.523)
Equity Ratio $_{t-1}$	0.011	0.167***	0.101**
	(0.013)	(0.045)	(0.042)
ROA $_{t-1}$	0.054	-0.151	0.087
	(0.047)	(0.134)	(0.126)
Δ MRO_t	3.772**	-9.128	-21.881*
	(1.474)	(13.340)	(12.534)
Δ $DFR_t \times NIM_{t-1}$	0.950	0.185	-4.950***
	(0.680)	(1.545)	(1.451)
Δ DFR_t × After2014	-6.156***	11.978	-13.980
	(2.345)	(13.052)	(12.264)
NIM_{t-1} × After2014	0.060	0.518	-0.422
	(0.153)	(0.374)	(0.352)
$NIM_{t-1} \times \Delta MRO_t$	-0.845	-0.341	5.040***
	(0.649)	(1.469)	(1.381)
Δ $DFR_t \times NIM_{t-1}\times$ After2014	0.104	0.513	5.769**
	(1.047)	(2.520)	(2.368)
Observations	2,955	2,955	2,955
R^2	0.030	0.053	0.072
Adjusted R^2	0.026	-0.111	-0.089
F Statistic	89.616***	6.384***	8.855***

NOTES: ***, **, * indicate significance at the 1%, 5%, and 10% risk levels, respectively.
Dummy variable *After2014* takes value 1 with the observations from 2015 afterward; otherwise, its value is 0.
The results in the first column are based on the random-effects model, while the results in the other columns are based on the fixed-effects model. The choices of the model are supported by Hausman Test. Time effects are included in the fixed-effects model but not reported. The constant term of the random model is not reported either.

Different from GIIPS, the effect of the negative interest regime is significant and negative on the relationship between DFR and banks' reserves. During the negative rate period (after 2014), when DFR drops 100 basis points, banks further increase their reserve ratio by 6.16% in addition to individual

DFR change effect. Furthermore, banks with different NIM level seem to have similar reactions to the NIRP.

For the part of lending activities, the highly positive coefficient of the dummy variable After2014 (28.996) shows a considerable stimulus on lending after 2014. Obviously, some parts of this stimulus may come from the other (unconventional) monetary policy actions implemented simultaneously with the NIRP. Moreover, the introduction of the NIRP seems to change the interaction of DFR and NIM significantly. Banks with higher interest sensitivity (proxied by 1% higher-than-average NIM values) increase their loan ratio by 4.95% more than on average when the DFR decreases (the relationship between DFR and loan change is negative). However, for the period since 2014, the coefficient on the triple effect term points out that the loans are likely to decrease 0.82% (= 5.769 – 4.950) rather than increase as before (the relationship turns to positive). Therefore, the NIRP seems to contract (rather than encourage) bank lending, and the final effect of a reduction in DFR under the NIRP is simply a rise in excess reserves. Indeed, the higher interest-sensitive banks are more affected, and this is complemented to the change in NIM effect on lending during the pre- and post-NIRP discussed in part 4.1.2.

As is well known and discussed also by Heider et al. (2018), the ECB decided to apply the NIRP due to the deteriorating economic activity under which lending opportunities were more limited and riskier than before. Given the high uncertainties in the business environment due to the abnormal negative era and depressed real investment opportunities, banks seem to have been interested to save more liquidity as the buffer for the unexpected events stemming from the aggregate economy. The results in this section seem to be consistent with Heider et al. (2018) that the banks generally want to withhold more liquidity in response to a decline in DFR. However, the result from the estimates of loan changes argues for the effect of other unconventional policies that have created a huge stimulus on the bank lending, but such stimulus is partly contracted by the NIRP if the banks have relatively high interest-rate sensitivity (proxied by NIM). This finding gets partial support from Altavilla, Canova, et al. (2019) who also argue for the superior effects of the quantitative easing and credit easing policies over the NIRP in pushing bank lending.

