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Master Thesis Financial Economics

Substitutes or Complements?

The Combined Effect of Negative Interest Rate Policy and Quantitative Easing on Bank Risk-Taking and Lending Behaviour

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The main object of this paper is to research the combined effect of two monetary policies, negative interest rate policy and quantitative easing, on bank risk-taking and lending behaviour. The question is if these policies substitute or complement each other. A difference-in-difference design is used to measure the proxies Non-performing loans ratio, Loan Loss Provisions ratio and Gross Loans ratio of European banks in and out of the Eurozone during 2014 and 2015. First, the effect of implementing negative interest rates is measured empirically. After that, the second set of DiD analyses measures the effect of negative interest rates in combination with quantitative easing. The results show that a combined positive effect can be measured of both policies on the NPL ratio. This points to a complementary effect of negative interest rates and quantitative easing on bank risk-taking behaviour. The ambiguous results of the effect on bank lending behaviour could point to a distorted channel.

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1. Introduction

Sweden set an unusual precedent for other countries in 2009, when the Swedish Riksbank introduced negative policy rates. The aim was to convince commercial banks to expand their lending activities and stimulate economic growth. The European Central Bank (ECB), Denmark, Switzerland and Japan followed Sweden in 2014. However, the Federal Reserve (FED) and other central banks outside of Europe were, and still are, hesitant to implement negative policy rates. Central banks entering negative territory with their policy rates is, despite central banks in advanced economies implementing it, still seen as a controversial method. As an expansionary monetary policy, negative rates serve the purpose of increasing inflation, expanding economic growth and decreasing the currency value (Jobst & Lin, 2016). The effects of the negative interest rate policy (NIRP) are still uncertain however, with academics expressing different views on going into negative territory. Heider, Saidi & Schepens (2021) predict that negative policy rates will remain a viable monetary policy choice. Lilley & Rogoff (2019) take this positive outlook a step further, by calling NIRP 'by far the most elegant and stable long-term solution to the severe limits on monetary tools that have emerged since the financial crisis'. On the other side, Palley (2016) argues that negative policy rates cause currency wars and create financial fragility.

A negative policy rate is not the only unconventional monetary policy used after the Financial Crisis of 2008. Apparently, the ECB felt that lowering their policy rate into negative territory was not sufficient to stimulate the economy. In March 2015 the central bank started with a quantitative easing program, which has also been described as the most feared monetary policy tool usable (Valiante, 2015). By purchasing long-term bonds, the central bank drives up the price of these bonds and injects money into the system (European Central Bank, 2021). Risk premia and the bond yield decrease and banks have more liquidity, which creates more room for banks to give out loans. Not only has the asset purchase program effect on the bank lending channel, but its mere announcement impacts the market since it gives such a clear signal. It shows that the central bank is willing to take serious measures to boost the economy.

Two important bank channels that have been researched because of their association with monetary policy are the bank lending and the risk-taking channel. Both channels highlight the importance of banks in the transmission of monetary policy. Specifically, the bank lending channel predicts that expansionary monetary policy causes banks to change their loan supply to borrowers. Kishan & Opiela (2000) conclude that the loan growth of mainly small banks is affected by the implementation of monetary policy. In addition to this, the risk-taking channel foresees increased risk-taking by banks when the central bank lowers the policy rate (Gambacorta, 2009). Ioannidou, Ongena & Peydró (2014) find evidence for this theory, as commercial banks grant riskier loans that have worse ex-post performance when the policy rate is decreased as a form of monetary policy.

Multiple papers try to explain the effect of negative policy rates and quantitative easing on banks via those two channels. Heider, Saidi & Schepens (2019) show that the NIRP affects bank credit supply negatively and explain their view on what happens to banks with high deposits if policy rates do not only decrease, but go negative. The bank net worth will decrease for banks with high deposits, because the rate on deposits will not become negative, whereas the rate on the market will. Negative rates on retail deposits scare consumers away to other banks who do not charge for storing deposits. This results in a smaller decrease in the cost of funding, thus disadvantaging the banks with high deposits. This has as effect that banks with more deposits take more risk but lend less. However, Boungou (2020) finds that the costs of lending decrease more for high-deposit banks, resulting in high-deposit banks not reducing their lending supply but increasing it. The effect of asset purchasing programs is less contradictory. Quantitative easing increases bank reserves, which in turn creates loan growth and increases bank risk-taking (Kandrac & Schlusche, 2021). This evidence is confirmed and specified by Rodnyansky & Darmouni (2017), who find that banks with a relatively high level of mortgage-backed securities expand bank lending more after quantitative easing. This leads us to believe that quantitative easing does not support banks in an equal manner.

A question that remains open after researching both expansionary monetary policies, is how the economy reacts to the combination of negative interest rates and quantitative easing. Heider, Saidi & Schepens (2021) have suggested researching the combined effect after writing a review about banks and the effect of negative interest rates. A negative policy rate and an asset purchase program could be substitutes or complements. Both are possible, since it is not quite clear how one influences the other. Heider et al. (2021) sketch two scenarios: one where the two policies are complements and one where they are substitutes. Quantitative easing affects the bank balance sheet by expanding the assets. Purchasing those assets creates liquidity and decreases the interest rates on loans. This makes it more expensive to hold on to liquid assets, which is why banks start lending more (Chakraborty, Goldstein & MacKinlay, 2020). Negative policy rates diminish bank funding costs, which makes lending cheaper for banks. These effects could complement each other, because the policies do not affect the same parts of the bank balance sheet. Since quantitative easing and negative rates both decrease the yield curve, they could also function as substitutes. This leads to the main research question of this paper:

What is the combined effect of NIRP and quantitative easing on banks' risk taking and bank lending?

This question has now become more pressing than ever, with the COVID-19 pandemic creating a worldwide economic recession even worse than the Financial Crisis of 2008 (IMF, 2020). Governments and central banks were quite suddenly put in a position where immediate response in the form of fiscal and monetary policies was required to lessen the impact of the pandemic on the global economy. Since this exogenous crisis affected multiple facets of the economy, a variety of different measures was implemented. More insight into how these measures can be combined to have the desired effect and on which variables this depends, could lead to better coordinated economic policies in times of crisis. Knowing which unconventional measures to implement in a negative-rate environment to stimulate the economy, could help hesitant central banks to take the step to the negative side. Multiple papers have reasoned the effect of combining two unconventional policies by arguing that certain mechanisms within the bank lending and risk-taking channels complement or substitute each other. To my knowledge, the combined effect of NIRP and quantitative easing on different bank channels has not yet been empirically analysed, which is why this paper will form an addition to the strand of literature about the effect of monetary policies on banks' risk-taking and lending behaviour.

The central question will be researched by formulating two hypotheses, which will be empirically analysed by using a Difference-in-Difference method (DiD). The research focuses on European banks from within and outside of the Eurozone between 2014 and 2015, when negative interest rates were implemented in the Eurozone, in combination with a quantitative easing program. For both hypotheses, control groups will consist of European countries that are not affected by the monetary measures. The DiD method will be performed on the dependent variables for risk-taking and bank lending with country-specific and bank-specific control variables. The data of banks from 15 countries within Europe is a collection of datasets from the Orbis databank and Eurostat.

Chapter two contains a literature review about negative interest rate policy and quantitative easing, which will lead to the hypotheses. The mechanisms from the bank lending and risk-taking channel will be further explored. Data and Methodology will be described in chapter three. An elaboration on the DiD method and the measurement of the dependent variables will be given. The control variables are derived from earlier research. After this, chapter four will show the results of the empirical analysis and chapter five will elaborate on the results with certain robustness checks. These results will lead to a logical conclusion which can be found in chapter six, as well as the discussion in which the limitations of this paper and further research suggestions will be covered.

2. Literature review

2.1 Negative Interest Rate Policy

Implementing a negative interest rate is an unconventional monetary policy, where the policy rate of the central bank is set below zero. Commercial banks can obtain liquidity from the central bank against a negative rate, making it easier to borrow. A central bank can use this unconventional policy when the policy rate is near the zero border and the contracted economy is in need of stimulus. The use of negative policy rates is still quite rare, since multiple monetary and fiscal policies exist for these circumstances and this policy is sometimes deemed more costly and legally and structurally difficult (International Monetary Fund, 2021). Only in the aftermath of the Financial Crisis of 2008 did a select group of central banks start breaking through the natural border of zero. Before, the zero border formed a constraint on the economic market, which influenced expectations. But the zero limit is not necessarily the Effective Lower Bound (ELB), where the unconventional monetary policy does not provide more stimulus to the economy and could even work contractionary (Brunnermeier & Koby, 2016). By breaking this barrier, the purpose of NIRP is to expand economic activity through multiple channels. Commercial banks are not only able, but also incentivized by the central bank to increase their lending supply. The mechanism is triggered because commercial banks make no profit on excess reserves with negative rates. Through the portfolio rebalancing channel, banks start increasing their loan supply (Schnabel, 2020). This creates a spending incentive among customers, which increases the aggregate demand and results in higher prices. The inflation rate rises again because of this process. Portfolio rebalancing can result in growing asset prices as well, since the increased activity brings down the risk aversion (Jobst & Lin, 2016). Another use of NIRP is to put a depreciating pressure on the exchange rate of the currency by increasing the capital yield. However, multiple other effects of the NIRP such as inflation and the rise of demand can nullify the depreciation. According to the IMF (2021), NIRP also enhances the forward guidance effect of central banks since both methods give signals about the future movements of interest rates.

2.1.1 NIRP and bank risk-taking behaviour

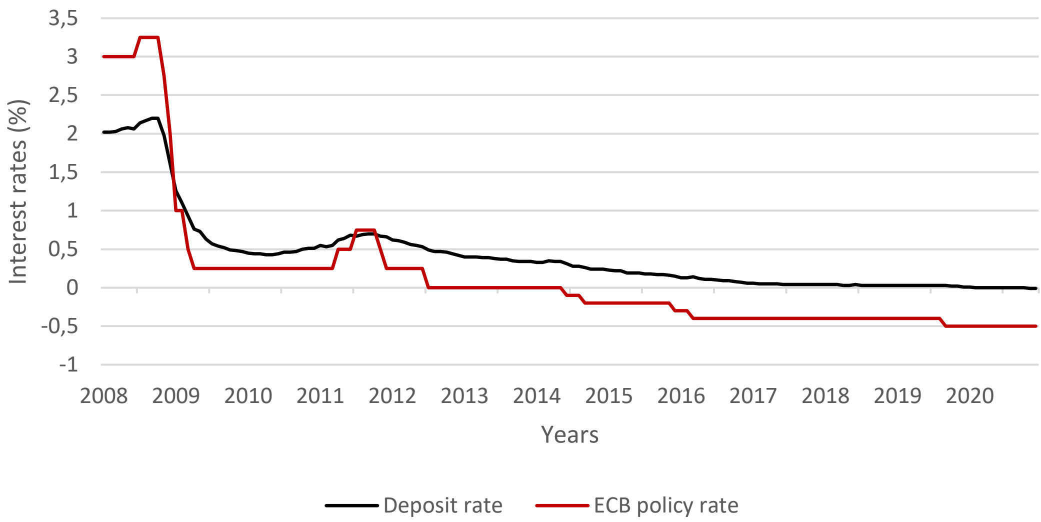
Banks play a significant part in transmitting the monetary policy of negative interest rates to the real economy through multiple mechanisms. Borio & Zhu (2008) describe one of these mechanisms as ‘the link between monetary policy and the perception and pricing of risk by economic agents’ and debut the concept of the risk-taking channel. The writers describe three possible ways through which this channel functions: via valuations of incomes, assets and cashflows, search for yield with rate-of-return targets and via transparency and communication to the public. When the policy rate is decreased, asset prices and incomes are raised, which impacts risk factors. Risk perception would decrease, since higher asset prices negatively impact the volatility surrounding these prices (Gambacorta, 2009). Other default settings are also adjusted, which can increase the risk tolerance. The risk-taking channel thus operates via the different ways banks can measure and estimate risk. Next to this, risk-taking behaviour can increase because investors search for yield when the policy rate drops. The target rate of return can be sticky due to institutional, regulatory or psychological factors. A bigger gap between policy rates and target rates moves investors to higher-risk instruments to gain a higher yield. This process also shows the mechanism of the risk-taking channel. Another theory regarding the effects of the risk-taking channel has been developed by Dell'Ariccia, Laeven & Marques (2011). This theory describes two channels that work in opposite directions. The first one is the portfolio-reallocation channel and regards a movement on the asset side of a banks' balance sheet. When introducing lower policy rates, banks' incentive to monitor their portfolio decreases because this is costly and the lower interest rates cause a reduction in the profit rates on bank loans. This goes together with the search-for-yield effect described by Borio & Zhu (2008), where banks shift their portfolio to riskier assets because profit expectations decrease due to lower interest rates. The result is a riskier portfolio with less monitoring. The other channel describes how the liabilities side of a banks' balance sheet is influenced by risk-shifting. When the interest rate decreases, this also decreases the costs of bank funding. Contrary to the portfolio-reallocation channel, bank profit increases via this channel, which creates an incentive for the bank to behave cautiously regarding risk. These theories find confirmation in the empirical evidence showed by Ioannidou, Ongena & Peydró (2014), who demonstrate that the effects of the portfolio-reallocation channel exceed the risk-shifting channel. They find that lowering the policy rate results in banks increasing their risk-taking behaviour. Riskier borrowers are granted loans and loans are more likely to default. A similar empirical result is obtained by Jiménez, Ongena, Peydró & Saurina (2012). According to their research, banks with a lower capital rate give out loans to riskier firms in larger volumes with a larger probability of default when the interest rate is lowered.

How these channels react to negative policy rates is still up for debate. Certain factors come into play that did not play a major role in the positive rate environment. Different theories have been devised to explain which mechanisms form the basis for more or less risk-taking after NIRP. Boungou (2019) voices two issues that might arise with NIRP: the transmission mechanism could be disturbed by declining profit margins and this could activate the search-for-yield mechanism. When banks cross the border from positive to negative the profit margin declines, because this reduction in interest rates is not passed on to deposit holders. This is called a two-tiered system, where banks go below zero with various rates, but not with the deposit rate (Jobst & Lin, 2016). The difference between the retail deposit rate and the ECB policy rate between 2008 and 2020 can be seen in Figure 1. This would lead to most deposit holders withdrawing their savings from commercial banks and instead of stimulating spending, banks would stimulate withdrawing cash and hoarding it. Banks would hit the so-called

Effective Lower Bound, the point where monetary policy has a contractionary impact on the economy instead of an expansionary impact. Instead, banks have no option but to reduce their margin of profit and internalize the blow. To mitigate this loss of profit, banks have two options: reducing their operating costs or raising their non-interest related income (Boungou, 2019). The first option is similar to the risk-shifting channel as described by Dell'Ariccia et al. (2011). Profit can grow via this mechanism which causes a decrease in risk-taking behaviour. The other option, raising non-interest related income, resonates with the portfolio-reallocation channel. Part of banks' liquidity is then exchanged for other securities or loans to avoid being charged for holding cash.

