Negative Monetary Policy Rates and Systemic Banks' Risk-Taking: Evidence from the Euro Area Securities Register*

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Preliminary draft

Abstract

We show that negative monetary policy rates affect the securities portfolio of large, systemic banks. For identification, we exploit the introduction of negative deposit rates by the ECB in June 2014 in conjunction with a novel, securities register for the 26 biggest euro area banking groups. Overall, the size of the security portfolios of the large euro area banks declined in the aftermath of the introduction of negative policy rates. Banks that are more reliant on customer deposits are more affected by negative rates, as these banks do not pass the negative rates to their customers. Affected banks retained assets yielding higher returns compared to the other banks. This result holds when controlling for security risk characteristics, like maturity and ratings, which are the main determinants of capital regulation, and security and bank fixed effects. Affected banks reach-for-yield via investment in securities issued by the private sector (financial and non-financial) and by issuers residing in the euro area and in other developed countries. Along the currency dimension, affected banks increase holdings of securities issued in US dollars paying higher yields. The overall asset concentration of these large banks decreases, though part of this diversification generates real effects outside the euro area. Finally, banks more reliant on deposits also grant more syndicated loans to ex-ante riskier borrowers.

Keywords: Negative policy rates, non-standard monetary policy, search for yield, banks.

JEL Codes: E43, E52, G01, G21, G11.

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1 Introduction

Central banks have implemented a series of unconventional monetary policies during the last decade. An important difference in the implementation of monetary policy between the euro area and the US has been the use of negative policy rates. The Federal Reserve in particular (and also the Bank of England) have been somewhat critical of the use of negative rates (see Bernanke, 2016). In the euro area, however, negative policy rates were introduced by the ECB in June 2014, when the deposit rate for commercial banks with an account at the central bank was lowered to -10 basis points. Negative rates have also been introduced by the central banks in several countries (Japan, Denmark, Sweden and Switzerland), therefore they currently represent an important policy tool. Given the current low level of policy rates, negative rates may be even become more important in the future. Thus, a key question for academic researchers and policy makers is what the effects of negative policy rates are for banks? There is evidence that, at least in the medium term, banks do not pass through the negative rates to their depositors, in particular to retail customers. This in turns lowers bank net worth and increase risk-taking (search for yield) incentives.[1] Given the importance of banks as financial intermediaries in several regions of the world (e.g. the euro area is a bank dominated economy), there might be important aggregate consequences for the economy from the introduction of negative rates.

The transmission of monetary policy at the "zero lower bound" and below has become a topic of particular interest for researchers and policy makers since several central banks have chosen this path in the last few years (Brunnermeier and Koby, 2017; Eisenschmidt and Smets, 2018). There is also a very recent literature assessing how negative policy rates (NPR) are transmitted through the banking sector and how they affect credit supply to the economy and the equity valuations of banks (see for example Ampudia and Van den Heuvel, 2018; Basten and Mariathasan, 2018; Heider, Saidi, and Schepens, 2019). However, to the best of our knowledge, ours is the first paper to analyze how negative policy rates affect investment choices in the securities portfolios of banks.

Securities holdings are an important fraction of bank balance sheets. On average they account for around 20% of total banking assets in the US and Europe. There are important financial stability considerations arising from securities portfolios and indeed recent policy initiatives aimed at limiting securities trading by banks (e.g. the Volcker Rule in the Dodd-Frank Act in the US, the Liikanen Report in the EU and the Vickers report in the UK). This also takes into consideration that banks may engage in risk-taking more easily through adjustments of the liquid securities holdings rather than the rather illiquid loan portfolio (Myers and Rajan, 1998). Furthermore, the euro area sovereign crisis has shown the vicious cycle arising from banks' holdings of sovereign debt during periods of market stress, and the risks associated with the so-called sovereign-bank nexus (Acharya and Steffen, 2015; Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh, and Vayanos, 2016).

[1]Low interest rates may also drive reach-for-yield behaviour by financial intermediaries (Rajan, 2005; Taylor, 2009; Allen and Rogoff, 2011; Martinez-Miera and Repullo, 2017), consistent with a risk-taking channel of monetary policy (Adrian and Shin, 2010; Borio and Zhu, 2012)

In this context, finding evidence of *search for yield* is especially challenging, as it requires to observe micro-level information on the riskiness of all securities, e.g. the yield or the rating of a security. Access to comprehensive, granular banking data is thus crucial to identify phenomena of 'reach for yield'. The security register that we use in this analysis contains — at the security (ISIN) level – all securities investments of each of the 26 largest banking groups in the euro area (it does include but it is not limited to government bonds, or to securities that banks pledge as collateral to borrow liquidity from the ECB). We restrict the analysis to the holdings of debt securities. The overall holdings are around 3 trillion euros. For each security we have information on yield, issuer, ratings, price and remaining maturity. In particular we observe, even within the same issuer (like a sovereign), all the different securities with different yields and maturities held by the banks in each quarter. For the sake of completeness, we also analyse (syndicated) loans for the 26 banking groups.

A reduction in the policy rate transmits to short-term rates first. Since banks tend to have long-term assets and shorter-term liabilities on their balance sheets, a rate cut should result in an increase in bank net worth. This is based on the assumption that banks can immediately pass-through the rate cut on their liability side — and therefore fund themselves at lower rates, while the asset side remains largely unaffected at first – leading to an increase in the value difference between assets and liabilities, and hence in the net worth of banks. This should relax financial constraints and possibly increase lending and investment in securities. However, negative rates may result in a somewhat different outcome since banks may be unwilling to pass-through negative rates to their retail customer depositors – fearing the withdrawal of deposits. Therefore, the degree to which banks are affected by the introduction of negative rates depends on their funding structure. A cut that brings policy rates into negative territory should have a stronger positive effect on the net worth of banks largely funded by wholesale debt, as opposed to retail customer deposits. Similarly, operating in a negative interest rate environment is likely to put negative pressure on the net worth of banks with a high customer deposit ratio, and could even induce a *reversal rate* such that lower monetary rates could become contractionary, rather than expansive, for banks (see Brunnermeier and Koby, 2017; Eggertsson, Juelsrud, Summers, and Wold, 2019). Banks more negatively affected (lower net worth due to reliance on customer deposits) may take risk by reaching for higher yield (Freixas and Rochet, 2008; Heider et al., 2019). Hence the intensity of the treatment that is induced by the introduction of negative policy rates varies across banks with the degree to which they are funded by retail deposits. This enables us to identify the effect of negative interest rates on the securities holdings of banks.

Both the supply and the demand of securities should respond to changes in policy rates. We use a differences-in-differences specification in order to analyze how the holdings of a particular security change in response to the introduction of negative policy rates, differentiating between high-deposit ratio banks and low-deposit ratio banks. We argue that banks with different deposit ratios are affected differently when policy rates reach negative territory and this provides a way to identify the effects of negative policy rates on the security portfolio from other forces that shape both monetary policy and the investment behaviour of large euro area banks (Heider et al., 2019).

We use a difference-in-differences specification to analyze how the holdings of a particular security change in response to the introduction of negative policy rates, differentiating between high-deposit ratio banks and low-deposit ratio banks. We exploit the data on securities holdings in Q4 2013 – Q1 2014 for the pre-NPR (negative policy rates) period and Q2 2014–Q4 2014 for the post-NPR period. We end the analysis in Q4 2014 because the implementation of the asset purchase program of the ECB (the PSPP program started in January 2015) is likely to confound our results. We analyse the data at the security-bank-quarter level. This allows us to: (1) test whether the reaction to the introduction of negative policy rates differs with certain (observed) bank characteristics controlling for unobserved bank heterogeneity; (2) control for unobserved security characteristics that affect the supply of a particular security via security (or other related) fixed effects (e.g. issuance of some securities); and (3) identify search for yield, in particular whether banks with different characteristics (deposit ratio) change their holdings of securities with different ex-ante yields. We analyse the data in a cross-section comparing the period before and after the introduction of negative policy rates (identifying the post dummy on banks with different deposit ratios). We also analyse in a panel quarter by quarter to check the parallel trend assumption (i.e., we allow each estimated quarter to have a different effect).

Our robust results suggest that the introduction of negative policy rates induced overall a deleveraging of the securities portfolio of the large euro area banking groups. More importantly, negative policy rates led to search for yield behaviour in the securities portfolio of more exposed banks. Banks more reliant ex-ante on customer deposits retained in their securities portfolio assets yielding ex-ante higher yields compared to the other banks, also when controlling for security risk characteristics, like maturity and ratings, which are the main determinants of capital regulation, or even security fixed effects. We find no evidence of a similar relationship in the period before the introduction of negative rates. Before the introduction of negative rates, the response of banks' portfolios to changes in security yields for different levels of deposit ratio would not differ. Overall the economic effects are significant: a difference in the deposit ratio of 10% (approximately one standard deviation) would imply a 2 percentage points increase in the sensitivity of holdings of a particular security in response to a 1% change in the adjusted current yield.

We then analyze how more affected banks take on higher risk. The analysis of portfolio among different asset classes shows that these reach for yield effects are confined to holdings of debt securities issued by private firms, financial and non-financial, including ABS. Effects are not economically and statistically significant for public debt (for ABS, estimated effects are large, though the standard errors increase substantially for this asset class). Moreover, effects are also strong for securities issued in the euro area and in other developed economies, while there are no significant effects on the holdings of securities issued in emerging markets, suggesting that portfolio rebalancing was only confined to developed economies. As regards to currency, the more affected banks reshuffled their portfolio towards securities issued in US dollar. Overall, we also find that the securities concentration across all banks decreases after the introduction of negative rates (thus potentially reducing systemic risk), but this diversification is in part achieved via increasing the exposure to non-euro area securities, which suggests that some positive real effects take place outside the euro area. Finally, our results suggest that more exposed banks increase their risk also in loans, therefore reach for yield takes place in both securities and loans.

Our main contribution is to the growing literature on the impact of non-standard monetary policy measures. Despite a substantial large number of empirical studies on quantitative easing, lending policies by central banks (such as e.g. LTROs and TLTROs) and forward guidance, there is substantially less evidence on negative rates, which is a more unique and special policy. To the best of our knowledge, this is the first paper to show how negative policy rates affect the securities portfolios of banks. We exploit a new, administrative dataset on the securities holdings of the very large euro area banks.As mentioned above, analyzing risk-taking in securities is particularly important for policy makers concerned for financial stability (see e.g. also the Volcker Rule) as reaching for yield through changes in securities holdings can be easier and faster for banks rather than through changes in their loan portfolio (Myers and Rajan, 1998). Securities represent around 20% of banks' assets (3 trillion euros in our sample), and in Europe the holdings of sovereign debt in particular has reinforced the *diabolic loop* between sovereign debt and banks.