4.2 WSF as a proxy of business model

In the second part, the NIM will be replaced by the WSF variable as the proxy of bank interest sensitivity and as a commonly used measure of the bank business model. In other respects, I will conduct the same process as in Section 4.1 except for the part of the comparison with Buchholz et al. (2020), since they did not focus on the WSF at all. Notably, due to the strong (negative) correlation between the deposit ratio and WSF as stated in Table 3 (at the range between -0.86 and -0.88), the deposit ratio variable will be excluded in the regressions with WSF to prevent multicollinearity. The main aim of this analysis is to investigate the effects of DFR changes on banks' asset reallocation with an alternative proxy of the bank business model.

Although NIM and WSF are used as the alternative proxies of the business model in this study, both of them still retain their own characteristics. While NIM relates very directly to the bank profitability, WSF reflects more directly the funding structure of the bank. Therefore, it is inevitable to have some similarities and differences in the results between these two proxies, but they also can provide a broader picture of how DFR changes influence the banks' asset allocation.

4.2.1 Baseline regressions with WSF

In general, with WSF being used as the proxy of the bank business model (interest insensitivity), most of the findings in part 4.1.2 are still the same.

TABLE 8. Baseline results with WSF as the business model variable (whole data set)

	Dependent variable:		
	Δ Reserves$_t$/ Assets $_{t-1}$	Δ Liquid Assets$_t$/ Assets $_{t-1}$	Δ Loans$_t$/ Assets $_{t-1}$
	(1)	(2)	(3)
Δ DFR$_t$	-4.133***	13.274	6.007
	(1.231)	(14.667)	(13.826)
WSF$_{t-1}$	-0.004	-0.010	-0.028*
	(0.004)	(0.017)	(0.016)
Ln Asset $_{t-1}$	-0.110**	-3.166***	-4.238***
	(0.043)	(0.545)	(0.514)
Equity Ratio $_{t-1}$	0.009	0.161***	0.079**
	(0.012)	(0.042)	(0.040)
ROA $_{t-1}$	0.050	-0.140	0.048
	(0.047)	(0.134)	(0.126)
Δ MRO$_t$	4.137***	-9.764	-13.925
	(1.125)	(13.090)	(12.339)
Δ DFR$_t$ × WSF$_{t-1}$	0.015	-0.082	-0.054
	(0.035)	(0.080)	(0.076)
Δ MRO$_t$ × WSF$_{t-1}$	-0.013	0.071	0.044
	(0.032)	(0.074)	(0.070)
Observations	2,955	2,955	2,955
R^2	0.023	0.052	0.065
Adjusted R^2	0.021	-0.110	-0.095

F Statistic	68.852***	7.680***	9.728***

NOTES: ***, **, * indicate significance at the 1%, 5%, and 10% risk levels, respectively.
The results in the first column are based on the random-effects model, while the results in the other columns are based on the fixed-effects model. The choices of the model are supported by Hausman Test. Time effects are included in the fixed-effects model but not reported. The constant term of the random model is not reported either.

The results in this section once again confirm the significant individual impacts of both DFR and MRO rates on the reserve ratios, and the effects on liquid assets remain insignificant as well. The effects of size and capitalization remain the same here, too.

However, all effects of the policy rates on loans become insignificant when we use the WSF as the business model. The reason may be due to the irrelevance of WSF in interaction with the policy rate changes compared to NIM. It is obvious that the interest-related income and risks (implied by NIM) are more relevant to the lending decisions under the changes in the policy rates than the source of funding.

The significant negative coefficient of WSF in column (3) implies that banks with higher WSF than the average in the previous period probably lower their loan component in the portfolio but to a very small extent in comparison with the effects of the bank size. With a 1% difference in WSF, the change in loans as a proportion of total assets is just over 3 basis points. Thus, such an effect is not significant in terms of economic meaning.

4.2.2 Heterogeneity between stressed and non-stressed countries

When adding the GIIPS dummy variable, the effects of the two policy rates, banks size, and capitalization are almost unchanged. However, the country effect does create significantly heterogeneous responses to the DFR change from the banks. The WSF effects are statistically significant, but their economic implications are still limited.