Figure 1

The overnight-deposit rate and the ECB policy rate between 2008 and 2020



Note. This figure demonstrates the overnight-deposit rate on retail and the ECB policy rate between 2008 and 2020. The retail deposit rate does not cross the zero border, whereas the ECB policy rate does. The overnight-deposit rate is an average of the rates on deposit on non-financial corporations from Euro area banks.

Next to this theory pointing to both decreasing and increasing risk-taking behaviour, Blot & Hubert (2016) explain a third mechanism triggered by the decreasing profit margin that could mitigate the loss of profit. According to them, the solvency of non-financial agents increases when the interest rate declines, which would reduce the non-performing loans, a measure of risk for banks. So the default risk of debtors decreases when interest rates are reduced. Consistent with this, Boungou (2019) finds that during the NIRP period, banks were less inclined to take risk and lessened the amount of non-performing loans. This does however depend on the balance sheet structure: banks with relatively more deposits are not able to use the risk-shifting channel because there is a ZLB for banks that are mostly funded with deposits. This might be the reason why Heider et al. (2019) find that risk-taking of banks with higher deposits increases during negative deposit rate periods. The search-for-yield mechanism, or the portfolio-reallocation channel, overpowers the risk-shifting channel and increases bank risk-taking in this situation. Other empirical evidence does however point to the risk-shifting theory and the mechanism developed by Blot & Hubert (2016). In a second paper focussing on bank risk-taking in 59 countries, Boungou (2020) finds again that risk-taking decreases after the installation of NIRP. He notes that the extent to which risk decreases does depend on bank-related factors such as size and capitalization. Another recent paper from Bongiovanni, Reghezza, Santamaria & Williams (2021) concludes that commercial banks hold safer assets after the introduction of negative interest rates and suggests that this is caused by a mechanism opposite to the portfolio-allocation channel. The so-called de-leverage hypothesis claims that banks shift to safer assets and gain a better capital position instead of shifting to riskier assets to search for yield.

2.1.2 NIRP and bank lending behaviour

Just as with risk-taking behaviour after NIRP, there are several theories that describe how bank lending behaviour changes after NIRP is introduced. The purpose of negative interest rates is to stimulate economic growth, among others by increasing both loan supply and demand. Supply grows because banks make an effort to diminish their excess reserves, which are costly to hold with negative rates. Demand naturally increases when interest rates fall and it becomes cheaper to take out a loan. However, the question is if this lending channel is indeed so efficient or if there are factors that disturb the transmission. Boungou (2020) concludes that the transmission of NIRP through the bank lending channel works efficiently, because his empirical evidence points to both a decrease in lending costs and an increase in loan supply from commercial banks. These results are confirmed by bank lending research in Italy and Switzerland. Basten & Mariathasan (2018) show that banks in Switzerland transfer their central bank deposits to the loan market and Bottero et al. (2019) find that banks in Italy raise their loan supply soon after implementation of the monetary policy. The increase in lending to households and firms was also observed by the Bank Lending Survey of the ECB in 2016 (Blot & Hubert, 2016).

Despite a significant body of evidence showing that the lending channel is working properly, some researchers point to a concept that distinguishes between banks with and without a high deposit ratio when determining the efficiency of the policy. Heider et al. (2019) point out that banks do not transmit negative deposit rates on retail deposits, because they fear customers might withdraw their funds and store them somewhere else. The cost of funding for banks normally decreases when NIRP is implemented, however, banks with high deposit ratios do not experience the same deduction as banks with lower deposit ratios. According to Heider et al. (2019) this should lead to a negative effect on the banks' net worth, which in turn would cause less lending to customers than banks with lower deposit ratios. This concept can be supported by the empirical evidence, as the results of their analysis show that high-deposit banks lend less than low-deposit banks after NIRP. Molyneux, Xie, Thornton &

Reghezza (2017) found that bank lending in countries with NIRP even decreased compared to countries without negative policy rates. The writers explain this by arguing that negative rates go through the ZLB and thus have a contractionary effect. Retail deposits block the bank lending channel from passing on the unconventional monetary policy efficiently to the real economy. The contractionary effect of negative interest rates expresses itself in smaller profit margins which add additional pressure to banks to diminish lending.

Diametrically opposed to this is the research of Boungou & Mawusi (2020), who state that high-deposit banks show a significant increase in their loan supply after the introduction of NIRP. This points to the existence of an efficient bank lending channel with interest rates below zero. Demiralp, Eisenschmidt & Vlassopoulos (2017) agree with this by concluding that high-deposit banks give out more loans after the implementation. This can be explained by the argument that banks want to remove their costly excess liquidity and do this by shifting their assets to securities and loans. Demiralp et al. (2017) state that shifting the bank portfolio to loans is a special form of the bank lending channel, which is used especially by high-deposit banks since they usually have high excess liquidity. Empirical evidence that banks issue more loans to individuals and firms is also found in the euro area after the implementation of NIRP by the ECB (Bräuning & Wu, 2017). This too is explained with lowering excess liquidity in order to avoid costs. From the above, it is clear that there is no consensus between academics regarding the efficiency of the bank lending channel with negative policy rates. There are multiple theories to explain the different empirical outcomes.

2.2 Quantitative easing

Another unconventional monetary policy, quantitative easing, was first implemented on a larger scale by the Bank of Japan in 2001. It is a less controversial measure than NIRP and since 2001 many countries have implemented QE programs in crises. Quantitative easing can be described as an asset purchase program from the central bank to stimulate the economy by providing new money to the economy and raising investing and lending levels (ECB, 2021). Central banks purchase relatively stable and safe securities, such as long-term sovereign bonds or asset- and mortgage backed securities. NIRP impacts interest rates directly, but QE impacts interest rates indirectly by creating a higher money level in the market. Lower interest rates make it cheaper for consumers to take out a loan, which in turn impacts lending and investing behaviour positively. Higher lending and investing levels create more consumption which makes prices rise. The objective of QE is to reach a healthy inflation rate of 2% and bring down the unemployment rate to create an equilibrium between the two and to stimulate economic activity. Interest rate policy cannot reach these objectives anymore in situations where QE is implemented, because the ELB has been reached and further implementation would only cause the economy to contract further (ECB, 2021). Quantitative easing is therefore seen as a monetary policy of last resort. Two channels through which the transmission of QE works are the interest rate channel and the portfolio-rebalancing channel (Demertzis & Wolff, 2016). QE lowers the interest rates by raising the money supply. Via the interest rate channel it should thus be easier to invest and take out a loan. The portfolio-rebalancing channel explains how investors are made to invest in riskier assets, because the central bank purchases the safer assets. Krishnamurthy & Vissing-Jorgensen (2011) also find evidence for a signalling channel pressuring different interest rates downwards after the implementation of QE.

2.2.1 QE and bank risk-taking behaviour

As has been said above, quantitative easing can be passed on to the real economy through the portfolio-rebalancing channel (Demertzis & Wolff, 2016). Similar theories and empirical evidence can be found in other papers. Kandrac & Schlusche (2021) explain that the Federal Reserve implemented an asset purchase program that indirectly raised the commercial bank reserves. This has a positive impact on loan growth. From the empirical evidence it can be deduced that banks show signs of portfolio-rebalancing behaviour, because bank portfolios contain more high-risk loans after the loan growth. A possible explanation for the portfolio adjustment is a search for yield, since the extra reserves have a negative effect on the profit margins of banks. Next to this, the level of NPLs increases after reserves grow due to QE, especially in smaller banks. This points to increased risk-taking by commercial banks after quantitative easing as well. Contrary to the findings of Kandrac & Schlusche (2021), Mamatzakis & Vu (2018) find that QE lowers the risky loan ratios in Japan. They explain this by stating that quantitative easing in combination with low interest rates can make it easier for borrowers to borrow more and pay off their loan costs. This results in a smaller amount of bankrupt or restructured loans. However, Mamatzakis & Vu (2018) explain how quantitative easing could increase risk-taking behaviour as well. When interest rates are low, banks may show the search-for-yield behaviour as explained before. The asset purchase program in the United States in 2008 had a two-sided effect on bank risk-taking: larger banks took more risk, while smaller banks took less risk with commercial loans after the implementation (Black & Hazelwood, 2013). This nuanced result shows how the effect of quantitative easing on bank risk-taking depends on factors such as the objective of the program and the interest rate level.

2.2.2 QE and bank lending behaviour

Different papers describe the effect of asset purchase programs on loan supply via the bank lending channel. Multiple transmission mechanisms can be distinguished. One effect of quantitative easing on bank-lending behaviour can be described via the so-called net-worth channel. This channel describes how by raising the price of certain assets, the balance sheets of those banks are affected positively. This in turn improves their financial situation which causes certain constraints to disappear.

Rodnyansky & Darmouni (2017) show that banks with a high mortgage-based security level increased their lending supply significantly after the Federal Reserve launched an asset purchase program targeting those assets. This points to an efficient transmission of quantitative easing through the net-worth channel. Kandrac & Schlusche (2021) show how banks increase their loan supply when their reserves have increased due to an asset purchase program. As explained before, bank reserves increase when the central bank purchases securities, either because the bank is the seller of those securities, or because the sellers store their security value as deposit at the bank. This leads to more bank reserves than optimal, which is why banks choose to increase their loan supply and investments. Kandrac & Schlusche (2021) show with their theory and empirical evidence that QE has a positive impact on loan growth just by increasing the bank reserves. Tischer (2018) has analysed quantitative easing effects in Germany and found similar results to Kandrac & Schlusche (2021) about the effect of reserves on bank loan supply. His paper focusses on how relative price changes in bonds and loans cause portfolio rebalancing as well. When bonds are bought by the central bank, the relative price of bonds rises and makes loans a more attractive option. Portfolio rebalancing should be especially visible with banks that have a high bond redemption rate. Those banks can easily exchange their bonds at maturity for loans. Empirical evidence indeed indicates that banks with many bond redemptions show a higher loan growth (Tischer, 2018). Thus both theories and empirical evidence point to an increase in loan supply after the implementation of quantitative easing. It does not particularly matter which assets are being purchased by the central bank, since QE works via bank reserves as well. What does matter is if an incentive to rebalance exists.

2.2.3 Specifics of the asset purchase program

In this paper, the asset purchase program concerned is the ECB Asset Purchase Programme started in March 2015. This program consisted of two parts, the Covered Bonds Purchase Programme 3 (CBPP3) and the Asset-Backed Securities Purchase Programme (ABSPP). The ECB bought both covered bonds and asset-backed securities with a total value of 60 billion Euros (ECB, 2021). The covered bonds were bought directly from banks and mortgage institutions, which means that liquidity was directly injected into the banking system. It might prove important to mention that the ECB had loosened its collateral policy before the implementation of the two asset purchase programs. The credit rating of asset-based securities was reduced to BBB- in July 2014 (Blot & Hubert, 2018). According to van Bekkum, Gabarro & Irani (2016), loosening the central bank’s collateral framework impacts the risk-taking and lending behaviour of affected banks. Bank lending increases, but the acceptance of lower credit rates also comes with more risk-taking, as the loan performance goes down in quality. Another important phenomenon described in this paper is how credit risk is transferred to the state when loans are given out with state guarantees in combination with a lower credit rating.

2.3 The combined effect of NIRP and QE

After discussing the separate effects of NIRP and quantitative easing on the risk-taking and bank lending channel, it remains open how the combination of these monetary policy measures will affect the highlighted channels. This debate was emphasized by Heider et al. (2021), who stated that the two policies could be either complements or substitutes. Complementarity could follow from the evidence that both measures affect bank lending but in different ways. Negative interest rates decrease funding costs because the bank can offer lower rates on their short-term liabilities. According to Heider et al. (2019), this means that certain long-term assets such as loans can be financed by the liabilities. Lower funding costs imply that issuing loans becomes cheaper for these banks. Quantitative easing injects the economy with liquidity by acquiring assets such as bonds and other securities. This increases bank reserves, which causes banks to rebalance their portfolio and issue more loans. QE also pushes the interest rate level downwards because of an increase in the money supply. Together, these policies complement each other: NIRP makes it cheaper to issue loans, while QE both creates the liquidity to issue more loans and creates an extra nudge down on the interest rates (Heider et al., 2021). As has been explained, NIRP affects the liabilities side, while an asset purchase programme affects the asset side of the balance sheet. However, the policies could be substitutes just as easily. Because both QE and NIRP have a downwards effect on the interest rates and the expectation on future interest rates, the policies could also be exchanged for each other. Quantitative easing has an indirect negative effect on the interest rates because of the increase in market liquidity. The long-term expectations are also adjusted, since long-term bonds are bought by the central bank (Heider et al., 2021). NIRP has a direct effect on policy rates and by showing that the zero border does not necessarily form the Effective Lower Bound, the expectations of future interest rates can also be adjusted downward (Brunnermeier & Koby, 2016). Blot & Hubert (2016) believe that the two policies complement each other in the sense that QE provides the liquidity and NIRP reallocates it to increase the loan supply. Both measures force the interest rates down, which is seen as a reinforcement to rebalance the bank portfolio towards riskier assets.

2.3.1 Hypotheses

Three mechanisms can be distinguished when determining the effect of NIRP on bank risk-taking. As a result of the two-tiered system of NIRP, banks can decide to raise their non-interest related income or reduce their operating costs to compensate for the reduction of their net interest margin (Boungou, 2019). Reducing operating costs is consistent with the risk-shifting channel, where lower policy rates decrease the operating costs, thus raising profitability and stopping risky behaviour (Heider et al., 2019). On the other hand, raising non-interest related income would match with the portfolio-reallocation channel (Dell'Ariccia, Laeven & Marques, 2011). This would lead to a shift towards riskier assets and thus more risk-taking. Next to this, the default risk of debtors decreases when interest rates are reduced. According to Blot & Hubert (2016), the solvency of those non-financial agents increases, which would reduce the non-performing loans (NPL), which is a measure of risk for banks. Empirical evidence points out that the amount of non-performing loans decreased after implementation of NIRP and that commercial banks shifted towards a portfolio with safer assets (Boungou, 2019; Bongiovanni et al., 2021). This points to the existence and efficiency of the risk-shifting channel and the theory developed by Blot & Hubert (2016). However, other empirical evidence shows how the two-tiered system causes the portfolio-reallocation channel to overpower the risk-shifting channel and thereby increasing risk-taking behaviour (Heider et al., 2019).

In the literature review it has been mentioned that the evidence on the effect of negative policy rates on bank lending behaviour is quite contradictive as well. Boungou (2020) shows that the bank lending channel works efficiently by providing evidence that loan supply increased and lending costs decreased because excess reserves were exchanged for loan supply. The same results are found for negative policy rates in Switzerland and Italy (Basten & Mariathasan, 2018; Bottero, Minoiu & Peydró, 2019). The Bank Lending Survey performed by the ECB after the implementation of NIRP found similar evidence (Blot & Hubert, 2016). Opposite to this is the empirical evidence found by Molyneux et al. (2017) and Heider et al. (2019). Both papers explain how retail deposits create an inefficiency in the transmission of NIRP through the bank lending channel. Because high-retail deposit banks do not have the same advantage as low-retail deposit banks from the NIRP implementation, they do not increase their loan supply as much as low-retail deposit banks (Heider et al., 2019). Molyneux et al. (2017) show evidence that banks diminish their lending supply in countries with NIRP implemented, which is induced by the contractionary effect of going through the Zero Lower Bound. Retail deposits are the cause of the inefficiency of the bank lending channel according to the writers. Demiralp et al. (2017) and Boungou & Mawusi (2020) both contradict these papers by showing evidence of a significant growth in loan supply for high-deposit banks after NIRP. This can be explained by portfolio rebalancing to lose excess reserves, which are costly in times of negative interest rates.