Our results are complementary to the results found by Heider et al. (2019). We broadly share their identification strategy, based on the banks' reliance on deposits. They look at the risk profile of the syndicated loan portfolio of banks during the period of the introduction of negative interest rates and disentangle bank specific determinants using different banks within a loan syndicate (see also Aramonte et al., 2015). They analyze the impact of negative policy rates on the loan supply provided by banks and show that banks with more deposits tend to lend less and to riskier borrowers. Using loans provided to the same firm by different banks and a differences-in-differences strategy via the deposit ratio Schelling and Towbin (2018) find that banks with a lot of deposits offer more generous lending terms in order to capture market shares. We provide complementary evidence to these studies based on the analysis of holdings in the securities portfolio of banks and in particular of different banks holding the same security. Taken together, the results in these studies suggest that banks that are more affected by negative policy rates through the negative impact on profit margins increase their risk in both their loans and securities portfolios. In the last part of the paper, we also run a robustness analysis using syndicated lending data for the banks in our sample, and we find evidence of reach for yield in both securities and loans for the 26 largest euro banks, which are the most important banks for systemic risk.

Abbassi et al. (2016) find evidence of search for yield behaviour for a sample of German banks in response to the shock of the bankruptcy of Lehman Brothers. Banks with higher trading expertise increased their investments in securities, especially in low-rated and long-term securities. At the same time, these banks reduced their credit supply, suggesting a substitution from loans to securities yielding higher returns. Our results also complement these findings, since we find evidence related to banks' portfolio holdings for the euro area that can be related to changes in monetary policy, as opposed to the financial crisis. Our work is close in spirit also to the analysis of Koijen et al. (2018) which use a security- level dataset on holdings for euro area sectors (e.g. the holdings for all banks). We use the holdings of a limited sample of euro area banks (albeit covering a large majority of the assets of the euro area banking sector), but we can disentangle the holdings at the level of a single banking group.

Our study is also related to the analysis of Demiralp et al. (2017), who assess the impact of negative policy rates on lending volumes and holdings of government bonds. Their identification strategy is based on banks' excess liquidity deposited at the ECB. They find that more exposed banks increase their overall holdings of non-domestic government bonds: however their dataset does not have the granularity to control for the risk at the security level nor the exhaustive analysis of heterogeneous effects across different securities with different risk level (i.e., we exploit a securities register). In our sample we do not find significant effects for sovereign bonds. Using a similar identification strategy — central bank reserves at the Swiss National Bank – Basten and Mariathasan (2018) show that, in aggregate, more affected banks are lending more and invest more in financial assets. However, also in their study, they cannot control for the borrower and/or the security-level risk, which is important for identification. Arce, Garcia-Posada, Mayordomo, and Ongena (2018) rely on bank's ex-post self-reports of the degree to which negative interest rates affect their net income for identification of the effects of negative interest rates on credit. They use banks that report their profits to be unaffected by negative policy rates as the control group in a differences-in-differences analysis on the bank- and (non-syndicated) loan-level. Finally, Bottero, Minoiu, Peydró, Polo, Presbitero, and Sette (2019), exploiting administrative data from Italy, find that negative rates have expansionary effects on credit supply (and the real economy) through a portfolio rebalancing channel, rather than a deposit channel. Differently to all the papers mentioned above, we analyze the securities portfolio and the largest euro area banks.

Ampudia and Van den Heuvel (2018) look at the effects of ECB monetary policy announcements on bank equity, measured by a bank's stock market capitalization, including during periods of low interest rates. They find that when interest rates are positive, an unexpected decrease in policy rates raises bank equity – as in English, Van den Heuvel, and Zakrajšek (2018). However, when rates are negative, the impact can be reversed and further rate cuts lower bank equity, a result consistent in spirit with the notion of a reversal rate as in Brunnermeier and Koby (2017). Moreover, Altavilla, Boucinha, and Peydró (2018) analyse the impact of standard and non-standard monetary policy on bank profitability. They find that a monetary policy easing (a decrease in short-term interest rates and/or a flattening of the yield curve) is not associated with lower bank profits once they control for the endogeneity of the policy measures to expected macroeconomic and financial conditions, though accommodative monetary conditions asymmetrically affect the main components of bank profitability. Differently to these papers, we analyze security-level data.

Finally, we corroborate some of the findings by Peydro, Polo, and Sette (2017). Using the Italian security register during the recent crisis period, but before the introduction of negative rates, they show that in response to a monetary policy loosening bank risk-taking is proportional to a particular bank's risk-bearing capacity (i.e. bank leverage) – a result inconsistent with the risk-shifting hypothesis which would apply to banks with low levels of capital (gambling for resurrection). We confirm their findings for the period in which negative policy rates were introduced by the ECB, showing that this relationship holds for a sample of banks incorporated in both core and periphery euro area countries.

2 Data and Empirical Strategy

The main database used in the analysis is the new Securities Holdings Statistics by Group (SHSG) database of the Eurosystem. The database contains security-level information on the securities portfolios of 26 reporting banking groups in the euro area (see Annex 1 for a list of the banking groups in the sample), which overall covers the large majority of the euro area banking sector in terms of financial assets. Data are collected on a quarterly basis since 2013Q4.

The SHSG database provides information on holdings at the security level as identified by the International Securities Identification Number (ISIN). For the purpose of the analysis in this paper, we focus on the portfolio of debt securities (both short-term and long-term) and enrich the database with security level information from the Eurosystem Centralised Securities Database (CSDB) – like rating and maturity.[2] Data on banks' balance sheets are from SNL Financials.

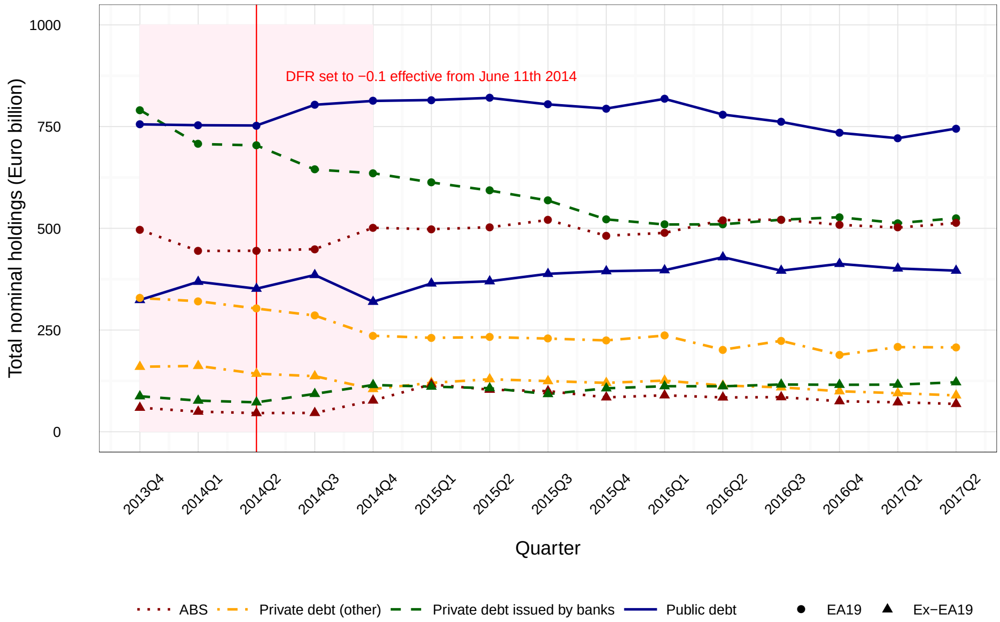
Using information on the issuer of the debt securities, we classify the assets in four broad categories. Securities are classified as Public Debt if they are issued by the sectors "General Government" and "Central Bank" as well as by certain supranational institutions such as the European Investment Bank (EIB) or the European Stability Mechanism (ESM). Securities from private issuers are grouped into three distinct categories. Securities issued by "Deposit-taking corporations except the central bank" are classified as "Private debt issued by banks". "Asset backed securities (ABS)" includes different types of securitized debt securities: covered bonds, MBS, Pfandbrief, CDOs and other ABS. The asset class "Private debt (other)" is a residual category and includes debt issued by Financial Corporations other than banks and by the corporate sector. Figure 1 shows the evolution of total nominal holdings for the four asset classes considered over the period following the introduction of negative policy rates.

Figure 1 shows the nominal holdings of the different classes of securities in the SHSG database. The figure shows nominal holdings in euro but it also includes securities issued in other currencies. The shaded area represents the time frame considered in our analysis (2013Q4 to 2014Q4). Overall, we see that during this period there was a broad disinvestment from debt securities issued by euro area banks and other private issuers, while there were rather stable patterns with respect to public debt securities and asset backed securities (ABS). Additionally, Figure B.12 in the Appendix shows the market values of the securities portfolio of banks across the time period considered in our analysis.

Policy rates in the euro area moved into negative territory in June 2014, when the ECB lowered the deposit facility rate to -0.10%. Three further reductions in the policy rate brought the rate on the deposit facility to -0.40% by March 2016 (see Figure B.13 in the Appendix for the evolution of the policy rates in the euro area). These policy actions were aimed at incentivising bank lending in the interbank market while preserving the difference between the cost of borrowing from the ECB (at the Main Refinancing Operation, MRO, rate) and the cost

[2]The percentage of securities portfolio invested in equities is below 5% for the banking groups in our sample.

Figure 1: Evolution of the holdings of debt securities by the 26 reporting banking groups



of depositing liquidity to the ECB (in excess of reserve requirements). In the current economic and institutional environment in the euro area, where central bank liquidity is allocated on a full allotment basis and a series of non-standard monetary policy actions are in place, commercial banks hold in aggregate excess liquidity at the central bank, i.e. more liquidity than what they need in order to fulfil reserve requirements. The deposit facility rate has therefore become the relevant policy rate in the euro area (see Heider et al. (2019) for a detailed discussion of the policy actions of the ECB during the period that we consider).