TABLE 9. Results when controlling for the difference in results for the part of GIIPS countries (using the WSF as the business model variable)

	Dependent variable:		
	Δ $Reserves_t$/ Assets $_{t-1}$	Δ Liquid $Assets_t$/ Assets $_{t-1}$	Δ $Loans_t$/ Assets $_{t-1}$
	(1)	(2)	(3)
Δ DFR_t	-4.236***	12.846	8.191
	(1.234)	(14.668)	(13.836)
WSF_{t-1}	-0.010**	0.018	-0.050**
	(0.005)	(0.021)	(0.019)
GIIPS	-0.840**	-	-
	(0.341)		

Ln Asset $_{t-1}$	-0.101**	-3.199***	-4.254***
	(0.043)	(0.548)	(0.517)
Equity Ratio $_{t-1}$	0.012	0.157***	0.081**
	(0.012)	(0.042)	(0.040)
ROA $_{t-1}$	0.042	-0.167	0.034
	(0.047)	(0.134)	(0.127)
Δ MRO$_t$	4.286***	-8.734	-15.001
	(1.126)	(13.078)	(12.336)
Δ DFR$_t$ × WSF$_{t-1}$	0.017	-0.085	-0.069
	(0.035)	(0.080)	(0.076)
Δ DFR$_t$ × GIIPS	-0.204	-1.813	-3.040**
	(0.590)	(1.396)	(1.317)
WSF$_{t-1}$ × GIIPS	0.025**	-0.085**	0.074**
	(0.010)	(0.036)	(0.033)
WSF$_{t-1}$ × Δ MRO$_t$	-0.017	0.074	0.042
	(0.032)	(0.074)	(0.070)
Δ DFR$_t$ × WSF$_{t-1}$ × GIIPS	0.005	0.031	0.099**
	(0.019)	(0.044)	(0.042)
Observations	2,955	2,955	2,955
R^2	0.026	0.056	0.068
Adjusted R^2	0.022	-0.107	-0.093
F Statistic	75.926***	7.133***	8.730***

NOTES: ***, **, * indicate significance at the 1%, 5%, and 10% risk levels, respectively.
Dummy variable *GIIPS* takes value 1 if the observations are from Greece, Italy, Ireland, Portugal, or Spain; otherwise, its value is 0.
The results in the first column are based on the random-effects model, while the results in the other columns are based on the fixed-effects model. The choices of the model are supported by Hausman Test. Time effects are included in the fixed-effects model but not reported. The constant term of the random model is not reported either.

The significant coefficient of the GIIPS dummy in column (1) implies that the stressed-country banks seem to keep their reserve ratios lower than the banks in non-stressed countries. This is consistent with what we already observed in Figure 3.

The interaction terms of GIIPS and previous WSF are statistically significant in all three regressions, implying that the banks with higher-than-average-WSF in the stressed countries are likely to reallocate their liquid assets to reserves and lending. However, such an increase in lending is cancelled out if there is a small reduction in the DFR because the coefficients of the triple term are just a bit higher than that of DFR and WSF interaction (0.099 and 0.074, respectively). In other words, the heterogeneous change in loans between the high-WSF banks and low-WSF banks just exists when DFR increases or remains unchanged.

Moreover, in column (3), the interaction of the GIIPS dummy variable with DFR change is negative (-3.040) and statistically significant at the 10% level, showing that banks in the GIIPS countries seem to increase their loans as a proportion of the total assets more than banks in the sound countries whenever DFR declines. With the significant coefficient much higher in absolute value than the coefficients of the other interaction terms, this result implies that the decline in DFR successfully improves the pass-through to lending at least in the stressed countries. Combined with the individual effects of DFR on reserve ratio (column (1)), the results in this part suggest that a DFR reduction encourages the non-GIIPS banks to withhold more liquidity while pushing bank lending in the GIIPS countries. This finding partially supports Altavilla, Canova, et al. (2019) that the monetary policies of the ECB have helped to normalize the lending capacity of banks in stressed countries, thus increasing the credit supply there.