From the theories and empirical evidence mentioned above, it is obvious that there is no consensus among academics about the efficiency of the risk-taking and bank lending channel in the negative area. Convincing arguments and mechanisms have been described on both sides that directly and indirectly contradict each other. However, most papers measure significant effects from the NIRP on both bank risk-taking and lending behaviour. This leads to the following hypothesis:

Hypothesis 1: NIRP has a significant effect on both bank risk-taking and bank lending behaviour.

After the effect of the NIRP has been determined, the joint effect of NIRP and quantitative easing has to be examined. The monetary policies could complement or substitute each other. The purpose of quantitative easing, as a monetary policy of last resort, is to function and reach the set objectives when other monetary policies do not function as well. This would point to a complementary role when combined with other monetary measures to stimulate economic growth. Heider et al. (2021) state that complementarity is a possibility, because NIRP influences the balance sheet on the liabilities side, whereas quantitative easing focusses on the asset side. Hence, these monetary policies could affect bank behaviour at the same time in different ways. Blot & Hubert (2016) believe that the two expansionary monetary policies are complementary, since the asset purchase program creates more liquidity for banks and the NIRP reallocates the liquidity. Reserves are more costly to hold with negative interest rates, which stimulates banks to lend more to consumers. Both measures can impact the interest rate level as well, NIRP directly and QE indirectly. Heider et al. (2021) present this as a substitution, but Blot & Hubert (2016) emphasize that this could create a double effect on portfolio rebalancing towards riskier assets. The second hypothesis is derived from this:

> *Hypothesis 2: The joint effect of NIRP and quantitative easing is complementary and will have a significant effect on risk-taking and bank lending behaviour.*

3. Data and Methodology

3.1 Data

To research the effect of monetary policies on bank risk-taking and lending behaviour, different data sources are used. Bank-specific data will be collected from the Orbis databank. Orbis Focus is a worldwide database specialised in bank data, with information about around 400 million firms and banks. It provides the information about gross loans, loan loss provisions (LLP), NPLs, size, liquidity and deposit level for this paper. Data is collected from countries of the Eurozone, other countries within the EU & EEA and Switzerland. Eurostat, another databank specialised in European data, provides the data for the control variables GDP, Unemployment and Inflation. The databank forms the official statistical source of the European Union and has detailed information about European economics among others. Both data banks provide quarterly information on GDP and Unemployment for 2014 and 2015 and yearly data for Inflation. The yearly data from the last control variable, the Herfindahl index, is retrieved from the WITS databank. This source originated as a combined effort of different world trade organisations, such as the United Nations Conference on Trade and Development, the International Trade Center and the World Trade Organization. It provides trade information about more than 170 countries. The complete dataset is then retouched to create a representative sample of European banks. Outliers of the dataset are removed to avoid biases and missing data are also removed. This resulted in a balanced panel dataset of 34 banks for the independent variable Loan Loss Provisions and 42 banks for the independent variable Non-performing Loans for the empirical analysis of risk behaviour during NIRP. A balanced panel dataset consisting of 45 banks is used for the bank lending analysis for NIRP. For the second DiD analysis, 20 banks were found for Loan Loss Provisions, 19 for Non-performing Loans and 34 banks were found for the Gross Loans.

3.2 Methodology

3.2.1 Model specification

Basing the research method on Heider et al. (2019) and Boungou (2019), a Difference-in-Difference method will be performed on a panel dataset of banks to assess the effect of negative interest rate policy on bank lending and risk-taking behaviour. The datasets for European banks comes from 15 countries that are or were members of the European Union. From those countries, some are also member of the Eurozone and adhere to the European Central Bank. Switzerland is also included in the sample. The treated banks are affected by the policy and the control group will stay unaffected by negative interest rates. The time framework for the analysis will be from January 2014 to December 2014, with the start of the NIRP in June 2014. This is a relatively small time window, fitted to end before the asset purchase program of the ECB is implemented, to avoid measuring the effect of more than one policy. All equations below will be empirically estimated twice: once in a fixed effects model and once in a random effects model. In the random effects model, a slightly bigger sample can be used and the country-specific variables Inflation and Herfindahl Index can be included whereas in the fixed model a country-year fixed effect will be used which absorbs those variables. The time variable Time and treatment variables NIRP and Combined are used in the random effects model, but are not included in the fixed effects model to avoid collinearity. Using a fixed effects model results in removing countries with only one bank in the sample, which would cause collinearity too. Both models are estimated to create the possibility to compare the results and analyse which model gives clearer estimates. The following equations will be estimated:

(1) $Y(Non-performing\ Loans\ ratio_{\mathrm{i,\,t}}) = \beta_0 + \beta_1 NIRP_{\mathrm{i}} + \beta_2 Time_{\mathrm{t}} + \beta_3 NIRP_{\mathrm{i}} * Time_{\mathrm{t}} + \beta_4 Country_{\mathrm{i,\,t}} + \beta_5 Bank_{\mathrm{i,\,t}} + \varepsilon_{\mathrm{i,\,t}}$

Where Non-performing Loans ratio $_{\mathrm{i,\,t}}$*:The level of non-performing loans to total assets of bank i at time t*
NIRPi: Dummy variable for treatment where 0 is for banks without NIRP and 1 for banks with NIRP implemented
Timet: Dummy variable where 0 is pre-treatment and 1 is after implementation of NIRP
Country $_{\mathrm{i,\,t}}$*: Collection of all country-specific variables, which are:*
Inflation $_{\mathrm{i,\,t}}$*: Annual inflation of the country where bank i is based at time t*
Herfindahl Index $_{\mathrm{i,\,t}}$*: Annual market concentration of the bank industry in the country of bank i at time t*
GDP level: Gross Domestic Product index with 2010=100 at market price in the country of bank i at time t
Bank $_{\mathrm{i,\,t}}$*: Collection of all bank-specific variables, which are:*
Liquidity $_{\mathrm{i,\,t}}$*: Liquid assets to total assets in percentages of bank i at time t*
Capital $_{\mathrm{i,\,t}}$*: Equity to total assets ratio in percentages of bank i at time t*
Size: Natural logarithm of total assets of bank i at time t
Deposit level: Total customer deposits to total assets as a ratio of bank i at time t
$\varepsilon_{\mathrm{i,\,t}}$*: the idiosyncratic error*

(2) $Y(Loan\ Loss\ Provisions\ ratio_{\mathrm{i,\,t}}) = \beta_0 + \beta_1 NIRP_{\mathrm{i}} + \beta_2 Time_{\mathrm{t}} + \beta_3 NIRP_{\mathrm{i}} * Time_{\mathrm{t}} + \beta_4 Country_{\mathrm{i,\,t}} + \beta_5 Bank_{\mathrm{i,\,t}} + \varepsilon_{\mathrm{i,\,t}}$

Where Loan Loss Provisions ratio $_{\mathrm{i,\,t}}$*:The level of loan loss provisions to total assets of bank i at time t*

The first equation (1) estimates the effect of negative interest rates on non-performing loans (Boungou, 2019). Non-performing loans are loans that are overdue for 90 days or longer and show how banks take risk by lending to possibly insolvent customers. The second equation (2) measures the NIRP effect on loan loss provisions. Loan loss provisions are built by banks to factor in that some clients are insolvent. The first measure focusses on the quality of the loans that are issued by banks, while provisions focusses on bank credit risk. The first variable, NIRP, is cross-sectional and indicates 1 for the countries who are affected by negative interest rates and 0 for countries that stay unaffected. Time is the time-series variable, with a value 1 for after NIRP has been implemented and a 0 for before the treatment period. The third variable, an interaction variable of the dummies for NIRP and Time, is the independent variable of interest in this DiD method. It indicates the difference in average results in the affected countries before and after NIRP minus the difference in average results in the unaffected countries before and after NIRP. All variables of interest in the following equations can be interpreted in the same manner. The expectation of the independent variable is only that the result will be significant. As the first hypothesis makes clear, it is not possible to predict whether the independent variable will be negative or positive since there are multiple theories regarding risk-taking behaviour stating different results. Control variables are added to control for differences between countries and banks.

The third equation (3) measures the effect of NIRP on the ratio of total gross loans (Molyneux et al., 2019). Again, the interaction variable of NIRP and Time is the variable that indicates the effect of negative interest rates on countries and thus the variable of interest. The variable can be interpreted in the same manner as the independent variable of interest for the risk-taking model. With bank lending too, it is only reasonable to state that the expectation for the independent variable will be that the result will be significant. Theories and the accompanying empirical evidence are contradictive, making it impossible to predict more.

(3) $Y(Gross\ Loans\ ratio_{i,\,t}) = \beta_0 + \beta_1 NIRP_i + \beta_2 Time_t + \beta_3 NIRP_i * Time_t + \beta_4 Country_{i,\,t} + \beta_5 Bank_{i,\,t} + \varepsilon_{i,\,t}$

Where Gross Loans ratio $_{i,\,t}$*: The level of gross loans to total assets of bank i at time t*

A second DiD strategy will be applied to the second hypothesis. The effect of both policy measures on risk-taking and bank lending will be analysed. The same dependent variables will be used as for the first hypothesis. In this case, the treated banks are affected by both NIRP and quantitative easing and the control banks will only be affected by NIRP. Since all banks within the Eurozone are affected by both measures, the control group will consist of banks from Denmark and Switzerland with negative interest rates but without asset purchase programs. The time window will start July 2014 and end in September 2015, with the start of the program in March 2015. Again, there is a short measuring window to avoid overlap. This will show if quantitative easing adds to or diminishes the effects of negative interest rates. The following equation will be tested:

(4) $Y(Non-performing\ loans_{i,\,t}) = \beta_0 + \beta_1 Combined_i + \beta_2 Time_t + \beta_3 Combined_i * Time_t + \beta_4 Country_{i,\,t} + \beta_5 Bank_{i,\,t} + \varepsilon_{i,\,t}$

(5) $Y(Loan\ Loss\ Provisions\ ratio_{i,\,t}) = \beta_0 + \beta_1 Combined_i + \beta_2 Time_t + \beta_3 Combined_i * Time_t + \beta_4 Country_{i,\,t} + \beta_5 Bank_{i,\,t} + \varepsilon_{i,\,t}$

This model focusses on the effect of quantitative easing within Eurozone countries on the level of risk-taking. The first variable Combined measures the differences on a cross-sectional level, which is between countries, while the second variable Time indicates before and post-treatment. Comparable to the equations of the first hypothesis, the third variable indicates the interaction effect of treatment and the different countries. This can be interpreted as the difference in outcome from the Eurozone countries before and after QE minus the difference in outcome from the non-Eurozone countries before and after QE. The expectation for the independent variable follows the second hypothesis, namely that the two monetary measures will be complementary. This means that the result should be significant, but the direction in which it will go cannot be determined yet.

(6) $Y(Gross\ Loans\ ratio)_{\mathrm{i,\,t}} = \beta_0 + \beta_1 Combined_{\mathrm{i}} + \beta_2 Time_{\mathrm{t}} + \beta_3 Combined_{\mathrm{i}} * Time_{\mathrm{t}} + \beta_4 Country_{\mathrm{i,\,t}} + \beta_5 Bank_{\mathrm{i,\,t}} + \varepsilon_{\mathrm{i,\,t}}$

The last equation (6) tests the effect of quantitative easing on bank lending behaviour, measured in total gross loans ratio. The variable of interest is the interaction between the Combined and Time variables. Similar to the other equations, the control variables consist of country-specific variables to control for the country-related differences in the dataset and bank-specific variables to control for differences between banks. The independent variable representing bank lending is expected to be significant and in the same direction as the bank lending variable from the first hypothesis. This should prove if the two monetary policies are complements.

Because the countries in the dataset all have specific characteristics regarding banking and the implementation of monetary policy that could influence the model, it is worth debating if countries should be clustered within the models. This would mean that certain standard errors would be clustered, because certain observations can be related to each other. Not accounting for observations that are connected on a group-level could create a downward bias in the results (Donald & Lang, 2007). However, the data sample is too small to cluster the standard errors in groups with enough observations. Multiple rules of thumb exist to test if the data set contains enough observations to cluster. For example, Formann (1984) suggests that the number of observations should be five times 2^d, in which d is the number of variables and Qiu & Joe (2009) state that the smallest cluster should at least have 10*d observations (Dolcinar, Grün, Leisch & Schmidt, 2014). Both rules of thumb suggest a bigger sample size than the data set for this paper is, which rules out the use of clustered standard errors. For all model analyses, a significance level of 5% is used.

3.2.2 Dependent and independent variables

Three variables form the dependent variables, as can be read above. Both Non-performing Loans and Loan Loss Provisions are divided by assets to be able to measure the ratio and not the absolute levels. Bank lending is measured by estimating the effect on the gross loans divided by total assets as well. All DiD methods contain control variables to control for country-specific and bank-specific influences. Most of the included variables have an effect on bank behaviour. Country-specific control variables are considered to smooth out macro-economic differences between countries. Inflation, Unemployment and GDP growth are included for that reason. The effect of GDP on bank profit can be twofold: it can cause a greater demand for loans and a decline in lending supply (Molyneux, Reghezza, & Xie, 2019). The level of GDP is measured as the index level with 2010 as the base level of 100. Inflation also has an effect on the net interest margin, but this differs per country (Almarzoqi & Naceur, 2015). Following Boungou (2019), the Herfindahl index is included as a variable to control for bank market structure. Together with inflation, the Herfindahl index is sometimes included in a year-fixed effect, because these variables are measured per year and are common to one year in a certain country. Multiple bank-specific control variables are included to correct for different sorts of banks. Economies of scale can occur and affect bank profitability in multiple ways, such as creating lower margins and increasing lending by going international (Molyneux et al., 2019). The impact of bank size on bank lending behaviour points into another direction. According to Kishan & Opiela (2000), smaller banks adhere better to implemented monetary policies. This is why size, measured as the logarithm of total assets, is added. Liquidity is also included in the form of liquid assets to total assets, because liquid banks are better protected against going bankrupt (Boungou, 2019). Next to this, liquid banks are more likely to lend more to customers, as reserves can be converted to loan supply (Alper, Hülagü & Kelec, 2012). As Heider et al. (2019) showed, the bank deposit level has an impact on bank lending and risk-taking, so the deposit level will also be a control variable. Bank capitalization is also used as bank characteristic, because banks with higher capitalization lend more and have lower funding costs (Gambacorta & Shin, 2018). The capital variable is the equity to total assets ratio of the commercial banks.