The ECB deposit facility rate was set to -0.10% effective from June 11th 2014. We classify the period Q4 2013 – Q1 2014 as the pre-NPR period and Q2 2014 – Q4 2014 as the post-NPR period. We stop our analysis at the end of 2014 so that we can interpret our findings as resulting from the introduction of negative policy rates, and we exclude the following period when the ECB announced and then implemented the expanded Asset Purchase Programme (APP).[3] Heider et al. (2019) perform their analysis until the end of 2015 and run robustness checks for the sub period of 2014. We chose to stop our analysis at the end of 2014 because extending the time period further would overlap with the period in which central bank asset purchases were carried out. Obviously this policy action has a direct impact on the securities portfolio and may have affected banks differently, depending on their ex-ante securities allocation, possibly confounding our results. Both the pre-NPR and the post-NPR periods are highlighted in light red in Figure 1, while the red vertical line indicates the start of the post-NPR period.

[3]During the period that we consider there were other measures of non-conventional monetary policy that were undertaken. In June 2014 the ECB announced the two targeted longer-term refinancing operations (TLTRO) with allotments taking place in September 2014 and December 2014. Heider et al. (2019) argue that there were significant substitution effects with respect to other types of central bank funding and the 2011 and 2012 LTROs. It is not clear ex-ante, why the TLTRO take-up would differ across large banks with different deposit ratios and therefore affect the results of our analysis. Bottero et al. (2019) construct a bank-level measures of borrowing capacity and show that it does not affect changes in loan supply immediately after the introduction of negative rates.

2.1 Empirical Strategy

There is a wide literature on the impact of policy rates on banks' investment. Lower policy rates decrease the cost of funding of the banks and this generally translates in higher bank net worth, because of the maturity transformation operated by banks (see for example Dell'Ariccia et al., 2014). However, negative policy rates add an additional dimension to the analysis, because deposit rates are sticky when reaching the zero lower bound and therefore negative deposit rates are not immediately passed-through.

Our main identification argument is based on the limited pass-through of negative policy rates to the rates paid on bank deposits of households and firms. For systematic evidence on this, we refer to Heider et al. (2019) as well as Eisenschmidt and Smets (2018). Figure B.14 in the Appendix shows that the average deposit rates paid on deposits of households and firms in the euro area remained positive even after the introduction of negative policy rates.[4]

Banks may be reluctant to charge negative rates to depositors for several reasons, at least over shorter horizons. Indeed, banks may not want to jeopardize long-term customer relationships, and depositors can just decide to hold currency and/or move deposit to another bank that doesn't charge negative rates. This seems to be especially true for retail deposits that are typically smaller in size. There may also be legal constraints in charging negative deposit rates, due to the institutional setting of some deposit-taking corporations (like cooperative banks for example).

At the same time, the rate on overnight interbank lending in the euro area — EONIA – turned negative during the 3rd quarter of 2014. Therefore, the ability of banks to pass-through negative interest rates depended on the composition of their liabilities and in particular on the relative importance of deposit funding. Figure 2 shows that the large euro area banks in our sample fund between 20% and 60% of their balance sheet via customer deposits. It is remarkable that there is an ample variation in terms of deposit ratios even across this limited set of large banking groups.

Negative rates may affect negatively profitability by compressing margins. This may induce these same banks to invest in higher yielding assets in order to make up for the losses in profitability – i.e. *search for yield*. We investigate if banks with a larger deposit base are systematically investing in higher yielding securities.

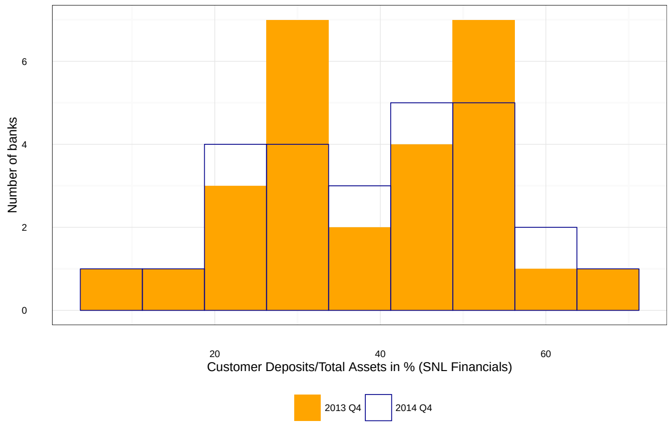
The benchmark specification that we consider has the following form:

$$ln(holdings)_{ijt} = \beta_0 \times Post_t \times Deposit\_ratio_{jt} \times ACY_{it} + \beta_1 X_{ijt} + \mu_j + \eta_\diamond + \varepsilon_{ijt}$$

The dependent variable is the holdings of the security i, held by banking group j at time t. $Deposit\_ratio_{jt}$ is the ratio of customer deposits over total assets. $Post_t$ is a dummy variable equal to one for the period June 2014 onwards. The vector X_{ijt} contains control variables and their interactions with our variables of interest. We include the log of total assets and the ratio of equity over total assets (i.e. the leverage ratio of the bank) as controls. The fixed

[4]Eisenschmidt and Smets (2018) show that by the end of 2016, in some core European countries, banks started to charge negative deposit rates but only to corporations (-0.02% on average as of July 2017 in Germany for example), while rates for households deposits remained positive. This suggests that eventually the pass-through of negative rates takes place, but it is more sluggish than with positive rates and it may affect only some customers.

Figure 2: Distribution of the deposit ratio pre-NPR vs. post-NPR



Source: SNL Financials

effects term $\eta_\diamond$ includes bank fixed effects in all specifications. We add time, security and maturity-rating-time fixed effects in some of the specifications. In all our specifications we cluster standard errors at the bank- and the security-level.

We employ fixed effects in order to control for the factors that can explain banks' portfolio investment in certain securities, such as regulatory pressures, strategic buying opportunities or the need to raise funding. A major development in the regulatory landscape during the period that we analyze was the implementation of the Single Supervisory Mechanism (SSM) in the euro area and the transfer of the direct supervision of large euro area banks from the national supervisory authorities to the ECB. All the banks in our sample were affected by this change and their direct supervision was transferred from the national competent (supervisory) authorities to the SSM.[5]

The analysis is based on a differences-in-differences estimation where we capture the effect of monetary policy through a dummy variable that equals 1 when policy rates are below 0. Figure B.13 in the Appendix shows the evolution of the ECB Marginal Lending Facility (MLF) rate, the ECB Main Refinancing Operations Rate (MRO) rate, the ECB Deposit Facility (DF) rate, and the Euro Overnight Index Average (EONIA) rate between January 2012 and July 2016. The vertical line indicates the date of June 11th 2014, the day the DF rate was set below zero.

To compare investment in financial assets with different yield patterns, we use the adjusted current yield (ACY) measure as in Abbassi et al. (2016). Differences in risk can explain differences in the ACY of otherwise similar securities. In the SHSG database the banking

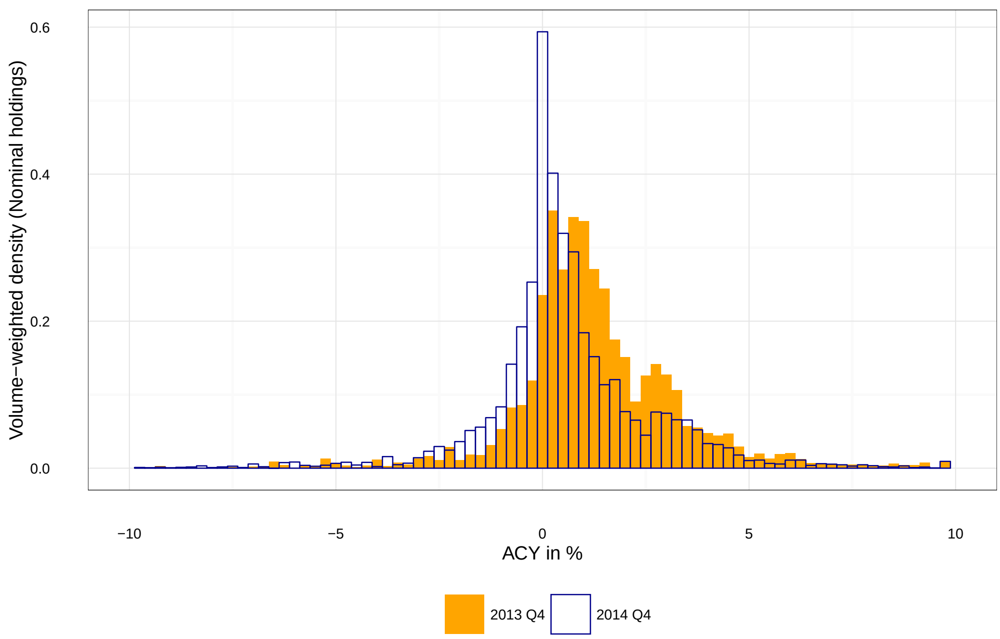
[5]The SSM became operational in November 2014, but preparatory work was well undergoing during the period of time that we analyse. Similarly, other regulatory measures were being implemented, in particular the Liquidity Coverage Ratio (LCR), that came into effect in October 2015. Our results may be affected by these developments as long as changes in regulation would have a differential impact across banks with high- and low deposit ratios during our estimation window in the years 2013-2014. Concerning in particular the LCR, it could be argued that the LCR could have created incentives to invest in high quality liquid assets, yielding lower returns, as opposed to riskier and higher yielding securities.

groups report the value of their holdings both in nominal terms and valued at market prices[6] along with the number of securities held at the end of the quarter.[7] We compute the ACY of security i as using the pricing information of bank j as:

$$\text{ACY}_{it} = 100 \cdot \frac{\text{coupon}_i[\% \text{ ann.}]}{\text{price}_{it}} + \frac{100 - \text{price}_{it}}{\text{residual\_maturity}_{it}/365}$$

Figure 3 shows how the overall distribution of the ACY (weighted by the nominal holding amount) for the securities portfolios in our sample changed between Q4 2013 (the beginning of our sample) and Q4 2014 (the end of our sample period). In between the two periods the cross-sectional distribution shifts to the left, also as a result of lower interest rates. Therefore at the end of 2014 a large fraction of the securities portfolios of the largest euro area banks was yielding a negative return.[8] We are interested in exploring changes in the composition of the portfolio that may have been spurred by negative policy rates. The question that we would like to answer is: If the return of the overall security portfolio declined due to the implementation of negative rates, did banks increase their relative exposure to certain (high-yielding) securities?

Figure 3: Distribution of ACY pre-NPR vs. post-NPR



Source: Authors' calculations, SHSG database

We include in the sample all securities with a nominal holding amount that at some point exceeded 0.5 million euro, summing up the holdings of the 26 reporting banking groups. Fur-

[6]See also Table 2 in "Who holds what – new information on securities holdings" (ECB Economic Bulletin, Issue 2/2015, p. 75).