Even though based on my results, the WSF does not play an essential part in bank lending, it shows an even clearer picture of the country's effect on the pass-through of the DFR on banks' asset changes than what we observed from the results with NIM. Despite some differences, results from the two proxies confirm a significant effect of bank country. Banks in stressed countries obviously increase their lending more actively than the banks in the non-stressed countries, while the non-GIIPS country banks probably prefer more reserve withholdings against the decline in DFR.

4.2.3 Effect of negative interest rate policy

With the inclusion of the After2014 dummy variable, the MRO rate loses its effect on banks' asset portfolio while the DFR only affects the reserve ratios conditioned on the negative era. The bank business model variable (WSF) just plays a minor role in the relationship between DFR and reserve ratio.

TABLE 10. Results when controlling for the effects of negative interest rate era (using the WSF as the business model variable)

	Dependent variable:		
	Δ $Reserves_t$/ $Assets_{t-1}$	Δ Liquid $Assets_t$/ $Assets_{t-1}$	Δ $Loans_t$/ $Assets_{t-1}$
	(1)	(2)	(3)
Δ DFR_t	-0.419	15.519	6.179
	(1.880)	(14.807)	(13.966)
WSF_{t-1}	0.005	-0.006	-0.029
	(0.010)	(0.028)	(0.027)
After2014	-0.007	-5.569	25.910***

	(0.441)	(5.022)	(4.737)
Ln Asset $_{t-1}$	-0.109**	-3.209***	-4.245***
	(0.043)	(0.546)	(0.515)
Equity Ratio $_{t-1}$	0.009	0.158***	0.078**
	(0.012)	(0.042)	(0.040)
ROA $_{t-1}$	0.055	-0.136	0.049
	(0.047)	(0.134)	(0.127)
Δ MRO_t	0.594	-12.087	-13.951
	(1.821)	(13.270)	(12.517)
Δ $DFR_t \times WSF_{t-1}$	-0.052	-0.133	-0.066
	(0.051)	(0.118)	(0.112)
Δ DFR_t × After2014	-10.488***	7.638	-6.538
	(2.468)	(12.514)	(11.804)
WSF_{t-1} × After2014	-0.001	0.016	0.008
	(0.012)	(0.029)	(0.028)
$WSF_{t-1} \times \Delta MRO_t$	0.050	0.117	0.054
	(0.049)	(0.114)	(0.108)
Δ $DFR_t \times WSF_{t-1}$× After2014	0.166**	0.279	0.086
	(0.076)	(0.177)	(0.167)
Observations	2,955	2,955	2,955
R^2	0.031	0.053	0.065
Adjusted R^2	0.027	-0.110	-0.096
F Statistic	92.606***	6.754***	8.355***

NOTES: ***, **, * indicate significance at the 1%, 5%, and 10% risk levels, respectively.
Dummy variable *After2014* takes value 1 with the observations from 2015 afterward; otherwise, its value is 0.
The results in the first column are based on the random-effects model, while the results in the other columns are based on the fixed-effects model. The choices of the model are supported by Hausman Test. Time effects are included in the fixed-effects model but not reported. The constant term of the random model is not reported either.

Regarding the changes in the reserve ratios, the statistically significant negative coefficient of the DFR change interacted with the After2014 dummy variable illustrates that the increase in banks' reserve ratios is especially significant after the NIRP introduction in June 2014. Corresponding to a reduction of one percentage point in DFR, banks seem to increase over 10% their reserve ratios in the asset portfolio under the negative era, while such a change probably did not exist before 2014. Furthermore, the triple term is also statistically significant, showing the less incentive of banks with higher wholesale funding reliance in building up their liquidity. This can be explained by the unwillingness of banks to hold idle excess reserves if their main funding comes from the wholesale market which is usually more expensive than the deposit-based source of funding.