3.2.3 Descriptive statistics

The descriptive statistics of both DiD analyses describe the mean, the standard deviation and the minimum and maximum of the variables of interest and the control variables. The tables can be found in the Appendix. What becomes clear after studying the descriptive information, is that the dataset includes a wide variety of banks. Both big and small, liquid and illiquid and capitalized and non-capitalized banks are included. Table 6 and 7 show that in the second DiD analyses, even banks with negative capitalization are included. There is a wide range of different deposit levels as well. The country control variables too show that there are big differences between the countries regarding GDP and unemployment level during the time period of interest. Concerning the loan variables, it is clear that banks have different approaches regarding their loan policy. Some banks take into account a large amount of non-performing loans and create large loan loss provisions, while other banks show much smaller accounts (Table 2,3, 5 &6). The descriptive statistics for the second DiD analysis of loan loss provisions show that the minimum is negative, which in reality means that the bank in question did not build its loan loss provisions, but released part of its provisions due to the previous provisions being too high (Table 6). Another point of interest is the different levels of NPLs and LLPs between the first DiD analysis and the second. The mean of both NPLs and LLPs in the second dataset is much higher than the mean for the first dataset. This is most likely due to the fact that most non-Eurozone countries are not included in the second dataset, which creates a different selection of banks.

3.2.4 Correlation

The independent variables most likely affect the dependent variable significantly, which is why they are added to the models as control variables. To assess the correlation between the dependent and independent variables, correlation tables are included in the Appendix. When variables show a very strong relationship, multicollinearity can be suspected. Multicollinearity forms a problem, because the estimated variables can show large variances and may be imprecise (Mansfield & Helms, 1982). According to Shrestha (2020), multicollinearity can be detected if the correlation between two variables is around or higher than 0.80. Inflation and Unemployment seem to be highly related (Table 8, 9, 10 & 13). From Table 11, 12 & 13, it is clear that GDP level and Unemployment level are highly correlated. This is why the variable Unemployment level is removed from the first and second set of DiD analyses.

3.2.5 Parallel trends assumption

The DiD analyses can only produce valid results if one important assumption holds. The parallel trends assumption implies that the outcome for the treated and untreated groups would have developed in the same direction, if the treatment of the experiment would stay absent (Marcus & Sant'Anna, 2021). This means that there should be parallel trends between the treated and untreated group pre-treatment. If there are no common trends before treatment, there is no reason to assume that there would be parallel trends after treatment. The results of the DiD analysis would be biased, since the effects cannot be estimated correctly (Sasabuchi, 2021). If the treatment group would have a positive trend in comparison to the control group, an upward bias would arise in the results. The reverse is true for a negative trend in the pre-treatment part of the treatment group compared to the control group, here a downward bias on the results would be visible (Greenstone & Hanna, 2014). There are two methods to check if the assumption holds, one is to plot the trends graphically and visually compare them to one another and the other one is to perform a t-test on the trends of the control and treatment groups.

The figures with the graphical representations of the parallel trends can be found in the Appendix. For this paper specifically this assumption means that for the first set of DiD analyses, the banks with and without NIRP should show the same trends in the means of risk-taking and bank-lending behaviour before the treatment. The second set of DiD analyses can only be performed if there are parallel trends between the risk-taking and lending behaviour of banks with both monetary measures and banks with only NIRP. As can be seen in Figure 2, the level of total non-performing loans is constant during the first two quarters of 2014. This means that the parallel trends assumption holds for the DiD analysis of the effect of NIRP on the level of non-performing loans. The average level of loan loss provisions in countries with NIRP shows not exactly same trend as the level of loan loss provisions in countries without NIRP in quarter one and two, but this can be insignificant (Figure 3). Parallel trends can also reasonably be assumed for the growth of gross loans in the first two quarters, as both stay relatively constant over the first two quarters, as can be seen in Figure 4. This means all three DiD analyses on NIRP can be performed. The second set of DiD analyses on the combined effect also require the parallel assumption to hold. The variable Non-performing Loans shows parallel trends, as both lines are very stable on their respective levels and even show a similar trend after the pre-treatment period (Figure 5). Loan Loss Provisions does not seem to change at the same strength, but the countries with and without QE show similar trends with a rise between the third and fourth quarter and a decrease between Q4 of 2014 and Q1 of 2015 (Figure 6). The growth in gross loans of the second DiD analysis shows clearly that there are parallel trends between the countries with and without both policy measures (Figure 7). In conclusion, all DiD analyses can be performed based on the visual assessment, because the most important assumption holds for all three interest variables and the two time periods.

In Table 14, the results of the t-tests on the parallel trends assumption can be found. This test shows if there are significant differences between the trends of treated and untreated countries before the implementation of the measures. The table shows if there were significant p-values for respectively a negative difference, a difference between the trends in general and a positive difference between the trends of untreated countries and treated countries pre-treatment. In the first DiD set, the NPL ratio has no significant p-values which means that there are no significant differences between the two groups before treatment. This corresponds to the visual comparison of the two trends in Figure 2. Both the results for the LLP ratio and the Gross Loans ratio show significancy on a 10% level, but not on the 5% level. Because a 5% significance level is used in this paper, both show parallel trends because the trends do not differ significantly. This too is in line with the visual representations in Figure 3 and 4. However, the results for LLP ratio especially are very close to violate the parallel trends assumption, which means that an upward bias could occur. The results of the second DiD set show contain the trend between quarter three and four of 2014 and the trend between quarter four of 2014 and quarter one of 2015. This explains why there are two rows with results. The NPL ratio shows no significant results for a difference in trends between 2014 quarter three and 2015 quarter one. The Gross Loans ratio does not show any significancy in difference between trends as well. It is possible to conclude that the parallel trends assumption holds for both variables, which is in line with the conclusion drawn from the visual assessment in Figure 5 and 7. The only significant result of Table X occurs in the second row of the LLP ratio, which implies that there is a significant difference between the untreated and treated countries between quarter four (2014) and quarter one (2015). This points to a possible downward bias of the results for the second DiD analysis of the LLP ratio.

Despite both LLP ratios showing possible signs of biases, the DiD analyses will still be performed. The differences between the groups are not very large, meaning that a visual assessment shows little difference in the trends pre-treatment. The data set consists only of European commercial banks that might show differences in the short run, but will mostly show similar trends in the longer run. The set is filtered with the purpose of creating a compatible group of banks, which is why the DiD will still be analysed.

Table 14

The parallel trends assumption t-test results

Dependent variable	p-value Ha: diff < 0	p-value Ha: diff ≠ 0	p-value Ha: diff > 0
DiD set 1: NIRP			
NPL ratio	0.358	0.717	0.642
LLP ratio	0.059*	0.119	0.941
Gross Loans ratio	0.921	0.158	0.079*
DiD set 2: NIRP and QE			
NPL ratio	0.443	0.886	0.557
	0.223	0.446	0.777
LLP ratio	0.229	0.457	0.771
	0.961	0.078*	0.039**
Gross Loans ratio	0.398	0.796	0.602
	0.866	0.269	0.134

Note. This table presents the t-test results on the trends of the treated and untreated group of banks to see if the parallel trends assumption holds. The p-values of the three alternative hypotheses of the t-test are shown. The significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

4. Empirical analysis and results

In this chapter, both hypotheses will be analysed on the basis of the empirical results obtained by running the DiD regressions. For all six regressions, three variables were created: Time, Treated and Time*Treated. Time represents the dummy variable that distinguishes between the quarters before the implementation of NIRP and after NIRP in the first three DiD analyses. NIRP is the treated dummy variable which separates the treated banks from the untreated banks and Time*NIRP is the interaction effect of the two and also the difference-in-difference estimator. The last three DiD regressions have the same variables, but Time represents the dummy variable where 0 stands for the quarters without QE and 1 stands for the quarters with both NIRP and QE. The variable representing treated and untreated banks is called Combined.

4.1 Results first hypothesis

In the literature overview, the different views on the effect of NIRP on bank risk-taking have been described. Three mechanisms could affect bank behaviour regarding risk, but in opposite directions. Reducing operating costs and increasing the solvency of non-financial agents both decrease NPLs, while raising non-interest related income would lead to a shift towards more risk and thus raise the level of NPLs (Dell'Ariccia et al., 2011; Blot & Hubert, 2016; Boungou, 2019). The hypothesis that was derived from this pointed to a significant effect of NIRP on bank risk-taking.

4.1.1 Risk-taking measured by the NPL ratio

The hypothesis is tested by performing two DiD analyses with control variables for country- and bank-specific characteristics. Two of the country-specific control variables, Inflation and Herfindahl index, are absorbed in the fixed effects regression as a country-year fixed effect to avoid multicollinearity. The results of the difference-in-difference estimations for the effect of NIRP on the level of non-performing loans can be found in Table 15.

Overall, the fixed effects and random effects model show only few similarities regarding the significance of variables. Both models do show an ambiguous effect of the interaction effect on the NPL ratio. This implicates that the implementation of NIRP had no significant effect on the NPL ratio of treated banks compared to untreated banks after the treatment. The first hypothesis did predict a significant effect, which means that the empirical evidence on bank risk-taking rejects the first hypothesis. Next to this, the fixed effects model has two significant control variables. Liquidity shows a very significant negative effect on the NPL ratio, which can be interpreted such that a 1% positive change in the liquidity ratio would cause a decrease of the NPL ratio with 0.1 percentage point. This is in line with the theoretical expectations, which stated that liquid banks are less likely to go bankrupt

(Boungou, 2019). Although this result is quite significant statistically, the economic influence of this is most likely negligible. The deposit level too shows a significant effect on the NPL ratio, but this effect is positive and was already predicted by Heider et al. (2019). This positive effect would translate to a change of 1% in deposit level causing a 0.048 percentage point increase in NPL ratio. This effect is even smaller than the influence of liquidity, and quite small economically speaking.

Table 15

Difference-in-difference estimation results of the implementation of NIRP on the NPL ratio

	NPL ratio (%)	
Variable	Fixed effects model	Random effects model
constant	9.938	36.883***
	(7.283)	(11.294)
NIRP		-0.753
		(2.333)
Time		-0.109
		(0.304)
NIRP*Time	0.085	0.505
	(0.612)	(0.376)
Liquidity (%)	-0.104***	-0.048*
	(0.025)	(0.029)
Capital (%)	-0.007	-0.108
	(0.106)	(0.128)
Size	-0.120	-0.906*
	(0.234)	(0.542)
Deposit level (%)	0.048**	0.076*
	(0.024)	(0.041)
GDP level	-0.023	-0.051*
	(0.050)	(0.027)
Inflation (%)		-4.887***
		(1.186)
Herfindahl index		-97.971*
		(51.626)
Number of observations	148	168
R^2	0.910	0.474

Note. This table demonstrates the results of the DiD analyses of the implementation of NIRP on the bank NPL ratio in both a fixed effects and a random effects model. There is a country-year fixed effect included in the fixed effects model, which causes the control variables Inflation and the Herfindahl Index to partial out.
Standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

The results of the random effects model show more significant control variables. However, the interaction effect of NIRP and Time shows an ambiguous result. This means that both the fixed and the random effects model show ambiguous results and do not match with the first hypothesis. Liquidity has a smaller negative effect on the NPL ratio and is also less significant compared to the results from the fixed effects model. Size shows a negative effect on the 10% significance level. The effect of a 1% increase of size on the NPL ratio is a decrease of 0.009 percentage point, since Size is measured as the natural logarithm of total assets. Theory predicted that Size would have a negative effect on NPL (Molyneux et al.). This effect of Size on the NPL ratio is economically very insignificant. A change in deposit level of 1% would mean an increase of 0.076 percentage point for the NPL ratio, which is bigger but still quite small. This effect can be compared in size to the effect of a 1-unit change in GDP level, which would lead to a decrease of 0.051 percentage point in NPL ratio. The GDP level shows a significance on the 10% level, which is unexpected since Molyneux et al. (2019) predicted that there could be ambiguity in the relationship between GDP and risk-taking. Profitability could rise due to a greater demand for loans but the lending supply could also decrease due to a rise in consumption. Inflation shows a very significant negative effect on the NPL ratio. If Inflation increases with 1%, this would lead to a decrease of more than 4% in the NPL ratio. This is economically significant as it can lead to reasonably big changes on bank balance sheets. It should be noted as well that a change of 1% in inflation is a great change and is likely to happen in smaller steps. The Herfindahl Index is measured as a ratio from 0 to 1 with 1 meaning a very concentrated bank industry. The effect of this index on the NPL ratio can be interpreted as follows: a 0.01 ratio increase would translate to a 0.98 percentage point decrease in the NPL ratio. A more concentrated bank industry would create a lower level of NPL ratios. In both models, Capital shows an ambiguous results which is against expectations. According to the literature, a higher bank capitalization lowers the funding costs (Gambacorta & Shin, 2018). Lower funding costs could raise profitability, which would lower the tendency for banks to take more risk (Heider et al., 2019).

4.1.2 Risk-taking measured by the LLP ratio

To measure the DiD estimation for the LLP ratio, a panel regression with fixed and random effects is used (Table 16). Similar to the models from the NPL ratio, there is little resemblance between the fixed effects model and the random effects model. However, both models show that the interaction effect of Time and NIRP, the variable of interest, shows an ambiguous effect on the LLP ratio. There is no significant difference in LLP ratio between banks with and without NIRP before and after the implementation. In the fixed effects model, three control variables stand out: Liquidity, Capital and the Deposit level. Liquidity is negatively significant on the 5% level, which was expected theoretically. The result however is economically insignificant, because a liquidity rise of 1% would translate to a reduction of 0.003 percentage point in the LLP ratio. Capital points to a very significant negative effect, but is still economically quite insignificant. It is still in line with the expectations of Gambacorta & Shin (2018) and Heider et al. (2019). Size has an ambiguous effect on the LLP ratio. A significant negative effect was foreseen, because bank size can create economies of scale which in turn would lead to higher profitability (Molyneux et al., 2019). The deposit level has a rather small positive but very significant influence on the LLP ratio and would translate to an increase of 0.008 percentage point if the deposit level increases with 1%. Heider et al. (2019) find that banks with higher deposit levels are disadvantaged when interest rates go negative. The two-tiered system causes a smaller decrease in the cost of funding. The result is that high-deposit banks tend to take more risk, which is reflected in the empirical results. It will however have hardly any effect economically speaking. GDP level shows an ambiguous effect similar to the theoretical expectations.

Table 16

Difference-in-difference estimation results for the implementation of NIRP on the LLP ratio

	LLP ratio (%)	
Variable	Fixed effects model	Random effects model
constant	0.040	1.141*
	(0.521)	(0.703)
NIRP		0.123
		(0.135)
Time		0.012
		(0.042)
NIRP*Time	0.034	0.017
	(0.042)	(0.051)
Liquidity (%)	-0.003**	-0.005*
	(0.002)	(0.003)
Capital (%)	-0.029***	0.005
	(0.007)	(0.009)
Size	-0.007	-0.045
	(0.017)	(0.032)
Deposit level (%)	0.008***	0.005*
	(0.002)	(0.003)
GDP level	0.001	-0.002
	(0.004)	(0.004)
Inflation (%)		-0.143**
		(0.072)
Herfindahl index		-1.654
		(3.053)
Number of observations	116	136
R^2	0.699	0.372

Note. This table shows the results of the DiD analyses of the implementation of NIRP on the bank LLP ratio in a fixed effects model and a random effects model. Because a country-year fixed effect has been included in the fixed effects model, the control variables Inflation and Herfindahl Index cannot be estimated.
The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

In the random effects model there seem to be only a few significant variables. The effect of Liquidity can be compared to the effect of liquidity in the fixed effects model and can be interpreted accordingly. The deposit level has exactly the opposite effect on the LLP ratio, when customer deposits increase with 1%, the LLP ratio will also increase with 0.005 percentage point. Although this effect seems significant in the results, the economic significance is barely noticeable. Inflation is the only variable significant on a 5% level and has a slightly bigger negative effect than the other control variables. If the Inflation increases with 1%, the LLP ratio will decrease with 0.143 percentage point. This is considerably smaller than the effect of Inflation on the NPL ratio. Since this effect can differ per country, there was not a clear expectation on this variable (Almarzoqi & Naceur, 2015). The other control variables show ambiguous results, which was against expectations except for the GDP level.