[7]In order to obtain prices for all securities in our database we rely on this information as opposed to using external sources. We compute the prices by dividing the reported market value of the holdings of a certain ISIN by the number of securities that the bank holds. The information on coupon rates and residual maturities is obtained from the Centralised Securities Database (CSDB) of the Eurosystem.

[8]Please note that the ACY values securities at current market prices. Banks do not necessarily incur losses on their holdings at negative values of the ACY, e.g. since securities may have been bought earlier at different prices.

Table 1: Summary Statistics of the main variables of interest Q4 2013 – Q4 2014

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
ACY	454,534	0.979	4.008	-29.75	14.47
Equity/TA in % (from SNL)	453,144	4.812	1.156	3.109	8.167
Customer deposits / Assets in % (from SNL)	453,144	35.25	13.39	9.943	85.68
Total assets (ln)	453,144	27.48	0.745	25.02	28.36
Nominal holdings (ln)	404,039	14.22	3.619	-4.605	24.57

Source: SHSG database, SNL Financials

thermore, we trim our data according to the variable ACY and include all securities with an ACY between the 5th and the 95th percentile of the overall distribution. Table 1 shows summary statistics of the variables included in our empirical specification for all ISIN-bank-quarter observations.[9]

3 Results

We show three different sets of results. First, we estimate a baseline model and analyse how securities holdings in the banks' portfolios interact with changes in ACY. We consider the period before and after the introduction of negative policy rates and control for different sets of fixed effects. Second, we estimate the benchmark model, include interactions with the bank deposit ratios and see whether banks with a larger deposit base reacted differently to the introduction of negative interest rates. This enables us to quantify the relative impact of negative rates via a differences-in-differences approach. Third, we analyse diversification through asset classes and geographical regions of issuance. These channels might be of particular relevance in a sample consisting of large internationally diversified banks. We show the results of estimations based on subsamples by asset class, currency and country of issuance.

3.1 Negative policy rates and search for yield: Simple benchmark

The results of the baseline estimation as shown in Table 2 show that overall, the implementation of negative policy rates had a negative impact on securities holdings. The deleveraging was stronger for riskier securities with a high ACY. This holds both in a specification with bank + time fixed effects (column 2) as well as in specifications with security fixed effects (column 1 and 3).

In the fourth column we include fixed effects for securities in the same rating category, and with similar residual maturity. The rationale for these fixed effects is to group securities that need a similar amount of regulatory capital. We construct these fixed effects as follows: First, we group securities by maturity. We use multiples of 100 days (i.e. the first group contains all

[9]The summary statistics are simple (unweighted) averages computed from observations on the ISIN-bank-quarter-level.

Table 2: Baseline Model

	(1) Ln(holdings)	(2) Ln(holdings)	(3) Ln(holdings)	(4) Ln(holdings)
Post	-0.291**		-0.283**	
	(0.136)		(0.136)	
ACY		-0.00934	-0.00150	0.0278***
		(0.00671)	(0.00890)	(0.00870)
Post*ACY		-0.0393***	-0.0173**	-0.0148
		(0.0141)	(0.00719)	(0.0151)
Observations	386,551	402,649	386,551	276,939
R-squared	0.580	0.220	0.580	0.327
Bank Controls	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	–
Security FE	Yes	No	Yes	No
Maturity*Rating*Time FE	No	No	No	Yes

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: Ln(holdings) is calculated on nominal amounts

securities maturing between 0-99 days, the second group those with 100-199 remaining days of maturity etc.). Then we compute a common fixed effect for securities within the same maturity group, that hold the same rating during a certain reporting period. When estimating this specification, we find that within the same category of risky assets (maturity and rating) banks aim for riskier securities overall (positive coefficient of ACY in column 4), a result similar in spirit to Efing (2014). The limited availability of ratings information, however, restricts our analysis to a smaller subsample in this case.

3.2 Negative policy rates and bank deposit ratio

In order to identify the link between negative policy rates and search for yield behaviour, we estimate a differences-in-differences specification where identification is provided by the reliance of banks on customer deposits. We can then compare banks that were more affected by the introduction of negative interest rates to a control group that was less affected. Thereby we can disentangle the effects that are due to changes in the supply of securities, or driven by other economic developments, from those effects that we can attribute to the introduction of negative interest rates by the ECB.

Results are reported in Table 3 with different specifications of fixed effects. The estimated coefficient for the interaction **Deposit Ratio*Post*ACY** shows that the impact of an increase in the ACY in the post-NPR (negative policy rate) period was significantly different for banks with a higher deposit ratio. This can be interpreted as evidence of (relative) search for yield induced by the introduction of negative policy rates. We find that after the introduction of negative policy rates, a difference in the deposit ratio of 10% (approximately one standard

Table 3: Estimation of benchmark model with deposit ratio interaction

	(1) Ln(holdings)	(2) Ln(holdings)	(3) Ln(holdings)	(4) Ln(holdings)
Post	-0.291**		-1.204**	
	(0.136)		(0.494)	
ACY		0.0186	0.00133	0.0640***
		(0.0197)	(0.0133)	(0.0180)
Post*ACY		-0.115***	-0.0655***	-0.112***
		(0.0434)	(0.0206)	(0.0364)
Deposit ratio*Post		0.0317**	0.0251**	0.0379**
		(0.0130)	(0.0104)	(0.0149)
Deposit ratio*ACY		-0.000790*	-4.75e-05	-0.000976**
		(0.000411)	(0.000335)	(0.000402)
Deposit ratio*Post*ACY		0.00223**	0.00136**	0.00265***
		(0.000997)	(0.000533)	(0.000955)
Observations	386,551	402,649	386,551	276,939
R-squared	0.580	0.223	0.582	0.331
Bank Controls	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	Yes	No	–
Security FE	Yes	No	Yes	No
Maturity*Rating*Time FE	No	No	No	Yes

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: Ln(holdings) is calculated on nominal amounts

deviation) would imply a 2 percentage points increase in the sensitivity of the holdings of a particular security in response to a 1%-change in the adjusted current yield.

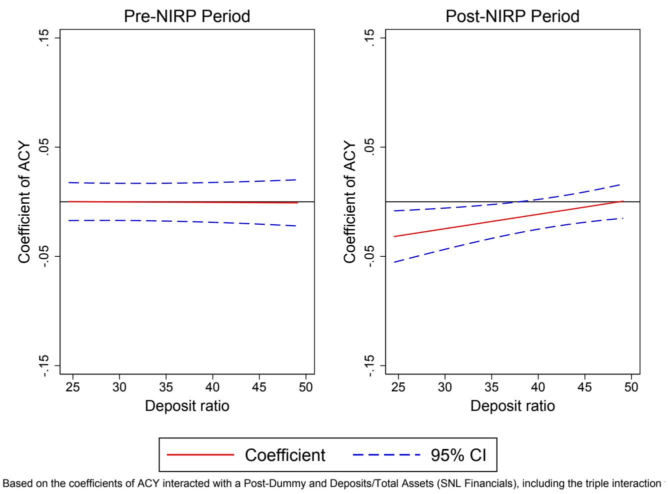
Overall, the signs and the significance of the estimated coefficients in Table 3 and Table 2 are broadly similar. The coefficient of the triple interaction **Deposit Ratio*Post*ACY** is positive and significant both exploiting within-security variation and within-maturity-rating-quarter variation.

The plots in Figure 4 can help to visualize the intuition behind our results.[10] In Figure 4, we show the coefficients of our model estimated using the specification including bank and security fixed effects. The coefficient of **Deposit Ratio*Post* ACY** determines the pre-NPR and the post-NPR difference in the slope of the relationship between the deposit ratio and the sensitivity of Ln(holdings) to a change in the ACY. For the left panel we set Post=0 and for the right panel we set Post=1, in order to highlight the differences before and after the introduction of negative policy rates. Figure 4 shows, that before the introduction of negative policy rates, the sensitivity of banks' portfolios to changes in ACY did not depend on the level of the deposit ratio. Conversely, post-NPR, low-deposit ratio banks disinvest in response to a positive change in the ACY, while high deposit ratio banks disinvest less or not at all. The overall result is that the post-NPR portfolio of high-deposit ratio banks became

[10]They also provide support to the parallel trend assumption before the introduction of negative rates.

riskier compared to low-deposit ratio banks. This can be interpreted as search for yield in the securities portfolio of the affected banks caused by the introduction of negative interest rates.

Figure 4: Marginal effect of ACY before and after negative policy rates



Note: Specification with bank and security fixed effects

3.3 Identification strategy and robustness

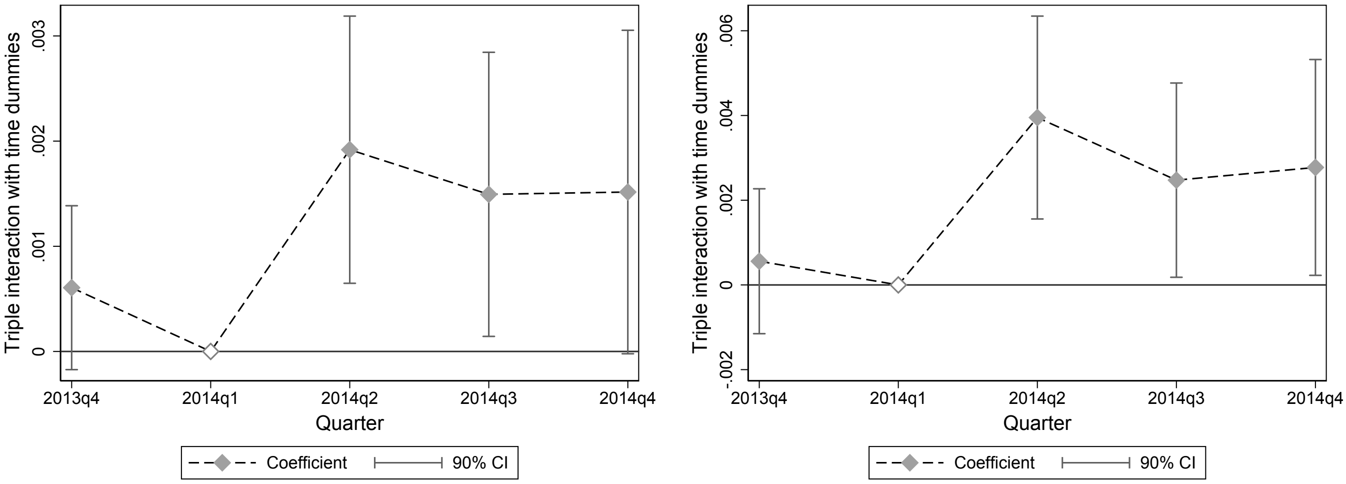
Our identification strategy relies on the assumption that, in the period before the introduction of negative policy rates, risk taking behaviour did not differ systematically across banks with low and high deposit ratios once we control for the patterns captured by fixed-effects and other covariates (parallel-trends assumption). To investigate further on this, we estimate a specification that includes dummies for the lags and leads of the policy change, as in Autor (2003). We estimate