There are no significant effects of policy rates and NIRP implementation on liquid assets. The effects of control variables are similar to the results in the previous two sections. For lending components, as the regression coefficients on the policy rates coefficients are not statistically significantly different from zero, the influences of both policy rates vanish and they are replaced by the effects of NIRP (with a significant coefficient of 25.910). This again highlights the role of other unconventional monetary tools conducted under the NIRP, such as APP and forward guidance, in accelerating bank lending.

5 CONCLUSIONS

This master's thesis focuses on the European banks' asset allocation decisions in response to the Deposit Facility Rate (DFR) changes. Based on using an extended sample of negative interest rate observations, in contrast to Buchholz et al. (2020), I find a negative and statistically significant effect of DRF on bank reserve changes, and this effect is not related to the bank business model. Although the DFR effect on liquid assets is limited, it has a significant impact on the loan change conditional on Net Interest Margin (but not on Wholesale Funding, WSF) levels. My findings show the failure of DFR-policy actions in directing the liquidity more to the bank lending, as expected from the standard banking theory and based on the main purposes of the ECB monetary policy actions. A plausible explanation lies in the need of banks to increase their buffers against compressed profitability and deteriorating equity due to the low-for-long period as well as economic uncertainties.

Using both the NIM and WSF as the proxies of the interest-sensitive business model, I find that the business model only plays a minor part in how the DFR affects banks' reserve and liquid asset holding decisions in general. Nevertheless, the business model has a significant effect on loans, especially for the part of NIM, as the lending decisions are apparently based on the interest rate risks and profitability implied by the development of NIM, instead of the funding structure captured by the WSF development.

However, according to the results obtained in this study, there is significant heterogeneity between the responses of banks in the stressed and non-stressed countries to the DFR changes. A reduction in DFR has empirically accelerated more lending in GIIPS countries than in non-GIIPS countries. On the other hand, within the GIIPS countries, banks having previously higher NIM than the average seem to have raised their lending ratio less actively than the others. When using the WSF for the analysis, banks in the non-stressed countries even show a greater incentive to increase their reserve holdings than to increase lending in their asset portfolio as a reaction to a drop in the DFR.

The implementation of NIRP since 2014 seems to have encouraged banks to build up much more liquidity than before. The results in this study imply a greater sensitivity in bank reserve holdings to a deeper move into the negative zone of nominal interest rates. For the lending activities, banks show a considerable increase in loans after 2014, but it is not due to the NIRP and the main refinancing operations. This increase may have been contributed by the other unconventional monetary policies such as APP and forward guidance. While some studies have claimed that banks have increased their lending due to the NIRP (e.g. Lopez, Rose, and Spiegel (2020), Buchholz et al. (2020)), the somewhat different results from the current study obviously require much more research on the direct determinants of lending increases during the NIRP.

In terms of bank-specific effects, my results highlight the effects of bank size on the banks’ asset allocation decisions. The previously larger banks lower their loan supply and liquid assets in the portfolio more than the smaller banks, but they do not necessarily build up their reserves. Thus, my finding supports the other studies related to the business model transmission towards the non-interest activities under the low-for-long period. In addition, the well-capitalized banks seem to increase liquid assets and loans in their portfolio more than the weak-capitalized banks. However, the effect of the capitalization factor is relatively much smaller than the size effect. The significant effects of size and capitalization in my study complement the results of Kohler (2015) who argues that these two characteristics are the most important ones for the effectiveness of the chosen bank business model.

Still, this study possibly has several limitations. The first one may arise from the random-effects model’s assumption which requires the lack of correlation between the independent variables and individual error terms. This assumption may be violated because it probably exists unobserved bank-specific factors that are significantly correlated with the explanatory variables. However, this issue is not likely because the applied regression models were chosen by the results based on a Hausman test for the specifications. Second, the use of NIM and WSF as the proxies of interest-sensitive business model may not be the best options as other indicators are used more widely in the relevant studies such as the loan share, net interest income to total assets, and the ratio of net fees and commissions to total assets. As each measure has both its own advantages and disadvantages and the robust tests of Buchholz et al. (2020) that utilize those alternatives do not affect substantially their main conclusion from the baselines, the role of NIM in this analysis still holds. Meanwhile, the results with WSF also strengthen most findings suggested by the results with NIM, so I believe that the two proxies in this study are suitable. The last limitation is related to the exclusion of some outliers which may mitigate the effect of DFR on the dependent variables. Nevertheless, based on a detailed look at all these observations, in this dataset many of such outliers were caused by either abnormal fluctuation (extreme observation observed only in one year) or due to mergers and acquisitions, rather than based on actual decisive changes in the asset reallocations. Thus, the outlier exclusion strategy was the favored option here.