4.1.3 Bank lending measured by the Gross Loans ratio

The first hypothesis stated that the effect of NIRP on bank lending would be significant, but that the direction of this significant effect was not determined. This was based on different papers stating that the bank lending channel works efficiently and empirical evidence pointing in this direction (Boungou, 2020; Demiralp et al., 2017; Boungou & Mawusi, 2020). Other papers argued that the bank lending channel did not lead to efficient transmission of monetary policy, too with empirical evidence (Molyneux et al., 2017).

Similar to the DiD estimation of the NPL ratio, the empirical analysis of the effect of different variables on the Gross Loans ratio is performed with two DiD estimations (Table 17). In both models the interaction effect, which describes the implementation of NIRP in treated banks, also has an ambiguous effect. There is no significant difference in gross loan ratios before and after implementation between treated and untreated banks. The fixed effects model shows some significant control variables. Liquidity should, according to the literature, have a significant positive effect on bank lending behaviour. The higher the bank liquidity, the higher the incentive to lend more (Alper, Hülagü & Kelec, 2012). This is contradicted in the empirical evidence, which shows a very significant negative effect on the gross loans ratio. Apparently, a 1% increase in liquidity decreases the gross loan ratio with 1.083 percentage point. Size shows a significant negative effect on the gross loan ratio as well which might seem unlikely, because economies of scale could also create a positive connection between size and bank lending behaviour. Kishan & Opiela (2000) however showed that small banks reacted stronger to monetary policy, which indicates a better transmission of the bank lending channel. The result is therefore not unexpected. A 1% increase in bank size would translate to a decrease of 0.027 percentage point in the gross loan ratio, which is too small to be economically significant. Capital and Deposit Level both unexpectedly show ambiguous results, whereas we would expect respectively a positive and a negative effect.

Table 17

Difference-in-difference estimation results for the implementation of NIRP on the Gross Loans ratio

	Gross Loans ratio (%)	
Variable	Fixed effects model	Random effects model
Constant	155.424***	163.086***
	(13.753)	(17.072)
NIRP		0.248
		(3.595)
Time		-0.337
		(0.477)
NIRP*Time	-1.762	-0.763
	(1..227)	(0.552)
Liquidity (%)	-1.083***	-0.400***
	(0.055)	(0.043)
Capital (%)	-0.226	-0.148
	(0.214)	(0.190)
Size	-2.736***	-4.761***
	(0.448)	(0.810)
Deposit level (%)	0.050	0.149**
	(0.040)	(0.059)
GDP level	-0.137	-0.107***
	(0.106)	(0.041)
Inflation (%)		0.068
		(1.751)
Herfindahl index		26.528
		(76.269)
Number of observations	164	180
R^2	0.883	0.667

Note. The table presents the results of the DiD analyses of the implementation of NIRP on the Gross Loans ratio in a fixed and a random effects model. The control variables Inflation and Herfindahl Index are not included in the fixed effects model, because the country-year fixed effect absorbs them.
The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

Similar to the fixed effects model, the random effects model shows a negative effect of liquidity on the gross loan ratio, albeit slightly smaller. Again, this is against theoretical expectations. Size can also be compared of the result in the fixed effects model, as it a negative influence on the gross loan. Apparently, a 1% increase in size would cause a decrease in gross loans of approximately 0.05 percentage points, which can be matched with the theoretical expectations from Kishan & Opiela (2000). Next to this, the effect of size on gross loans ratio is not economically significant. The deposit level shows that a 1% increase in customer deposits would create an increase of 0.149 percentage points in the gross loan ratio, which is significant statistically but negligible economically. This is in line with existing literature, as Demiralp et al. (2017) and Boungou & Mawusi (2020) show that the deposit level can impact bank lending behaviour positively. The GDP level shows an unexpected significant result, pointing to a negative effect on the gross loans ratio. A one unit increase of GDP would translate to a 0.107 percentage point decrease in the gross loans ratio. Capital, Inflation and the Herfindahl index show ambiguous results, which was partly unexpected. Bank capitalization should also have a significant positive effect on the lending variable, because banks with higher capitalization have a higher loan supply (Gambacorta & Shin, 2018). However, the results indicate that bank capital has an ambiguous effect on the gross loan ratio.

According to the first hypothesis, all three DiD sets should have resulted in significant effects of the interaction variable on the dependent variables representing risk-taking and bank lending. None of the analyses show significant effects of NIRP*Time on the NPL ratio, the LLP ratio and the Gross Loans ratio. This indicates that the first hypothesis can be rejected. An explanation for the lack of significant results of NIRP on risk-taking could be that the two channels from Dell'Ariccia et al. (2011), the portfolio-reallocation channel and the risk-shifting channel, cancel each other out. In a negative environment, banks can raise their non-interest related income and reduce their operating costs to mitigate the loss of profit caused by the two-tiered deposit system (Boungou, 2019). It could be that the search-for-yield tendency in combination with high deposits, which would result in more risk-taking according to Heider et al. (2019), was not strong enough to completely overpower the risk-shifting channel. Instead of the portfolio-reallocation channel and the risk-shifting channel overpowering one another, none of them appears to have the overhand, resulting in ambiguous effects. The ambiguous effect of NIRP on bank lending was also not expected. According to Heider et al. (2019), the transmission of the bank lending channel with negative interest rates can be distorted because of the two-tiered bank deposit system. Banks with higher deposits cannot decrease their funding costs to the same extent as low-deposit banks. This results in high-deposit banks not having the same advantage and not being able to lend as much as low-deposit banks. This could form an explanation of the empirical results. Another explanation could be that the banks in the sample did not have enough excess liquidity to lend significantly more after the implementation of NIRP (Demiralp et al., 2017). High-deposit banks tend to have more excess liquidity, which would imply that this sample has mostly low-deposit banks. Robustness checks are needed to conclude which explanation is more suitable.

4.2 Results second hypothesis

The second hypothesis was based on earlier literature which described how NIRP and quantitative easing could either substitute or complement each other (Heider et al., 2021). Since the monetary policies affect different parts of the bank balance sheet, they could very well be complementary. Blot & Hubert (2016) side with this too, as they point out that the monetary policies could create a double effect on portfolio rebalancing towards riskier assets. This lead to the second hypothesis stating that NIRP and QE are complementary, which would result in significant effects on bank risk-taking.

4.2.1 Risk-taking measured by the NPL ratio

To estimate the effect of both NIRP and QE on the NPL ratio, two DiD estimations with a random and fixed effects model have been performed. The results are shown in Table 18. This is the first set of results where the fixed effects model and the random effects model show a difference regarding the variable of interest. The random effects model shows that the interaction effect has a significant positive effect on the NPL ratio on a 10% level. This means that the implementation of both NIRP and QE shows an increase in bank NPL ratios compared to banks that only implemented NIRP. The interaction effect does not show a significant result in the fixed effects model, which leads to the question how strong the effect of implementing both measures really is. Liquidity on the other hand shows a strongly significant negative result in the fixed effects model. A 1% increase would translate to a decrease of 0.151 percentage points in the NPL ratio. This corresponds to earlier cited literature. Time shows a significant negative effect, which means that the implementation of NIRP and QE caused a negative movement in the NPL ratio. Combined shows a slightly significant positive effect on the NPL ratio, which points to a higher NPL ratio for banks within the Eurozone compared to banks outside of the Eurozone. What stands out is the ambiguous result of Liquidity in the random effects model. This is both unexpected and different from the fixed effects model result. Bank capitalization shows a significant and positive result in both models, which is not in line with expectations. According to Gambacorta & Shin (2018), higher capitalization means lower funding costs. This would lead to higher profitability and a lower tendency to take risk. Size shows a difference between models again, with a significant effect measured in the random effects model and an ambiguous result in the fixed effects model. According to the random models results, a 1% increase in bank size would cause a decrease of 0.03 percentage points in NPL ratio. This control variable shows a result that corresponds to theoretical expectations, as bank size affects bank profitability positively (Molyneux et al., 2019). What is remarkable is that the variable Deposit Level shows the exact same effect in the fixed effects model and the random effects model and strongly significant too. According to Heider et al. (2019), banks with higher deposit levels are generally disadvantaged and more prone to take risks, which is reflected in the results. GDP too fulfils theoretical assumptions, as it shows an ambiguous result in both the fixed and the random effects model. Inflation and Herfindahl Index too show ambiguous effects on the NPL ratio in the random effects model.

Table 18

Difference-in-difference estimation results for the implementation of NIRP and QE on the NPL ratio

	NPL ratio (%)	
Variable	Fixed effects model	Random effects model
Constant	12.872	48.594
	(30.659)	(17.323)***
Combined		5.213*
		(2.943)
Time		-1.058**
		(0.438)
Combined*Time	0.627	0.815*
	(1.588)	(0.464)
Liquidity (%)	-0.151***	-0.003
	(0.039)	(0.028)
Capital (%)	0.469*	0.562***
	(0.248)	(0.193)
Size	-0.453	-3.042***
	(0.572)	(0.883)
Deposit level (%)	0.125***	0.125**
	(0.038)	(0.052)
GDP level	0.006	-0.034
	(0.280)	(0.058)
Inflation (%)		-0.283
		(0.402)
Herfindahl Index		11.774
		(59.104)
Number of observations	80	95
R^2	0.921	0.668

Note. The table shows the results of the DiD analyses that have been performed on the implementation of NIRP and QE on the NPL ratio in a fixed effects model and a random effects model. In the fixed effects model, the control variables Inflation and Herfindahl Index are not included, because they are absorbed by the country-year fixed effect.
The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

4.2.2 Risk-taking measured by the LLP ratio

The DiD estimation was performed with a fixed effects model and a random effects model. The results of the estimations for the LLP ratio can be found in Table 19. A first look at the table shows that not many variables have a significant effect on the LLP ratio in both models. This might be because the NPL ratio is a better measure of bank risk-taking. The interaction variable also shows an undetermined effect on the LLP ratio, which means that there is no significant effect of the implementation of both NIRP and QE on the bank LLP ratios, compared to banks that only implemented NIRP. The fixed effects model shows a very significant negative effect of Capital on the LLP ratio, which means that a 1% increase in bank capital would translate to a 0.232 percentage point decrease in the LLP ratio. Since bank capitalization impacts bank profitability, the proxy for risk-taking should indeed be negatively connected to Capital. The effect might be very significant statistically, but the economic significance is much smaller or even negligible. All other control variables show ambiguous results, which is quite surprising not only because of theoretical expectations but also because the control variables showed more significancy on the NPL ratio.

Table 19

Difference-in-difference estimation results for the implementation of NIRP and QE on the LLP ratio

	LLP ratio (%)	
Variable	Fixed effects model	Random effects model
Constant	16.855	8.110***
	(13.664)	(2.983)
Combined		-0.218
		(0.595)
Time		0.143
		(0.510)
Combined*Time	1.031	0.281
	(0.668)	(0.578)
Liquidity (%)	-0.021	-0.020*
	(0.014)	(0.019)
Capital (%)	-0.232***	-0.243***
	(0.079)	(0.054)
Size	-0.309	-0.105
	(0.276)	(0.100)
Deposit level (%)	-0.001	0.013
	(0.018)	(0.012)
GDP level	-0.090	-0.046
	(0.115)	(0.032)
Inflation (%)		-0.151
		(0.301)
Herfindahl index		7.097
		(9.054)
Number of observations	90	100
R^2	0.230	0.345

Note. This table represents the results of two DiD analyses of the implementation of NIRP and QE on the LLP ratio. Both a fixed effects model and a random effects model are included. The control variables Inflation and Herfindahl Index are not estimated in the fixed effects model, due to a country-year fixed effect.
The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

The random effects model shows the same ambiguous results as the fixed effects model except for Liquidity, which is significant on the 10% level. This is in line with theoretical assumptions, because liquid banks are better protected against bankruptcy. However, the effect of Liquidity on the LLP ratio is so small, it is economically insignificant. According to the empirical analysis, Capital shows a very similar effect on the LLP ratio to the one measured in the fixed effects model, which is again in line with theoretical expectations. Size and Deposit Level are both bank-specific control variables and have an ambiguous effect on the LLP ratio. According to existing literature, Size was likely to have a negative effect on the risk proxy, whereas Deposit Level was expected to have a positive effect. Both expectations are clearly not fulfilled. GDP level, Inflation and Herfindahl Index represent the country-specific control variables of the estimation. None of the variables have a significant effect on the LLP ratio. This was however expected for GDP level, since its influence can be twofold (Molyneux et al., 2019). The effect of Inflation could not be determined beforehand, since the results can differ per country (Almarzoqi & Naceur, 2015). For the Herfindahl index, no expectations were formulated, as it was only included to control for bank market structure.

4.2.3 Bank lending measured by the Gross Loans ratio

The second hypothesis about bank lending stated that the negative interest rate policy and quantitative easing would complement each other and that this would result in a significant effect on bank lending behaviour. This was based on earlier research from Heider et al. (2021) and Blot & Hubert (2016), who both argued that the two monetary policies could be complements. Since QE is supposed to create more liquidity for banks and NIRP is supposed to reallocate liquidity to lending supply because keeping reserves is more costly, the two would support each other. This would lead to a significant increase in bank lending.

The DiD-estimation for bank lending is performed with random effects and fixed effects. The results of both models can be found in Table 20. The interaction variable, Combined*Time, shows an ambiguous effect on the Gross Loans ratio. There is no significant difference measurable between banks with both policies and banks with only NIRP after implementing quantitative easing. The control variables show both very significant effects and ambiguity. Time has a significant positive effect on the Gross Loans ratio, which means that the implementation of NIRP and QE combined had a positive effect on the Gross Loans ratio. Liquidity shows a small but very significant negative effect on the gross loans ratio in both models, but the effect is bigger in the fixed effects model. If bank liquidity increases with 1%, this would lead to a decrease of respectively 0.986 and 0.228 percentage point in the gross loans ratio according to the models. This does not correspond to the theoretical expectations regarding liquid banks. According to Alper, Hülagü & Kelec (2012), banks with higher liquidity are more likely to lend more. This is however economically quite insignificant. Capital too is significant in both models with a smaller effect in the random effects model. Literature predicts a positive effect of well-capitalized banks on bank lending, but the empirical results show a small negative effect. Size shows a negative and strongly significant effect on the gross loan ratio, which is in line with prior described literature.