$$\begin{aligned} ln(holdings)_{ijt} \quad &= \quad \beta_{01} \times d2013q4_t \times Deposit\_ratio_{jt} \times ACY_{ijt} \\ &\quad + \beta_{02} \times d2014q2_t \times Deposit\_ratio_{jt} \times ACY_{ijt} + \ldots, \end{aligned}$$

where $d2013q4_t$ is a dummy variable that takes value 1 during the last quarter of 2013 and is 0 for all other quarters. Figure 5 reports the coefficients β_{01}, β_{02} etc. If there is no systematic difference before the policy change, we would expect the pre-treatment interaction of a quarter dummy with ACY and the deposit ratio to be close to zero (not statistically significant). Our data is available from the 4th quarter of 2013 onwards and we use the quarter before the introduction of negative policy rates (2014q1) as our reference period. Figure 5 shows all estimated coefficients of the interaction variable of Deposit ratio, ACY and a dummy for each quarter with 90% confidence bands. Before the policy change, the coefficient of the triple interaction of Deposit ratio, ACY and the dummy variable for 2013q4 is insignificant.[11] Based on this evidence we do not reject the *parallel trend* assumption during the pre-period.

[11]Please note that the coefficient for 2014q1 is 0 by construction (reference period, omitted from the regressions). Using 90% percent confidence intervals makes the confidence bands "narrower" and hence a rejection of the "H_0 :

Figure 5: Evidence on the parallel trends assumption



(a) Security Fixed Effects

(b) Maturity*Rating*Quarter Fixed Effects

Figure 5 also illustrate the effects of negative interest rates over time: the strongest effect is already visible at the end of the 2nd quarter (the negative rates were first announced on June 11 2014). While the subsequent reduction in remuneration of the ECB's deposit facility on September 10 to -0.2 % was perceived by market participants as a "surprise decrease" the estimated coefficients suggest that the differential impact across banks with different deposit ratios was limited.

The results of this test also provide a rationale to define the time sample of our analysis and to identify the policy change in the second quarter of 2014. Indeed, if we included this quarter in the pre-period, we would violate the parallel trends assumption, which would prevent us from identifying a causal effect. We end our sample before the implementation of the asset purchases by the ECB in January 2015, which allows to have a symmetric time window around the introduction of negative policy rates. For robustness, we have carried out our analysis also extending the post-NPR period by up to three quarters in 2015 and our findings still hold. We cannot run a similar exercise for the pre-period, because the database starts in 2013Q4.

3.4 Diversification across assets and the international dimension of risk taking

We have shown that banks with different deposit ratios make different choices in terms of their aggregate securities portfolio after the introduction of negative policy rates. Using the granular database at our disposal, we now explore the drivers of these differences. We answer the following question: how did the response to negative rates affect the portfolio choices of high deposit ratio and low deposit ratio banks in terms of choices among different asset classes, currencies and countries of issuance of the securities? This question is of particular relevance

parallel trends during the pre-period" more likely. Nevertheless, we do not reject H_0 for both graphs displayed in Figure 5.

since our sample consists of large and internationally diversified banks. We perform the same estimations as in equation (1) but restrict our sample along asset classes, geographic areas of issuance and currencies.

Table 4: Regressions across asset classes

	(1) Public debt Ln(holdings)	(2) Private debt issued by banks Ln(holdings)	(3) Private debt (other) Ln(holdings)	(4) ABS Ln(holdings)
Post	-0.991***	-0.962**	-1.666**	-0.427
	(0.368)	(0.411)	(0.676)	(0.321)
ACY	-0.0629**	0.00345	-0.0147	0.170***
	(0.0312)	(0.0191)	(0.0155)	(0.0440)
Post*ACY	0.0222	-0.0476**	-0.0727***	-0.0255
	(0.0340)	(0.0221)	(0.0207)	(0.0623)
Deposit Ratio*Post	0.0195**	0.0207**	0.0362**	0.00515
	(0.00793)	(0.00864)	(0.0141)	(0.00676)
Deposit Ratio*ACY	0.000430	-7.04e-05	0.000610	-0.00387***
	(0.000652)	(0.000540)	(0.000498)	(0.00107)
Deposit Ratio*Post*ACY	0.000120	0.000879*	0.00152**	0.00111
	(0.000839)	(0.000501)	(0.000641)	(0.00124)
Observations	96,637	116,750	138,505	32,504
R-squared	0.436	0.601	0.652	0.708
Bank Controls	Yes	Yes	Yes	Yes
Security FE	Yes	Yes	Yes	Yes
Time FE	No	No	No	No
Bank FE	Yes	Yes	Yes	Yes
Maturity*Rating*Time FE	No	No	No	No

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: Ln(holdings) is calculated on nominal amounts

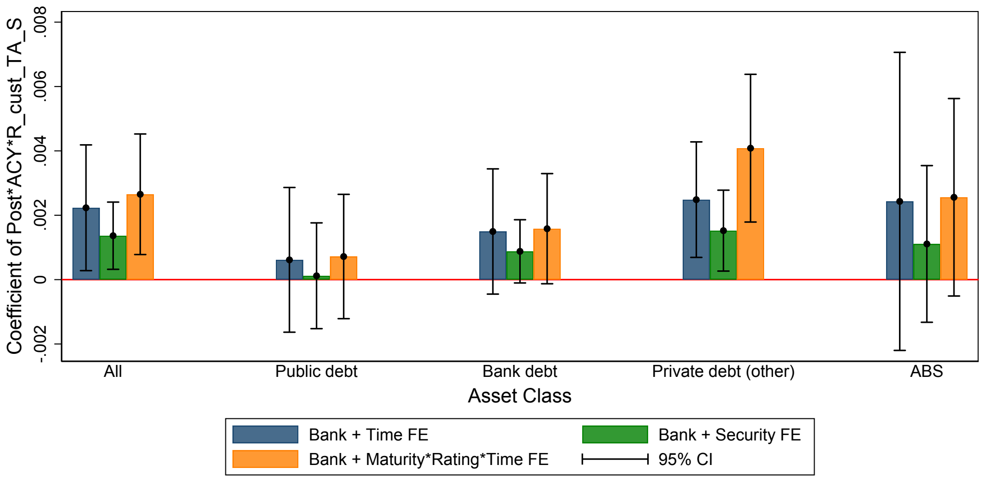
We start by considering portfolio reshuffling along different asset classes (Table 4).[12] We find that after the introduction of negative interest rates, high deposit ratio banks invest comparatively more in public and private debt securities, but there is no differential response in the investment behaviour towards asset-backed securities (see in particular the estimated coefficients of **Deposit Ratio*Post**). Looking at the sensitivity of portfolio holdings to changes in ACY, the coefficents of the triple interaction suggest that banks with a higher deposit ratio became more sensitive to changes in the ACY of private debt securities (issued by banks and by non-financial corporations) when reshuffling their portfolios.

Figure 6 reports the triple interaction coefficient **Deposit ratio*Post*ACY** of each separately estimated regression alongside a 95% confidence interval and for different specifications of fixed effects as reported in Table 4. The coefficients from the estimations based on the

[12]The table reports the results of the estimation of (1) only with the specification with bank and security fixed effects. The complete set of results is available from the authors.

total sample are reported on the first bar on the left, with the label "All" in order to provide a reference point. The values and the confidence intervals of the coefficients vary across the different specifications. The positive relationship captured by the coefficient of **Deposit ratio*Post*ACY** is confirmed for all asset classes, albeit for different levels of statistical and economic significance. Evidence for a risk-shifting behaviour of high deposit ratio banks is strongest and statistically significant for private debt securities issued by financial and non-financial corporations. Affected banks seem to have directed their investment more towards the class of private debt securities.

Figure 6: Coefficient of triple interaction term across different asset classes



Next, we analyse portfolio changes along the dimension of country of issuance. We find evidence that the introduction of negative policy rates spurred portfolio reallocation across geographical regions. We group the securities along four geographical regions by country of issuer: euro area, EU countries not in the euro area, other developed countries[13] and other countries. The results of the estimation carried out along this dimension are reported in Table 5.

We find that banks more affected by negative policy rates have a higher sensitivity to changes in ACY of securities issued in the euro area and in other developed economies — while the effect is not significant for emerging economies (positive and significant coefficients of **Deposit Ratio*Post*ACY** in Table 5).

Figure 7 shows the implications of our results for bank risk taking by plotting again the coefficients of the triple interaction **Deposit Ratio*Post*ACY** with different specifications of fixed effects. The more affected banks respond to an increase in ACY by increasing holdings in securities issued in the euro area and in developed economies outside the EU, including the United States and Japan. There is no evidence of a differential response of high-deposit ratio banks to changes in ACY when considering holdings in securities issued in countries that are member states of the European Union but are not part of the euro area. Coefficients are larger for developed economies outside the EU compared to euro area countries, where we find

[13]This group includes issuers of securities from Australia, Canada, Cayman Islands, Guernsey, Japan, United States, Virgin Islands and Switzerland. Please see Table A.9 in the Appendix for a detailed breakdown by countries.

Table 5: Regressions across geographic areas of issuance

VARIABLES	(1) Euro Area 19 Ln(holdings)	(2) EU non-EA 19 Ln(holdings)	(3) Developed Ln(holdings)	(4) Other Ln(holdings)
ACY	0.0725***	-0.0350	-0.0396	0.0661
	(0.0151)	(0.0363)	(0.0258)	(0.0435)
Post*ACY	-0.109***	0.0116	-0.0976*	0.0883
	(0.0335)	(0.0628)	(0.0519)	(0.0883)
Deposit Ratio*Post	0.0303**	0.0392**	0.0357***	0.0497***
	(0.0138)	(0.0159)	(0.0115)	(0.0167)
Deposit Ratio*ACY	-0.000728**	-7.90e-05	0.000589	-0.000697
	(0.000321)	(0.000813)	(0.000596)	(0.00125)
Deposit Ratio*Post*ACY	0.00253***	-0.000169	0.00269**	-0.000551
	(0.000925)	(0.00117)	(0.00131)	(0.00161)
Observations	154,387	34,317	56,481	28,306
R-squared	0.322	0.433	0.396	0.460
Bank Controls	Yes	Yes	Yes	Yes
Security FE	No	No	No	No
Time FE	No	No	No	No
Bank FE	Yes	Yes	Yes	Yes
Maturity*Rating*Time FE	Yes	Yes	Yes	Yes

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: Ln(holdings) is calculated on nominal amounts

statistically significant effects when we run the model with Bank and Time fixed effects and with Maturity*Rating*Time fixed effects. In this case, the fact that our estimates are not significant in specifications that include securities fixed effects could be due to shifts in the banks' investment behavior towards securities that were not held in the banks' portfolios in the period before the introduction of the negative interest rates. Hence, these securities were not in the dataset during the pre-NPR period. Such shifts would decrease our statistical power for estimations with security fixed effects.