During the recovery period from the COVID-19 pandemic, the ECB has declared that it will be continuing the aggressive, unconventional easing policies and this puts more pressure on the DFR changes in the future, too. Therefore, it will take more time, if possible, for the DFR to turn back to positive. However, based on the results from this study, the decrease in DFR cannot deal with the banks’ decisions about their excess reserves and it is also unlikely to improve lending. Therefore, the results of this study cast even more doubts on the efficiency of ECB’s monetary policy tools, and obviously, this absolutely calls for more studies on the underlying issues that affect the pass-through of the DFR especially under the negative interest rates era.

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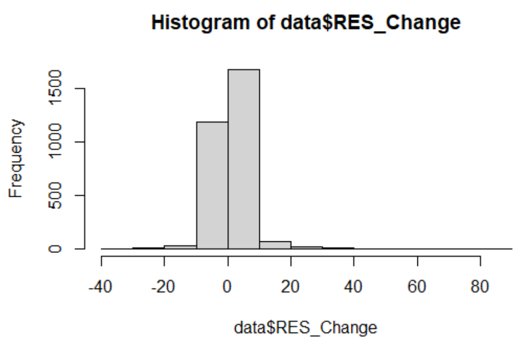
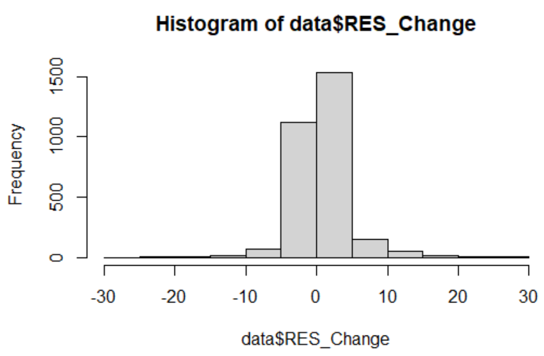
APPENDIX

EXPLANATION FOR OUTLIER DETECTION AND TREATMENT

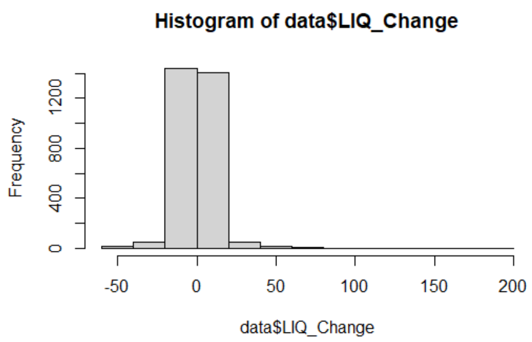
I use the histogram to detect the outliers of the three dependent variables and the two proxies of the bank business model. The histograms of the variables undergone the outlier treatment will be presented below with the before and after the treatment. The wholesale funding variable (WSF) does not have any significant outlier, so it does not have the histogram after the outlier treatment.