Small banks are prone to show a stronger reaction to monetary policies (Kishan & Opiela, 2000). A 1% increase in Size would create a decrease in the gross loans ratio of 0.043 or 0.066 percentage points, which is only statistically significant.

Table 20

Difference-in-difference estimation results for the implementation of NIRP and QE on the Gross Loans ratio

	Gross Loans ratio (%)	
Variable	Fixed effects model	Random effects model
Constant	163.856***	182.738***
	(47.916)	(19.375)
Combined		3.890
		(4.978)
Time		2.405***
		(0.780)
Combined*Time	2.510	-0.845
	(2.589)	(0.843)
Liquidity (%)	-0.986***	-0.228***
	(0.065)	(0.047)
Capital (%)	-0.892**	-0.399*
	(0.371)	(0.210)
Size	-4.294***	-6.634***
	(0.721)	(0.976)
Deposit level (%)	-0.154*	0.183***
	(0.079)	(0.056)
GDP level	0.130	-0.008
	(0.460)	(0.080)
Inflation (%)		2.086***
		(0.630)
Herfindahl Index		-28.303
		(104.646)
Number of observations	155	170
R^2	0.830	0.529

Note. The table demonstrates the results of the DiD analyses in a fixed effects model and a random effects model of the implementation of NIRP and QE on the Gross Loans ratio. The two control variables Inflation and Herfindahl Index are not estimated in the fixed effects model, because the country-year fixed effect absorbs those.
The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

According to the empirical results, the deposit level has a negative effect in the fixed effects model, but a positive significant effect in the random effects model. This is a significant incongruity between the two models, but it is likely that the random effects model is more credible as the significancy is higher and the theoretical expectations also point to a positive effect. Literature indicates that the effect of the GDP level is difficult to determine, because it affects both loan supply and demand (Molyneux et al., 2019). This is reflected in the empirical results, which show an ambiguous effect of GDP level on Gross Loan ratio. Inflation shows a significantly positive effect on the loan ratio in the random effects model. This points to a 1% increase in Inflation causing an increase in the Gross Loans ratio of approximately 2 percentage points, which can be seen as economically significant. The Herfindahl index was included to control for the bank structure per country and shows an ambiguous effect on the loan ratio.

The second hypothesis stated that the combination of NIRP and QE would have a significant effect on both risk-taking and bank lending behaviour, without specifying the direction this effect would go in. The significancy of the results should be visible in the interaction term of the Combined and Time variable. According to the empirical analysis, only the NPL ratio proxy for risk-taking had one significant result on the 10% level. This implies that the combination of negative interest rates and an asset purchase program had a significant increase in bank risk-taking as a consequence. However, there is no impact of the combined policies noticeable on the other proxy of risk-taking, the LLP ratio. This could imply that the NPL ratio is a better measure of risk. It could also be linked to the consequences of an asset purchase program in combination with loosening the collateral framework. The empirical results of van Bekkum et al. (2016) predicted that the loan repayment performance would worsen, whereas the credit risk could in some cases be transferred to the state. The NPL ratio measures the quality of the loans in the bank portfolios, while the LLP ratio measures the bank credit risk (Boungou, 2019). This would explain the significance of the increased NPL ratio and the ambiguous results on the LLP ratio. From the results, it is only possible to say that the quality of loans has changed significantly. The significancy of the NPL ratio result could be explained by the portfolio-rebalancing theory from Kandrac & Schlusche (2021). Rebalancing within the portfolios is caused by a search-for-yield mechanism, which results in more risky loans. This theory exists for both monetary policies, which would imply that the two support each other. According to Black & Hazelwood (2013), bank size is an important factor and influences the results. A robustness check will test if there is indeed a difference between smaller and bigger banks in the results. Next to this, there is no significant effect of the policies measurable on the gross loans ratio. In conclusion, the second hypothesis can be partly rejected. The effect of the combined measures on bank lending was expected to be significant, but showed ambiguity. The effect of QE alone should be positive according to previously discussed literature. It could be that the combination of NIRP and QE distorted the positive effect QE would have on bank lending. As explained before, the two-tiered deposit system could prevent the efficient transmission of bank lending. This would mean that the created liquidity was not used as lending supply. Or the asset purchase programme of the ECB did not have a significant positive effect on liquidity, which would mean that the lending supply could not grow significantly.

5. Robustness checks

5.1 Bank size

Apparently, the combined policies have a significant positive effect on the NPL ratio on the 10% level, which points to risk-increasing behaviour of banks after implementation. According to Black & Hazelwood (2013), bigger banks show increased risk-taking behaviour after QE implementation, whereas smaller banks show risk-decreasing behaviour. A question that could be derived from this is if the positive result would be stronger if only banks above a certain size would be included in the sample. To test this, a random effects and a fixed effects model are estimated with only the banks included that have total assets above 100 million US dollars. This point was decided on as it formed a very clear divide between smaller and bigger banks in the sample. The results are shown in Table 21.

Table 21

DiD-analysis results of the robustness check on the NPL ratio of larger bank

	NPL ratio (%)	
Variable	Fixed effects model	Random effects model
Constant	35.299**	42.995***
	(12.993)	(9.202)
Combined		2.409***
		(0.663)
Time		0.115
		(0.384)
Combined*Time	-0.459	-0.347
	(0.405)	(0.436)
Liquidity (%)	0.072***	0.031
	(0.019)	(0.021)
Capital (%)	-0.496	-1.004*
	(0.552)	0.562
Size	-1.706***	-2.443***
	(0.427)	0.427
Deposit level (%)	-0.003	0.042*
	(0.020)	(0.022)
GDP level	0.022	0.061
	(0.063)	(0.042)
Inflation (%)		0.350
		0.311
Herfindahl Index		48.985***
		(16.764)
Number of observations	35	45
R^2	0.954	0.944

Note. This table shows the results of two DiD analyses of the implementation of NIRP and QE on the NPL ratio of banks with total assets of $1.000.000 and more. A fixed effects model and a random effects model are estimated. The control variables Inflation and Herfindahl Index are not included, because a country-year fixed effect absorbs them in the fixed effects model.
The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

According to the results, no stronger effect of the interaction variable on the NPL ratio has been measured with only bigger banks included in the sample. This does not match with the theoretical expectations from Black & Hazelwood (2013). The significant effect measured in the complete sample does not show when only bigger banks are taken into account, which is remarkable. It means that the bigger banks in the sample did not specifically cause the positive effect of the implementation of NIRP and QE on the NPL ratio. The control variable Size shows a very significant and negative effect on the NPL ratio. Instead of increasing the risk-taking behaviour of banks, bank size seems to decrease the risk tendency of banks. Molyneux et al. (2019) predicted that bigger banks could use their economies of scale to their advantage after the implementation of NIRP to increase their profitability. An increase in profitability would lead to a decrease in risk-taking because there was no incentive for banks to take more risk. It could be that this effect overpowers the effect predicted by Black & Hazelwood (2013) when both measures are implemented almost directly after one another.

5.2 Deposit level

According to Heider et al. (2019), banks with high deposit levels show riskier behaviour after the implementation of NIRP compared to banks with low deposit levels. Lowering the interest rate causes the cost of funding to decrease. But since the customer deposit rate is almost never put below zero, high-deposit banks cannot benefit from the decrease as much as banks with low deposit rates. This causes the belief that banks with high deposit rates take more risk in a search-for-yield movement. The empirical analysis with both high- and low-deposit banks shows an ambiguous effect of NIRP on the risk proxies NPL ratio and LLP ratio. An explanation for these results is that the portfolio-reallocation channel does not overpower the risk-shifting channel as Dell'Ariccia et al. (2011) expected, because the Effective Lower Bound prevents high-deposit banks from using the risk-shifting channel.

In this robustness check, the hypothesis that high-deposit banks show a significant increase in risk-taking after the implementation of NIRP is tested. A fixed effects model and a random effects model are estimated on the NPL ratio and the LLP ratio with banks that belong to the highest tercile regarding deposit levels, with an average of respectively 65,18% and 70,55% for the NPL ratio and 63,82% and 69,30% for the LLP ratio. This selection of high-deposit banks is based on the research of Heider et al. (2019). The results of both models on the NPL and LLP ratio are visible in Table 22. Apparently, there is no significant effect of the implementation of NIRP on the NPL ratio of high-deposit banks. The results from both models show the same effect of the implementation of NIRP in high-deposit banks on the LLP ratio. There seems to be no distinction between the normal samples and the samples with only high-deposit banks. This is further evidence pointing to the explanation mentioned earlier, which said that the portfolio-reallocation channel and the risk-shifting channel would cancel each other out.

Table 22

DiD-analysis of the robustness check on the NPL & LLP ratio of high-deposit banks

	NPL ratio (%)		LLP ratio (%)	
Variable	Fixed effects model	Random effects model	Fixed effects model	Random effects model
Constant	14.463	-33.154	0.596	9.845*
	(16.747)	(36.605)	(1.834)	(5.596)
NIRP		20.334**		-0.232
		(8.610)		(0.432)
Time		-0.184		-0.009
		(0.407)		(0.110)
NIRP*Time	0.478	0.682	-0.079	-0.060
	(0.811)	(0.465)	(0.107)	(0.171)
Liquidity (%)	-0.165**	0.008	-0.003	-0.003
	(0.069)	(0.036)	(0.008)	(0.011)
Capital (%)	-0.292**	0.215	-0.023	-0.025
	(0.137)	(0.187)	(0.018)	(0.039)
Size	-0.085	1.511	-0.030	-0.411
	(0.752)	(1.632)	(0.096)	(0.260)
Deposit level (%)	0.034	-0.049	0.006	-0.018
	(0.052)	(0.081)	(0.005)	(0.019)
GDP level	-0.020	-0.013	0.001	-0.003
	(0.038)	(0.025)	(0.005)	(0.008)
Inflation (%)		-22.255**		-0.650*
		(9.050)		(0.382)
Herfindahl Index		201.625		-2.338
		(196.605)		(10.345)
Number of observations	56	56	48	48
R^2	0.907	0.581	0.694	0.449

Note. The table presents the results of four DiD analyses. The first two columns show the results of the robustness check with a fixed effects model and a random effects model on the NPL ratio of high-deposit banks after the implementation of NIRP. The last two columns show the fixed effects model and the random effects model of the effect on the LLP ratio of high-deposit banks. Again, Inflation and Herfindahl Index are not included in the fixed effects models because of the country-year fixed effect. The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

Another consequence of the dissimilarity between high- and low-deposit banks after implementation of NIRP is that high-deposit banks decrease their lending behaviour more than banks with lower deposits, because the inequality between banks causes a decrease in the net worth of high-deposit banks (Heider et al., 2019). The results from the first DiD-analysis on bank lending showed ambiguity. Two possible explanations were given: the first one was that the bank lending channel was distorted by the two-tiered bank deposit system, meaning that there is a difference in behaviour between high- and low-deposit banks. The other explanation was that a lack of liquidity created a situation where banks were not able to increase their lending after the implementation of NIRP (Demiralp et al., 2017).

This would point to a sample with more low-deposit banks, as high-deposit banks tend to have more excess liquidity.

In the robustness check, a sample of banks with only the highest tercile of deposit level will be tested on the effect of NIRP on their lending behaviour. The average deposit level is 73,23% in the random effects model and 67,49% in the fixed effects model. The results of this DiD-analysis will be shown in Table 23. Again, both a fixed effects model and a random effects model will be used. The results show no significant effect of the implementation of NIRP on high-deposit banks compared to high-deposit banks without this monetary policy. Apparently, there is not a big difference between the normal sample and the high-deposit sample. This leads us to believe that the first explanation, the distortion of the bank lending channel because of the two-tiered deposit system, is closer to the truth than the second explanation. High-deposit banks seem to not have more excess liquidity to push up their lending pattern compared to low-deposit banks.

Table 23

DiD-analysis results for the robustness check on the Gross Loans ratio of high-deposit banks

	Gross Loans ratio (%)	
Variable	Fixed effects model	Random effects model
Constant	142.786***	100.623*
	(34.074)	(59.466)
NIRP		-5.550
		(5.244)
Time		-0.396
		(1.127)
NIRP*Time	0.175	1.302
	(1.119)	(1.440)
Liquidity (%)	-0.771***	-0.495***
	(0.123)	(0.094)
Capital (%)	-0.114	0.020
	(0.2.67)	(0.423)
Size	-2.535**	0.093
	(1.236)	(2.344)
Deposit level (%)	0.027	0.134
	(0.165)	(0.235)
GDP level	-0.099	-0.026
	(0.074)	(0.074)
Inflation (%)		0.722
		(4.111)
Herfindahl Index		-309.591**
		(156.764)
Number of observations	48	48
R^2	0.944	0.779

Note. This table presents the results of the robustness check performed on high-deposit banks. The effect of the implementation of NIRP on the Gross Loans ratio is estimated in a fixed effects model and a random effects model. The control variables Inflation and Herfindahl Index are not included in the fixed effects model because of the country-year fixed effect. The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

5.3 Bank capitalization

The results show that bank capitalization has a significant relationship with the NPL, LLP and Gross Loans ratio in almost all DiD estimations. Previously discussed literature implies that the higher the bank capital, the more a bank lends and the lower the funding costs (Gambacorta & Shin, 2018). This could mean that a sample of only well-capitalized banks would show a significant increase in bank-lending contrary to the ambiguous results of the second DiD analysis on bank lending. To test this, two samples are created with the highest tercile of capitalization, for the fixed effects model and for the random effects model. The fixed effects sample has an average of 8,45% and the random effects model has an 8,95% average.

Table 24

DiD-analysis results for the robustness check on the Gross Loans ratio of well-capitalized banks

	Gross Loans ratio (%)	
Variable	Fixed effects model	Random effects model
Constant	123.248**	76.077**
	(50.445)	(37.602)
Combined		19.585***
		(5.019)
Time		1.185
		(1.887)
NIRP*Time	1.384	1.318
	(2.284)	(2.276)
Liquidity (%)	-0.667***	-0.562***
	(0.061)	(0.082)
Capital (%)	2.863***	1.158**
	(0.504)	(0.476)
Size	-4.849**	-1.032
	(1.899)	(1.846)
Deposit level (%)	0.245***	0.105
	(0.081)	(0.088)
GDP level	0.086	-0.014
	(0.380)	(0.177)
Inflation (%)		3.937***
		(1.386)
Herfindahl Index		-132.481
		(148.451)
Number of observations	55	55
R^2	0.962	0.940

Note. The table shows the results of the DiD analyses on the implementation of NIRP and QE on the Gross Loans ratio of well-capitalized banks. A fixed effects model and a random effects model were used for this robustness check. The control variables Inflation and Herfindahl Index were not included in the fixed effects model, because they are absorbed by the country-year fixed effect. The standard errors are in parentheses and the significance of the t-statistics is *, ** & *** for the 10%, 5% and 1% significance level respectively.