Finally, we consider portfolios shifts across different currencies. The differential response by high deposit ratio banks is particularly pronounced for securities denominated in US dollar (USD). Sensitivities in this category are estimated to be twice the size of those for euro securities (see Figure 8). Interestingly, we observe a counteracting effect for securities issued in Swiss Franc (CHF), British Pound (GBP) and other currencies. However, investment in these currencies represent a small fraction of the total portfolios of the banks in our sample, therefore the economic significance of the effects is rather limited.

Figure 7: Coefficient of triple interaction term across different geographic regions

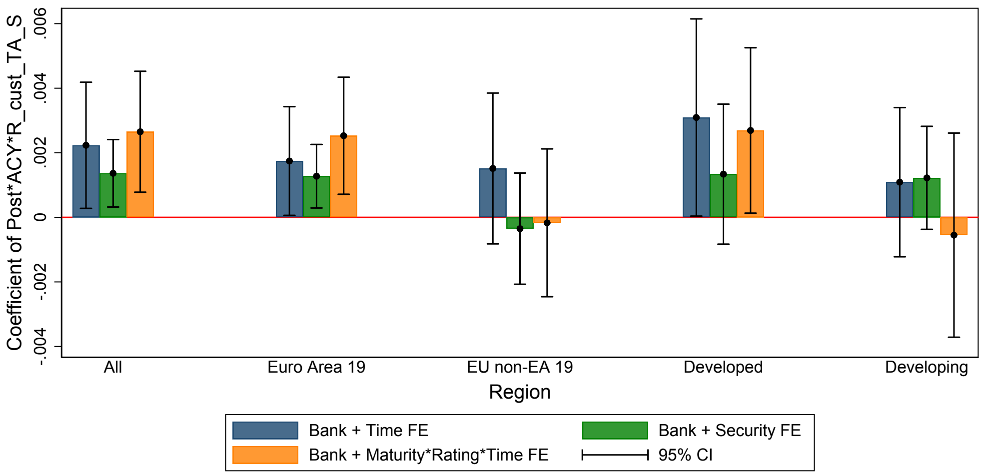
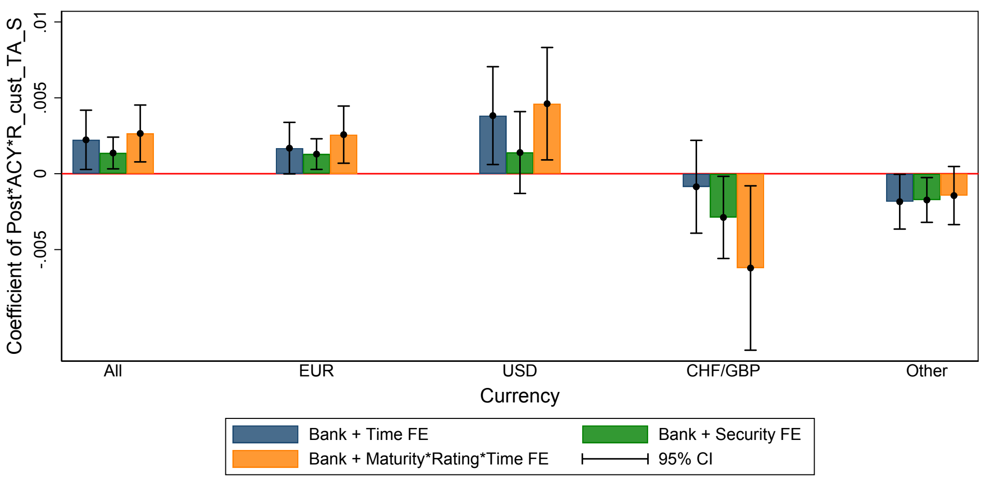


Figure 8: Coefficient of triple interaction term across different currencies



3.5 Alternative sources of risk: duration risk and asset concentration

In reaction to the pressures that negative interest rates induce on their balance sheets, banks could further increase risk taking using alternative channels. We analyze two alternative sources of risk in this section. Banks could seek to increase their exposure to duration risk by increasing the average maturity of their holdings. They could also increasingly invest into the same assets and therefore increase portfolio concentration and systemic risk in the banking sector. This latter argument is developed conceptually in the model proposed among others by Farhi and Tirole (2012) and Allen et al. (2012).

As in the previous section our identification strategy relies on banks' deposit ratios. First, we document aggregate shifts in duration risk during our sample period. We measure duration risk via the maturity structure of the asset portfolio. Figure B.15 in the Appendix shows the maturity structure of the securities portfolio in our sample before and after the introduction of negative policy rates.

To measure asset concentration in the banks' portfolios, we use a specification of the Herfindahl index, calculated for the holdings of asset i at time t as follows:

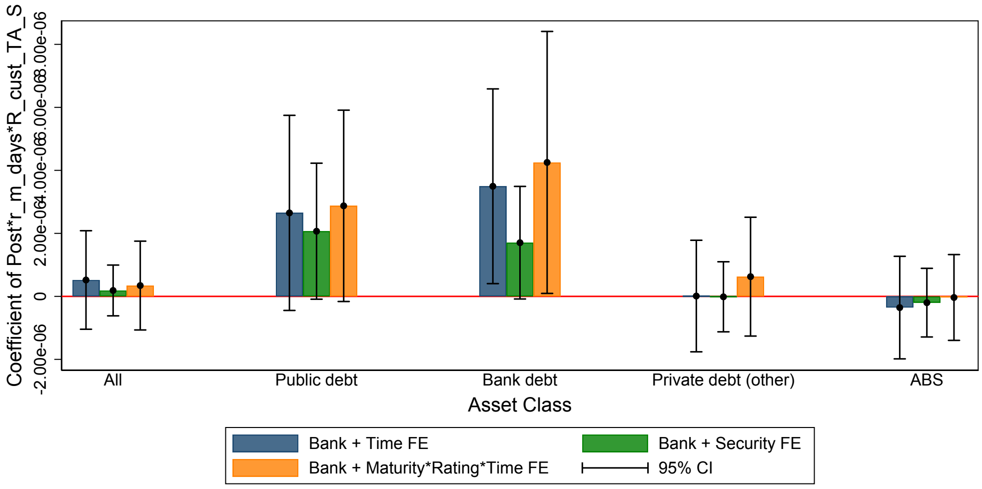
$$\text{Herfindahl}_{ijt} = \sum_{j=1}^{26} \left(\frac{h_{ijt}}{\sum_{k=1}^{26} h_{ikt}} \right)$$

The index takes a value of 1 if only one bank in our sample holds the asset. If all banks hold the same quantity of the asset it takes a value of 0.038 (=1/26). Figure B.16 in the Appendix shows the distribution of the concentration index pre-NPR and post-NPR. We note a small decrease in assets that are held by a single bank and a slight increase in assets that are held in a distributed fashion across the banking sector (when the Herfindahl index takes a value around 0.25). We have also used alternative concentration measures, for example the inverse of the number of holders of a security, and obtained similar evidence.

To further investigate changes in risk exposure linked to duration and concentration, we have estimated our model using maturity and concentration index as measures of risk. Indeed, an empirical specification with fixed effects confirms the patterns we find in the two histograms (see Table A.11 in the Appendix). We find no statistical significant effect of maturity on individual asset holdings. At the same time, concentration of assets (measured by Herfindahl index) is negatively associated to holdings in the securities portfolios in some of the specifications that we consider.

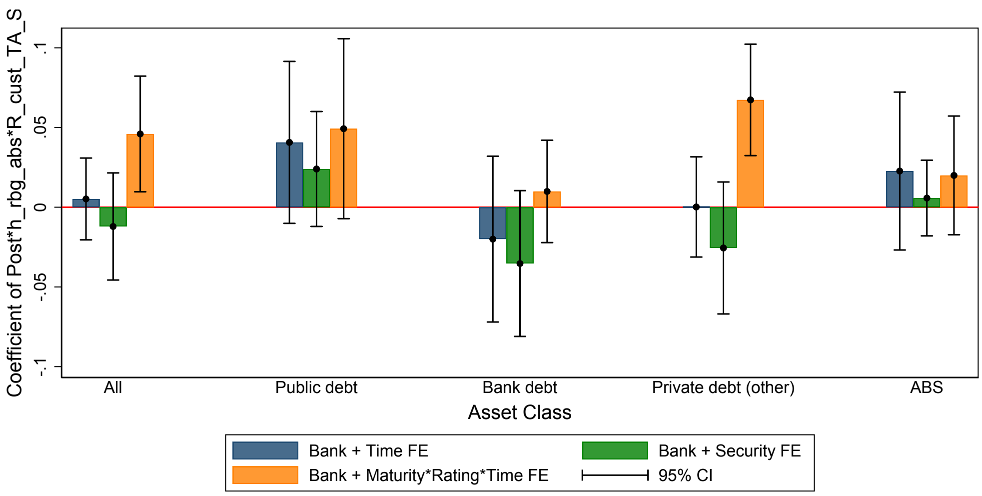
Overall we don't find a robust evidence that banks that are more affected by the negative interest rates via a high ratio of customer deposits have a different sensitivity to duration and concentration risk across the whole portfolio. Figures 9 and 10 plot the coefficient of the triple interaction term in an estimated model with securities holdings grouped by maturity and concentration index respectively. There are no significant coefficients that are robust across the different specifications of fixed-effects. The only statistically significant result concerns

Figure 9: Coefficients of triple interaction with deposit ratio and maturity



Source: Authors' calculations, SHSG database

Figure 10: Coefficients of triple interaction with deposit ratio and Herfindahl index of asset concentration



Source: Authors' calculations, SHSG database holdings of debt securities issued by banks, for which banks with a high deposit ratio seem to have increased average maturity.[14]

4 Heterogeneity induced by bank leverage

Peydro et al. (2017) provide evidence that bank risk-taking in response to a monetary policy loosening during a crisis period can be explained by a particular bank's risk-bearing capacity (i.e. bank leverage). They run their analysis using granular data on loans and securities holdings for Italian banks. Inspired by their results, we investigate how differences in bank leverage may affect allocation of securities portfolios in the context of negative rates.