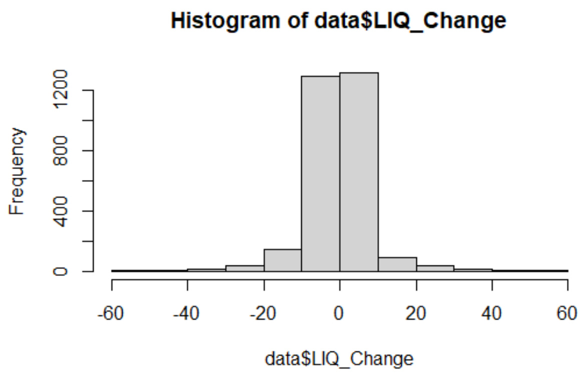
Before outlier treatment **After outlier treatment**





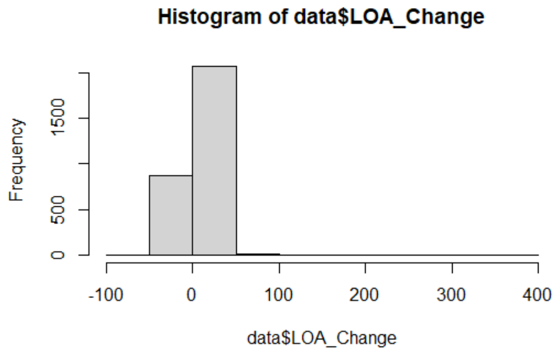
Changes in Bank Reserve ($\Delta Reserve$)

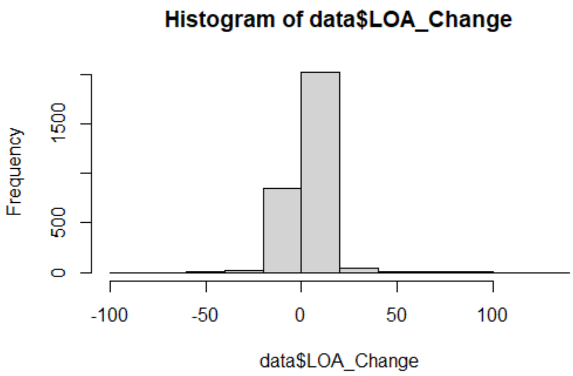




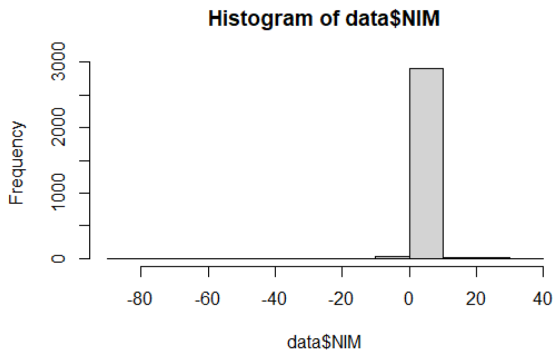
Changes in Liquid Assets ($\Delta Liquid\ Assets$)

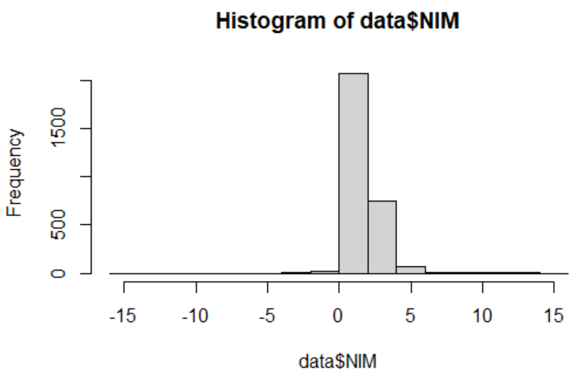
Before outlier treatment **After outlier treatment**



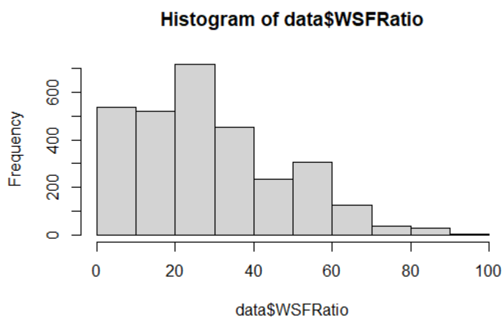


Changes in Loans ($\Delta Loans$)





Net interest margin (NIM)



Wholesale funding ratio (WSF)