In Table 24, the results of this DiD analysis on well-capitalized banks can be seen. The results show that the effect of implementing NIRP and QE in well-capitalized banks has an ambiguous effect compared to banks with only NIRP. This is surprising, as it does not match with the theoretical expectations explained before. Well-capitalized banks apparently do not differ very much in their behaviour when comparing them to all banks in the sample. However, there is one difference noticeable. The control variable Capital shows a significant positive effect on the Gross Loans ratio with only well-capitalized banks, whereas the control variable showed a significant negative effect on Gross Loans ratio with all banks in the sample. This does point to the theoretical expectations from Gambacorta & Shin (2018), because the higher the capital, the higher the Gross Loans ratio.

5.4 Placebo test

To research if the empirical analysis for the combined effect of NIRP and QE was solid, a placebo test could be performed on the exact same dataset, but a year before the actual implementation of the policies. A placebo test can show that the result of the DiD analysis are valid, because there is no such effect the year before. There should be no significant results visible to make this research plausible. Unfortunately due to a lack of available data from the year before the implementation of the monetary policies, this placebo test could not be performed.

6. Conclusion and Discussion

The empirical results of the first difference-in-difference estimation set shows that there is no significant effect of the implementation of NIRP on the proxies for bank risk-taking and bank lending behaviour. Because this does not match with the first hypothesis, the hypothesis can be rejected. Multiple theories can be cited to explain these results. The conclusion regarding the ambiguous results of bank risk-taking is that the portfolio-reallocation channel does not overpower the risk-shifting channel or the other way around, but rather that they cancel each other's effects out. The bank-lending channel shows inefficient transmission, which can be caused by different factors such as high deposit levels or a lack of excess liquidity. The second hypothesis was mostly not in line with the empirical results. The combination of NIRP and QE seems to only affect the NPL ratio proxy for risk-taking positively. This is also a logical progression of the discussed literature, in which the portfolio-rebalancing theory with the search-for-yield tendency as a basis is a vocal point and the loosened collateral framework causes banks to take more risk. The opposite goes for the bank lending channel, which is apparently distorted.

The research question focussed on the combined effect of negative interest rate policy and quantitative easing in the Eurozone between 2014 and 2015. Banks seem to take significantly more risk in the composition of their portfolio after the combination of policy measures was implemented by the ECB, whereas there were no significant results after the implementation of only NIRP. This points to a complementary relationship between the two policies. There seems to be no complementary effect of NIRP and QE on bank behaviour regarding their credit risk or lending supply. This does however not necessarily mean that the two policies function as substitutes, this first requires more research. What can be concluded overall is that there are many theories regarding the effects of negative interest rate policy and quantitative easing and that they do often oppose each other, which can lead to a distorted transmission of both the risk-taking and the bank lending channel. It is difficult to draw strong conclusions about which theory has the upper hand, because there is not one explanation that holds the most power. It is a combination of different theories that all seem to have explanatory value and that form a complex web of reactions and implications. The explanatory power of those theories is weakened or strengthened by certain bank characteristics, such as size, liquidity and deposit level. According to the robustness checks, size and capital did seem to play a role in bank risk-taking and lending, whereas the test on high-deposit banks only showed more evidence towards the explanation given earlier. Next to this, the robustness checks also pointed again to the conclusion that the bank lending channel is distorted by the two-tiered deposit system.

This paper is one of the first to take up the challenge to disentangle the effects of NIRP and QE together. Data availability formed a limitation, as it was challenging to compile a large dataset with bank- and country specific information. The results represent just a top of the iceberg, as there are still more questions to answer surrounding this topic. From the empirical evidence in this paper, no complementarity between NIRP and QE could be deduced concerning bank lending behaviour. Follow-up research could be done to see if NIRP and QE can be considered substitutes. It would also be interesting to assess what policy implications could follow from further research into this topic. Which policies can be combined because of their complementarity and which policies can be used when other policies have no use anymore? Other research could focus on the effect of differences in the asset purchases. Which assets should be purchased to give the best results and which composition of assets can be combined with other monetary policies?

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Appendix

Table 1

List of all banks used in the DiD analyses

Bank name	Country
Erste Group Bank AG	Austria
Raiffeisen Bank International AG	Austria
KBC Groep NV/KBC Groupe SA	Belgium
Croatian Bank for Reconstruction & Development	Croatia
Bank of Cyprus	Cyprus
Hellenic Bank	Cyprus
Ceskoslovenska Obchodni Banka A.S.	Czechia
Komercni Banka	Czechia
Danske Bank A/S	Denmark
Nykredit Realkredit A/S	Denmark
Nykredit Bank A/S	Denmark
Sydbank A/S	Denmark
Nordea Bank ABP	Finland
OP Corporate Bank PLC	Finland
Deutsche Bank AG	Germany
Commerzbank AG	Germany
Bayerische Landesbank	Germany
OTP Bank PLC	Hungary
Bper Banca S.P.A.	Italy
Banca Piccolo Credito Valtellinese	Italy
Banca Carige SPA	Italy
Credito Emiliano SPA	Italy
Siauliu Bankas	Lithuania
DNB Bank ASA	Norway
Sparebank 1 SR-bank ASA	Norway
Sparebanken Vest	Norway
Sparebank 1 SMN	Norway
Sparebank 1 Oestlandet	Norway
Sparebanken SOR	Norway
Sparebank 1 Nord	Norway
Sparebanken Ost	Norway
Helgeland Sparebank	Norway
Fana Sparebank	Norway
Sparebanken Sogn OG Fjordane	Norway
Powszechna Kasa Oszczednosci Bank Polski SA	Poland
Bank Polska Kasa Opieki SA	Poland
ING Bank Slaski SA	Poland
Bank Millennium	Poland
Getin Noble Bank	Poland
Mbank SA	Poland
Nova Ljubljanska Banka D.D.	Slovenia
UBS AG	Switzerland
Credit Suisse Group AG	Switzerland

Note. This table gives a list of all banks used in this paper. Per DiD analysis, the selection of bank differs slightly.

Table 2

Descriptive statistics of the first DiD analysis of the interest variable NPL ratio

Variable	N	Mean	St. Dev.	Min.	Max.
NPL ratio (%)	168	5.876	8.062	0.062	43.419
Liquidity (%)	168	25.899	12.662	9.645	67.205
Capital (%)	168	8.746	5.128	3.423	37.788
Size	168	17.522	1.629	14.504	21.545
Deposit level (%)	168	51.549	0.192	0.006	0.892
GDP level	168	104.481	7.291	86.377	127.623
Unemployment (%)	168	7.526	3.886	3.300	18.700
Inflation (%)	168	0.836	0.776	-0.300	1.900
Herfindahl index	168	0.073	0.023	0.038	0.113

Note. This table gives the summarizing statistics of the data sample collected for the DiD analyses of the effect of the implementation of NIRP on the NPL ratio. This sample is used for the random effects model and a slightly smaller sample taken from this sample is used for the fixed effects model. Most variables are measured in percentages, except Size, GDP level and Herfindahl Index. Size is measured as a natural logarithm, GDP level is an index and the Herfindahl index is measured as a ratio.

Table 3

Descriptive statistics of the first DiD analysis of the interest variable LLP ratio

Variable	N	Mean	St. Dev.	Min.	Max.
LLP ratio (%)	136	0.191	0.301	0.001	1.860
Liquidity (%)	136	25.797	12.963	9.645	67.205
Capital (%)	136	9.214	5.555	3.423	37.788
Size	136	17.551	1.555	14.806	21.545
Deposit level (%)	136	51.458	18.678	0.596	89.169
GDP level	136	103.984	7.192	86.377	124.276
Unemployment (%)	136	7.682	4.107	3.300	18.700
Inflation (%)	136	0.806	0.797	-0.300	1.900
Herfindahl index	136	0.074	0.022	0.038	0.113

Note. This table gives the summarizing statistics of the data sample collected for the DiD analyses of the effect of the implementation of NIRP on the LLP ratio. This sample is used for the random effects model and a slightly smaller sample taken from this sample is used for the fixed effects model. Most variables are measured in percentages, except Size, GDP level and Herfindahl Index. Size is measured as a natural logarithm, GDP level is an index and the Herfindahl index is measured as a ratio.

Table 4

Descriptive statistics of the first DiD analysis of the interest variable Gross Loans ratio

Variable	N	Mean	St. Dev.	Min.	Max.
Gross Loans ratio (%)	180	66.191	16.405	21.380	95.231
Liquidity (%)	180	25.084	12.403	3.521	67.205
Capital (%)	180	8.828	5.103	3.423	37.788
Size	180	17.566	1.653	14.806	21.545
Deposit level (%)	180	49.930	19.629	0.596	89.169
GDP level	180	103.248	8.216	76.828	124.276
Unemployment (%)	180	8.854	5.574	3.300	27.900
Inflation (%)	180	0.713	0.864	-1.400	1.900
Herfindahl index	180	0.071	0.024	0.038	0.113

Note. This table gives the summarizing statistics of the data sample collected for the DiD analyses of the effect of the implementation of NIRP on the Gross Loans ratio. This sample is used for the random effects model and a slightly smaller sample taken from this sample is used for the fixed effects model. Most variables are measured in percentages, except Size, GDP level and Herfindahl Index. Size is measured as a natural logarithm, GDP level is an index and the Herfindahl index is measured as a ratio.

Table 5

Descriptive statistics of the second DiD analysis of the interest variable NPL ratio

Variable	N	Mean	St. Dev.	Min.	Max.
NPL ratio (%)	95	9.535	10.921	0.130	38.546
Liquidity (%)	95	29.904	12.800	10.049	61.192
Capital (%)	95	6.885	2.540	3.734	14.622
Size	95	18.522	1.554	15.936	21.489
Deposit level (%)	95	45.959	18.523	4.170	89.169
GDP level	95	101.617	6.063	87.059	111.280
Unemployment (%)	95	8.839	3.588	4.300	17.700
Inflation (%)	95	0.198	0.672	-1.500	1.500
Herfindahl index	95	0.057	0.018	0.038	0.099

Note. This table gives the summarizing statistics of the data sample collected for the DiD analyses of the effect of the implementation of NIRP and QE on the NPL ratio. This sample is used for the random effects model and a slightly smaller sample taken from this sample is used for the fixed effects model. Most variables are measured in percentages, except Size, GDP level and Herfindahl Index. Size is measured as a natural logarithm, GDP level is an index and the Herfindahl index is measured as a ratio.

Table 6

Descriptive statistics of the second DiD analysis of the interest variable LLP ratio

Variable	N	Mean	St. Dev.	Min.	Max.
LLP ratio (%)	100	0.428	1.423	-0.036	13.860
Liquidity (%)	100	26.992	13.750	4.166	61.192
Capital (%)	100	7.163	2.716	-1.255	14.622
Size	100	17.976	1.675	15.190	21.489
Deposit level (%)	100	49.652	17.785	4.170	89.169
GDP level	100	98.755	9.231	76.697	111.280
Unemployment (%)	100	11.246	6.976	4.300	26.700
Inflation (%)	100	-0.079	0.811	-1.500	1.500
Herfindahl index	100	0.054	0.018	0.038	0.099

Note. This table gives the summarizing statistics of the data sample collected for the DiD analyses of the effect of the implementation of NIRP and QE on the LLP ratio. This sample is used for the random effects model and a slightly smaller sample taken from this sample is used for the fixed effects model. Most variables are measured in percentages, except Size, GDP level and Herfindahl Index. Size is measured as a natural logarithm, GDP level is an index and the Herfindahl index is measured as a ratio.

Table 7

Descriptive statistics of the second DiD analysis of the interest variable Gross Loans ratio

Variable	N	Mean	St. Dev.	Min.	Max.
Gross Loans ratio (%)	170	63.258	19.602	22.187	106.192
Liquidity (%)	170	24.964	13.846	1.239	61.192
Capital (%)	170	6.600	2.460	-1.255	14.622
Size	170	18.157	1.829	13.842	21.489
Deposit level (%)	170	41.080	20.603	0.009	89.169
GDP level	170	99.805	9.052	76.697	111.280
Unemployment (%)	170	10.865	6.802	4.300	26.700
Inflation (%)	170	0.074	0.779	-1.500	1.500
Herfindahl index	170	0.051	0.015	0.038	0.099

Note. This table gives the summarizing statistics of the data sample collected for the DiD analyses of the effect of the implementation of NIRP on the Gross Loans ratio. This sample is used for the random effects model and a slightly smaller sample taken from this sample is used for the fixed effects model. Most variables are measured in percentages, except Size, GDP level and Herfindahl Index. Size is measured as a natural logarithm, GDP level is an index and the Herfindahl index is measured as a ratio.

Table 8

Correlations between the interest variable NPL ratio and the control variables of the first DiD analysis

Variable	Total NPL	Liquidity	Capital	Size	Deposit level	GDP level	Unemplo -yment	Inflat- ion	Herfindahl index
NPL ratio	1.000								
Liquidity	-0.004	1.000							
Capital	0.091	0.332	1.000						
Size	-0.085	0.164	-0.412	1.000					
Deposit level	0.315	-0.261	-0.076	-0.328	1.000				
GDP level	-0.541	-0.195	-0.089	-0.083	0.214	1.000			
Unemployment level	0.706	0.349	0.342	-0.049	0.071	-0.545	1.000		
Inflation	-0.562	-0.387	-0.134	-0.162	-0.234	0.224	-0.796	1.000	
Herfindahl index	-0.336	-0.247	0.203	-0.341	0.377	0.393	-0.530	0.416	1.000

Note. This table represents the correlations between all independent and dependent variables for the DiD analyses of the implementation of NIRP on the NPL ratio. The correlation is 1 if the variables are 100% correlated and 0 if there is no correlation between the variables.

Table 9

Correlations between the interest variable LLP ratio and control variables of the first DiD analysis

Variable	Total LLP	Liquidity	Capital	Size	Deposit level	GDP level	Unemplo -yment	Inflat- ion	Herfindahl index
LLP ratio	1.000								
Liquidity	0.081	1.000							
Capital	0.069	0.378	1.000						
Size	-0.110	0.075	-0.449	1.000					
Deposit level	0.326	-0.187	-0.131	-0.215	1.000				
GDP level	-0.407	-0.137	-0.089	0.065	0.100	1.000			
Unemployment level	0.546	0.377	0.353	-0.060	0.036	-0.645	1.000		
Inflation	-0.472	-0.418	-0.108	-0.216	-0.164	0.329	-0.813	1.000	
Herfindahl index	-0.257	-0.223	0.178	-0.318	0.344	0.512	-0.580	0.521	1.000

Note. This table represents the correlations between all independent and dependent variables for the DiD analyses of the implementation of NIRP on the LLP ratio. The correlation is 1 if the variables are 100% correlated and 0 if there is no correlation between the variables.

Table 10

Correlations between the interest variable Gross Loans ratio and control variables of the first DiD analysis

Variable	Growth gross loans	Liquidity	Capital	Size	Deposit level	GDP level	Unemplo -yment	Inflat- ion	Herfindahl index
Gross Loans ratio	1.000								
Liquidity	-0.765	1.000							
Capital	0.011	0.320	1.000						
Size	-0.525	0.095	-0.357	1.000					
Deposit level	0.235	-0.147	-0.001	-0.128	1.000				
GDP level	-0.181	0.079	-0.080	0.105	-0.080	1.000			
Unemployment level	0.185	0.047	0.305	-0.111	0.345	-0.626	1.000		
Inflation	0.033	-0.217	-0.159	-0.063	-0.363	0.477	-0.863	1.000	
Herfindahl index	0.266	-0.122	0.210	-0.371	0.237	0.459	-0.402	0.398	1.000

Note. This table represents the correlations between all independent and dependent variables for the DiD analyses of the implementation of NIRP on the Gross Loans ratio. The correlation is 1 if the variables are 100% correlated and 0 if there is no correlation between the variables.