Hence we interact our coefficient of interest with the leverage ratio (equity divided by total assets) of each bank. We also add all relevant lower-level interaction terms to our regression. The results are displayed in Table 6.

First we observe that the coefficient of **Deposit ratio*Post*ACY** remains positive and significant throughout the different specifications. We find the coefficient of the interaction **Leverage ratio*Deposit ratio*Post*ACY** to be negative and significant. This evidence suggests that our effect of interest (how a bank with a high deposit ratio reacts to changes in the ACY after the introduction of negative policy rates) is weaker for highly capitalized banks.[15]

At this point, one might conclude that our results are evidence of risk-shifting: banks with low levels of capital seem to be more prone to risk-taking in response to monetary policy changes. However, to compute the overall effect we need to take into account also the change in the average effect of leverage on the sensitivity to changes in the ACY, i.e. the sign and significance of the coefficient of **Leverage ratio*Post*ACY**. On average, negative rates do not induce highly levered banks to increase their risk exposure more than better capitalized banks (risk-shifting). Instead, better capitalized banks increase their holdings of securities with a higher ACY in order to exploit their risk-bearing capacity. This result in particular is consistent with the results obtained by Peydro et al. (2017) during the sovereign debt crisis in the euro area.

The magnitude and the sign of the aggregate change in the sensitivity post-NPR depend both on the level of retail deposits and on the leverage ratio. The deposit ratio channel is active and stronger for less capitalized banks. However we find evidence of a counterbalancing effect that works through the bank's overall risk bearing capacity.

5 Negative rates and the lending portfolio

In the previous sections we have analyzed the impact of negative policy rates on the securities holdings of large European banks. Securities portfolios are easier to rebalance in response to

[14]The entire set of estimated results is available from the authors.

[15]We have run a similar analysis by dividing the sample in two groups depending on the leverage ratio (banks that have different levels of capital). Also with this specification we find stronger effects, larger coefficients for the interaction **Deposit ratio*Post*ACY** for the group of banks with a lower leverage ratio. This is consistent with our interpretation of the quadruple interaction term.

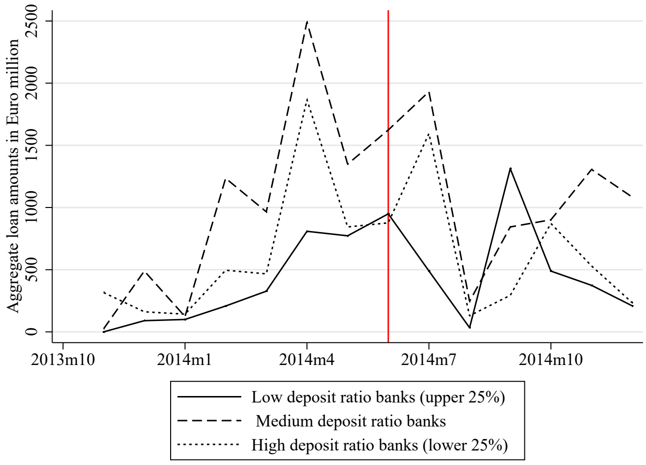
Table 6: Regressions with bank leverage ratio interaction

VARIABLES	(1) Ln(Holdings)	(2) Ln(Holdings)	(3) Ln(Holdings)
Post		-1.852***	
		(0.694)	
ACY	0.393***	0.301***	0.606***
	(0.122)	(0.106)	(0.168)
Post*ACY	-0.769***	-0.531***	-0.883***
	(0.216)	(0.146)	(0.221)
Deposit ratio	-0.0166	-0.0110	-0.0230
	(0.0181)	(0.0127)	(0.0191)
Deposit ratio*Post	0.0177*	0.0140*	0.0235**
	(0.00985)	(0.00802)	(0.0118)
Deposit ratio*ACY	-0.00962***	-0.00810***	-0.0131***
	(0.00280)	(0.00272)	(0.00369)
Deposit ratio*Post*ACY	0.0147***	0.0110***	0.0169***
	(0.00473)	(0.00348)	(0.00488)
Leverage ratio	-1.559***	-1.155***	-1.780***
	(0.571)	(0.418)	(0.648)
Leverage ratio*Post	0.255**	0.209**	0.263**
	(0.113)	(0.0868)	(0.120)
Leverage ratio*ACY	-0.0851***	-0.0666***	-0.127***
	(0.0268)	(0.0244)	(0.0399)
Leverage ratio*Post*ACY	0.155***	0.108***	0.185***
	(0.0450)	(0.0319)	(0.0510)
Leverage ratio*Deposit ratio*ACY	0.00196***	0.00172***	0.00277***
	(0.000605)	(0.000591)	(0.000835)
Leverage ratio*Deposit ratio*Post*ACY	-0.00300***	-0.00225***	-0.00349***
	(0.000959)	(0.000726)	(0.00106)
Observations	402,649	386,551	276,939
R-squared	0.225	0.583	0.333
Bank Controls	Yes	Yes	Yes
Security FE	No	Yes	No
Time FE	Yes	No	–
Bank FE	Yes	Yes	Yes
Maturity*Rating*Time FE	No	No	Yes

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: Ln(holdings) is calculated on nominal amounts changes in interest rates, but a large fractions of banks' assets is represented by loans. We provide some complementary evidence on the impact of negative rates on large banks' assets by using data on syndicated lending.[16] We investigate whether the high-deposit banks in our databse are more likely to grant loans to riskier borrowers compared to low-deposit banks, and therefore the analysis in this section is very closely related to the findings of Heider et al. (2019).

Figure 11: Evolution of the overall syndicated loan amounts



Source: Dealogic

We use syndicated loans data from Dealogic and we consider only loans where at least one of the banks in our sample was involved. Figure B.17 in Appendix shows the number of deals that took place during the period we analyze. French and Spanish banks are dominanting this market in our sample. To properly account for the borrower risk, we restrict the analysis only to loans where the rating of the borrower is specified, which further reduce the sample size. Ratings are coded with a numerical variable ranging from 1 for AAA to 16 for B-.

Syndicated lending was rising somewhat across different banks ahead of the introduction of negative rates in the euro area, while there was a contraction in lending amounts that seems to have been slightly more pronounced among high deposit ratio banks – even on the aggregate level (see Figure 11).

We run differences-in-differences regressions around the introduction of negative policy rates both at the bank-month level (aggregating the volumes of all deals within a month at the level of a bank holding company, and including only banks with the role of "Mandated Arrangers") and on the bank-borrower Level (i.e. looking at single deals, including banks in all roles, but each bank only once[17]). The second approach is closer to the approach we use with securities register data.

[16]Ideally, we would need detailed loan-level data for the banks in the sample in order to properly account for borrower's risk. These data are not available at this level of granularity for banks headquartered in different countries, while similar analysis can be carried out by using data of one country at the time (see for example Bottero et al., 2019).

[17]According to the Dealogic data it occurs quite frequently that one bank has two roles, e.g. Bookrunner and Documentation Agent.

Table 7: Table with syndicated loans between 1 November 2013 and 31 December 2014 (w/o APP period)

VARIABLES	(1) Ln(Amount)	(2) Ln(I-Amount)	(3) Ln(Amount)	(4) Ln(Amount)	(5) Ln(Amount)	(6) Ln(Amount)
Deposit Ratio*Post*Rating					0.00619**	0.00406*
					(0.00304)	(0.00223)
Deposit Ratio*Post	-0.0236	0.00602	-0.0152*	0.00270	-0.0684**	-0.0401*
	(0.0240)	(0.0125)	(0.00797)	(0.00381)	(0.0296)	(0.0213)
Deposit Ratio*Rating					-0.00149	-0.00203
					(0.00219)	(0.00169)
Post*Rating					-0.0366	
					(0.136)	
Rating					-0.192*	
					(0.102)	
Constant	4.015***	4.048***	3.731***	3.299***	6.933***	5.007***
	(0.564)	(0.279)	(0.212)	(0.101)	(0.659)	(0.612)
Observations	60	183	568	530	125	123
R-squared	0.508	0.606	0.197	0.920	0.744	0.906
Obs	60	183	568	530	125	123
Lead Arrangers Only	Yes	Yes	No	No	No	No
Bank-Month Level	Yes	Yes	No	No	No	No
Bank-Borrower Level	No	No	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	No	Yes	No
Borrower-Month FE	No	No	No	Yes	No	Yes

Results are shown in Table 7. Indeed when we run the analysis at Bank-Borrower level we find evidence that banks with higher deposit ratio decreased the amounts of syndicated loans consistent with similar results on deleveraging of securities portfolios during the same period of time (see negative coefficient of Deposit Ratio*Post in column 3). To control for the risk of the borrower we introduce in the regression the Rating of the borrower and therefore the interaction Deposit Ratio*Post*Rating. The coefficient of the interaction is positive, suggesting that while banks more dependent on deposits generally shrank also their lending portfolio, they did this at a lower pace in case of riskier borrowers (remember that the coding of the rating is such that a higher value correspond to a riskier rating). We find significant results when restricting the sample to end 2014 in order to exclude the beginning of the ECB asset purchases.[18]

Overall, this complementary analysis confirms the findings of Heider et al. (2019) – the banks in our sample with a higher deposit ratio grant lower loan volumes. We also find some evidence that high deposit ratio banks grant higher volumes to higher-risk (i.e. lower-rated) borrowers compared to banks with a lower deposit ratio.

6 Conclusions

The implementation of negative policy rates in several countries in the last few years constituted an important novelty for policy makers and researchers interested in the effect of monetary policy. We contribute to the ongoing literature addressing the impact that negative rates have on financial intermediaries, in particular banks. We exploit a new dataset covering the securities holdings of the 26 largest euro area banking groups and evaluate the impact of the introduction of the negative policy rates on these portfolios. The identification relies on a differential effect due to the inability or unwillingness of banks to pass-through negative policy rates to depositors. Indeed, we show that the portfolio holdings of banks that are more reliant on deposit funding are more sensitive to changes in the yields of the securities held after the introduction of negative policy rates. These banks are more likely to retain their investments in riskier securities compared to other banks. When considering allocation across asset classes and geographical issuers, we find evidence that the same banks reallocate more towards private debt securities (issued by the financial and non-financial sector), securities issued by entities residing in developed countries, both in the euro area and outside EU, and securities issued in US dollars.