Table 11

Correlations between the interest variable NPL ratio and the control variables of the second DiD analysis

Variable	Total NPL	Liquidity	Capital	Size	Deposit level	GDP level	Unemplo -yment	Inflat- ion	Herfindahl index
NPL ratio	1.000								
Liquidity	-0.239	1.000							
Capital	0.765	-0.197	1.000						
Size	-0.681	-0.066	-0.685	1.000					
Deposit level	0.680	0.042	0.561	-0.534	1.000				
GDP level	-0.766	0.197	-0.532	0.632	-0.412	1.000			
Unemployment level	-0.816	-0.197	0.562	-0.669	0.443	-0.932	1.000		
Inflation	-0.600	-0.100	-0.454	0.445	-0.275	0.541	-0.592	1.000	
Herfindahl index	-0.119	-0.011	0.115	0.044	0.242	0.344	-0.387	0.248	1.000

Note. This table represents the correlations between all independent and dependent variables for the DiD analyses of the implementation of NIRP and QE on the Gross Loans ratio. The correlation is 1 if the variables are 100% correlated and 0 if there is no correlation between the variables.

Table 12

Correlations between the interest variable LLP ratio and the control variables of the second DiD analysis

Variable	Total LLP	Liquidity	Capital	Size	Deposit level	GDP level	Unemplo -yment	Inflat- ion	Herfindahl index
LLP ratio	1.000								
Liquidity	-0.284	1.000							
Capital	-0.215	-0.155	1.000						
Size	-0.238	0.196	-0.327	1.000					
Deposit level	0.206	-0.034	0.369	-0.478	1.000				
GDP level	-0.368	0.516	-0.330	0.526	-0.442	1.000			
Unemployment level	0.386	-0.522	0.287	-0.493	0.413	-0.967	1.000		
Inflation	-0.252	-0.180	-0.317	0.302	-0.323	0.680	-0.720	1.000	
Herfindahl index	-0.149	0.209	0.076	0.187	0.100	0.459	-0.477	0.346	1.000

Note. This table represents the correlations between all independent and dependent variables for the DiD analyses of the implementation of NIRP and QE on the Gross Loans ratio. The correlation is 1 if the variables are 100% correlated and 0 if there is no correlation between the variables.

Table 13

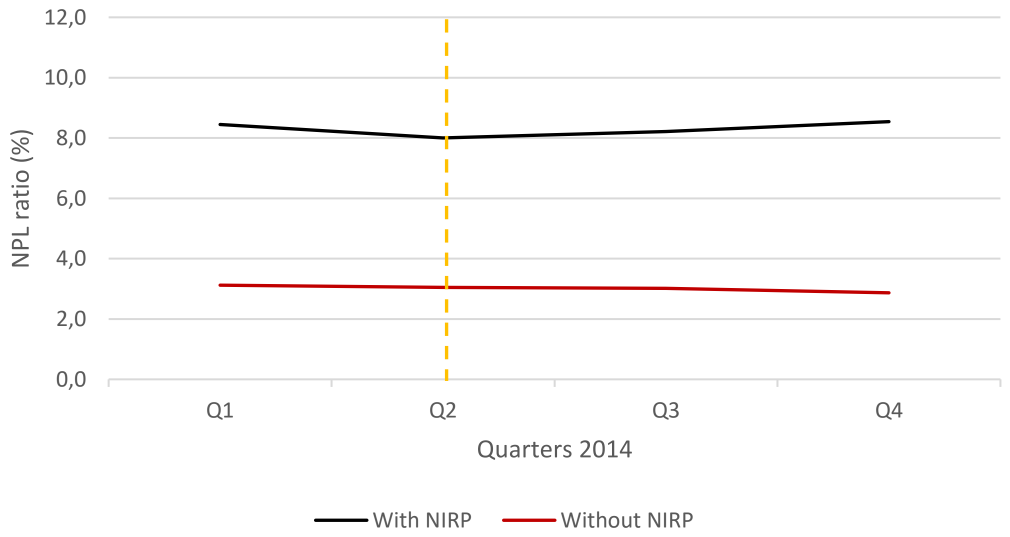
Correlations between the interest variable Gross Loans ratio and the control variables of the second DiD analysis

Variable	Growth gross loans	Liquidity	Capital	Size	Deposit level	GDP level	Unemplo -yment	Inflat-ion	Herfindahl index
Gross Loans ratio	1.000								
Liquidity	-0.800	1.000							
Capital	0.199	-0.093	1.000						
Size	-0.627	0.405	-0.222	1.000					
Deposit level	-0.021	0.162	0.433	0.065	1.000				
GDP level	-0.411	0.369	-0.410	0.237	-0.455	1.000			
Unemployment level	0.482	-0.448	0.372	-0.299	0.375	-0.953	1.000		
Inflation	-0.313	0.229	-0.414	0.256	-0.378	0.787	-0.814	1.000	
Herfindahl index	-0.028	0.093	0.123	0.023	0.164	0.304	-0.323	0.243	1.000

Note. This table represents the correlations between all independent and dependent variables for the DiD analyses of the implementation of NIRP on the Gross Loans ratio. The correlation is 1 if the variables are 100% correlated and 0 if there is no correlation between the variables.

Figure 2

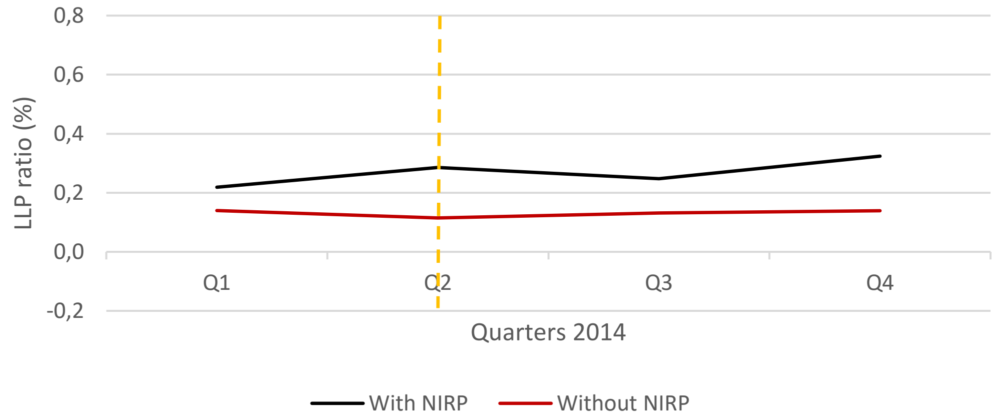
Visual assessment of parallel trends assumption for the first DiD analysis of the implementation of NIRP on the NPL ratio



Note. This figure shows the trends of the NPL ratios of the treated and untreated banks as a visual assessment of parallel trends. The parallel trends assumption implies that there should be similar trends visible before the implementation of NIRP, which is indicated by the yellow line.

Figure 3

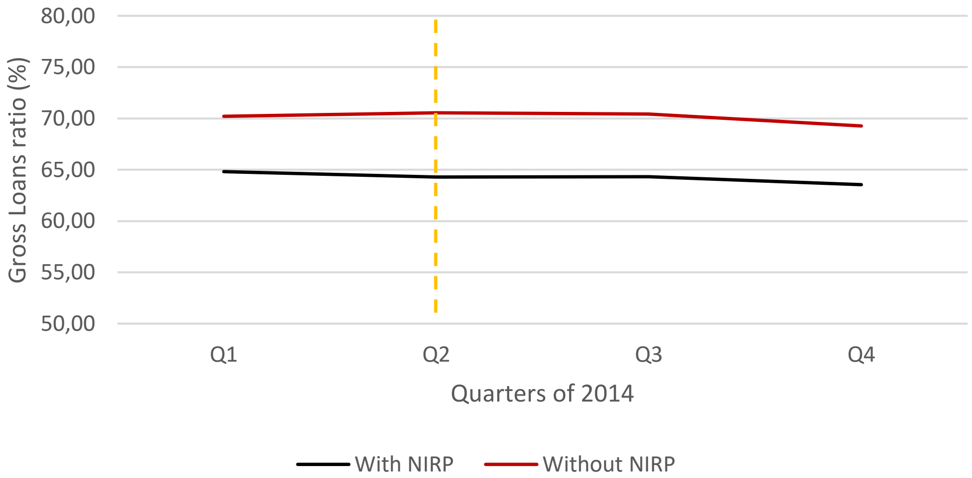
Visual assessment of parallel trends assumption for the first DiD analysis of the implementation of NIRP on the LLP ratio



Note. This figure shows the trends of the LLP ratios of the treated and untreated banks as a visual assessment of parallel trends. The parallel trends assumption implies that there should be similar trends visible before the implementation of NIRP, which is indicated by the yellow line.

Figure 4

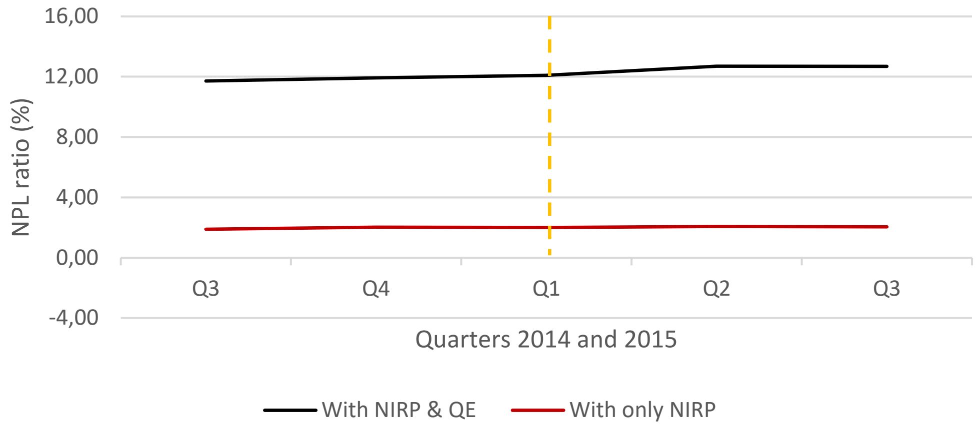
Visual assessment of parallel trends assumption for the first DiD analysis of the implementation of NIRP on the Gross Loans ratio



Note. This figure shows the trends of the Gross loans ratios of the treated and untreated banks as a visual assessment of parallel trends. The parallel trends assumption implies that there should be similar trends visible before the implementation of NIRP, which is indicated by the yellow line.

Figure 5

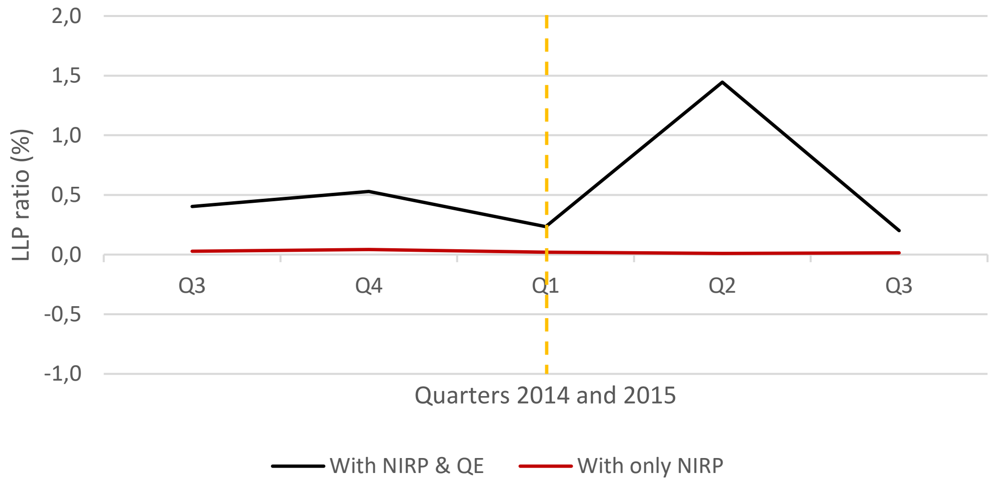
Visual assessment of parallel trends assumption for the second DiD analysis of the implementation of NIRP and QE on the NPL ratio



Note. This figure shows the trends of the NPL ratios of the treated and untreated banks as a visual assessment of parallel trends. The parallel trends assumption implies that there should be similar trends visible before the implementation of NIRP and QE, which is indicated by the yellow line.

Figure 6

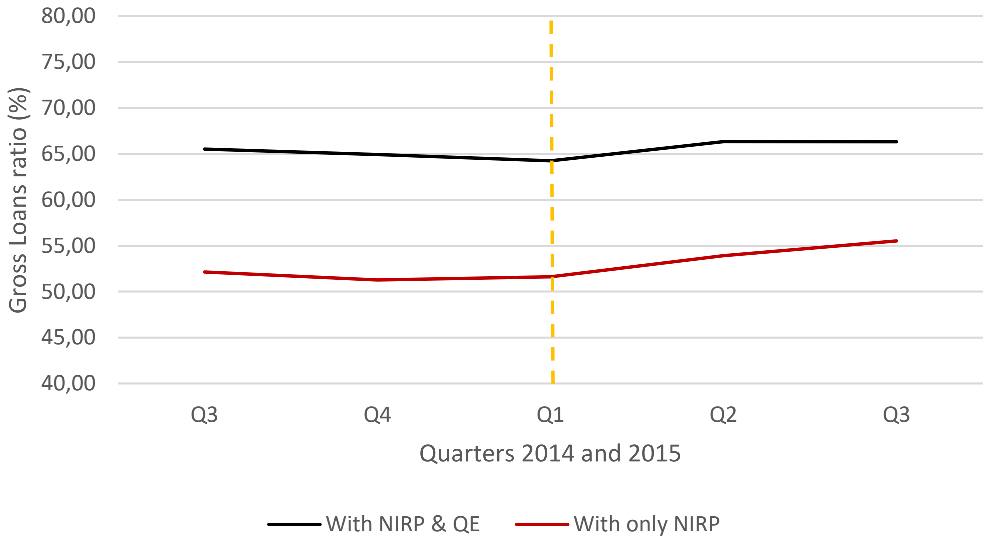
Visual assessment of parallel trends assumption for the second DiD analysis of the implementation of NIRP and QE on the LLP ratio



Note. This figure shows the trends of the LLP ratios of the treated and untreated banks as a visual assessment of parallel trends. The parallel trends assumption implies that there should be similar trends visible before the implementation of NIRP and QE, which is indicated by the yellow line.

Figure 7

Visual assessment of parallel trends assumption for the second DiD analysis of the implementation of NIRP and QE on the Gross Loans ratio



Note. This figure shows the trends of the Gross loans ratios of the treated and untreated banks as a visual assessment of parallel trends. The parallel trends assumption implies that there should be similar trends visible before the implementation of NIRP and QE, which is indicated by the yellow line.