Our analysis complements the results obtained by other researchers which mainly focused on the impact of negative policy rates on the lending portfolio of banks. It remains to be investigated how the results of all these studies can be combined to assess the macroeconomic impact of negative policy rates and to evaluate the possible trade-offs between temporary distortions in some part of the financial sector and the effects on the economy at large. Our results also have important implications for the assessment of non-standard monetary policy tools and how these tools can induce heterogeneous impacts across financial intermediaries, which are not directly related to the primary objectives of the policy makers.

[18] The coefficients of interest loose their statistical significance in regressions we run based on an extended sample covering syndicated loan transactions during the years 2013-2015 (cf. Table A.12) in the Appendix.

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A Appendix Tables

Table A.8: List of reporting banking groups

	Country	Code	Short name	Full name
1	AT	AT20100	Erste	Erste Group Bank AG
2	BE	BE0403227515	KBC	KBC Group-KBC Groep NV/ KBC Groupe SA
3	BE	BE0403201185	Belfius	Belfius
4	DE	DE00001	DB	Deutsche Bank AG
5	DE	DE00003	COBA	Commerzbank AG
6	DE	DE00316	LBBW	Landesbank Baden-Wuerttemberg
7	DE	DE00317	BLB	Bayerische Landesbank
8	DE	DE00319	HELABA	Landesbank Hessen-Thüringen Girozentrale
9	DE	DE00320	NORDLB	Norddeutsche Landesbank Girozentrale NORD/LB
10	DE	DE01121	DZ	Deutsche Zentral-Genossenschaftsbank-DZ Bank AG
11	DE	DE03249	PBB	Deutsche Pfandbriefbank AG
12	ES	ES0049	BSCH	Banco Santander SA
13	ES	ES0182	BBVA	Banco Bilbao Vizcaya Argentaria SA
14	ES	ES7865	BFA	BFA Tenedora de Acciones SA
15	ES	ESHO486478	La Caixa	Criteria Caixa Holding SA
16	FR	FR10278	BFCM	Credit Mutuel CM5-CIC
17	FR	FR16188	BPCE	Group BPCE
18	FR	FR30003	SG	Société Générale
19	FR	FR30004	BNP	BNP Paribas
20	FR	FR30006	CA	Crédit Agricole Group-Crédit Agricole
21	IT	IT0000203426147	MPdS	Banca Monte dei Paschi di Siena
22	IT	IT0000102484824	UC	Unicredit SpA
23	IT	IT0000101262255	ISP	Intesa Sanpaolo
24	NL	NL149	ABN	ABN Amro Group NV
25	NL	NL163	ING	ING Groep NV
26	NL	NL600	Rabobank	Rabobank Group-Rabobank Nederland

Table A.9: Country classification

Euro area 19	European Union non-EA 19	Developed	Other
Belgium	Bulgaria	Australia	All other countries
Germany	Croatia	Canada	
Estonia	Czech Republic	Japan	
Ireland	Denmark	Guernsey	
Greece	Hungary	Switzerland	
Spain	Poland	Virgin Islands	
France	Romania	Cayman Islands	
Italy	Sweden		
Cyprus	EU Institutions		
Latvia	United Kingdom		
Lithuania			
Luxembourg			
Malta			
Netherlands			
Austria			
Portugal			
Slovenia			
Slovakia			
Finland			

Table A.10: Average nominal holdings by asset class and region

	2013q4-2014q1		2014q2-2014q4	
	Euro billion	%	Euro billion	%
Asset Class				
ABS	524.8	17.8%	521.4	18.5%
Private debt (other)	485.5	16.5%	403.0	14.3%
Private debt issued by banks	830.8	28.2%	754.7	26.8%
Public debt	1100.7	37.4%	1141.9	40.5%
Region				
Developed	219.9	7.5%	221.5	7.9%
Other	211.6	7.2%	209.5	7.4%
EU non-EA 19	211.6	7.2%	199.1	7.1%
Euro Area 19	2298.5	78.1%	2190.9	77.7%
Total	2941.7		2821.0	

Table A.11: Baseline regression for alternative risk indicators

VARIABLES	(1) Ln(Holdings)	(2) Ln(Holdings)	(3) Ln(Holdings)	(4) Ln(Holdings)	(5) Ln(Holdings)	(6) Ln(Holdings)
Post		-0.338*			-0.351	
		(0.191)			(0.244)	
Maturity	(7.94e-06)	(0.000454)	(0.000378)			
	2.59e-05***	-0.000268	-0.000308			
Herfindal				-0.320*	-1.928***	-0.0226
				(0.171)	(0.349)	(0.160)
Post*Maturity	-1.36e-05	-8.57e-07	0.000134			
	(1.01e-05)	(5.00e-06)	(0.000578)			
Post*Herfindal				-0.576***	0.101	-1.333***
				(0.214)	(0.205)	(0.334)
Observations	402,649	386,551	276,939	402,649	386,551	276,939
R-squared	0.219	0.580	0.327	0.222	0.582	0.332
Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Security FE	No	Yes	No	No	Yes	No
Time FE	Yes	No	–	Yes	No	–
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Maturity*Rating*Time FE	No	No	Yes	No	No	Yes

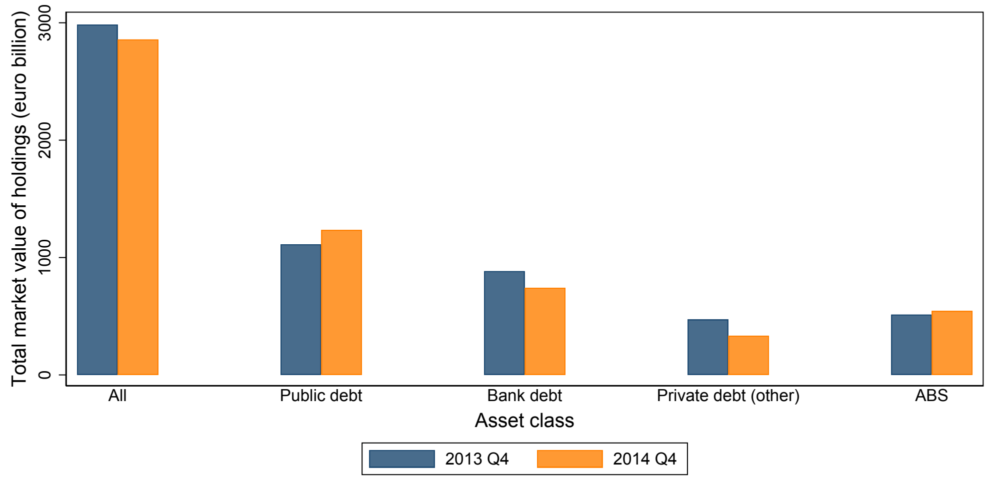
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.12: Table with syndicated loans between 1 January 2013 and 31 December 2015 (includes APP period)

VARIABLES	(1) Ln(Amount)	(2) Ln(I-Amount)	(3) Ln(Amount)	(4) Ln(Amount)	(5) Ln(Amount)	(6) Ln(Amount)
Deposit Ratio*Post*Rating					0.00178	0.00206
					(0.00328)	(0.00194)
Deposit Ratio*Post	0.000693	0.00277	-0.00889*	-0.00356	-0.0243	-0.0187
	(0.0140)	(0.00741)	(0.00480)	(0.00269)	(0.0321)	(0.0188)
Deposit Ratio*Rating					0.000900	-0.00178
					(0.00251)	(0.00151)
Post*Rating					0.127	
					(0.148)	
Rating					-0.236**	
					(0.114)	
Constant	3.581***	4.249***	3.480***	3.332***	5.558***	4.935***
	(0.367)	(0.177)	(0.140)	(0.0777)	(0.871)	(0.572)
Observations	176	455	1,925	1,814	379	374
R-squared	0.398	0.561	0.211	0.884	0.463	0.864
Obs	176	455	1925	1814	379	374
Lead Arrangers Only	Yes	Yes	No	No	No	No
Bank-Month Level	Yes	Yes	No	No	No	No
Bank-Borrower Level	No	No	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	No	Yes	No
Borrower-Month FE	No	No	No	Yes	No	Yes

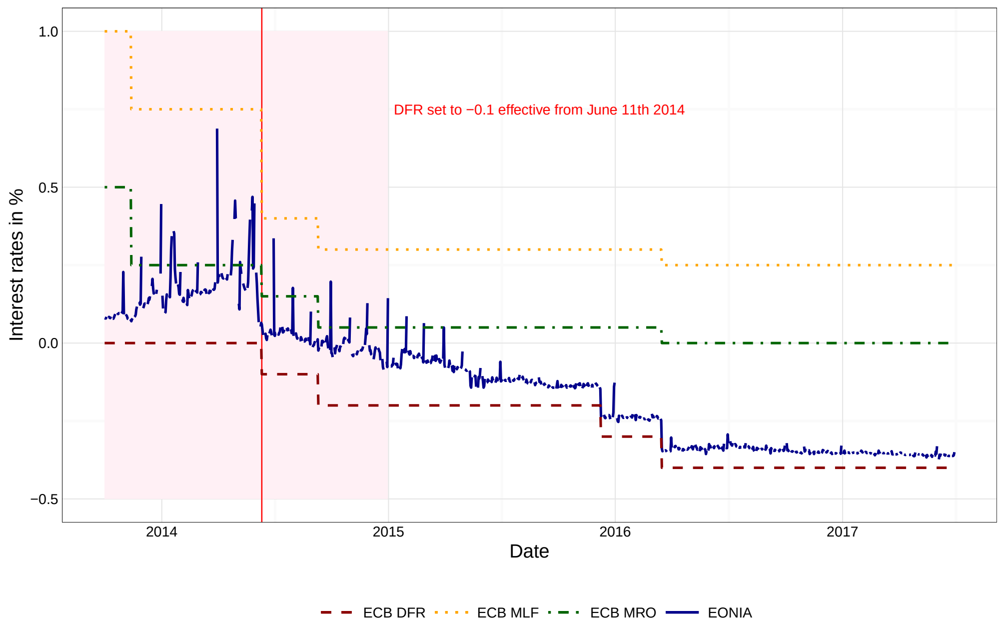
B Appendix Figures

Figure B.12: Evolution of the holdings of debt securities by the 26 reporting banking groups (at market values)



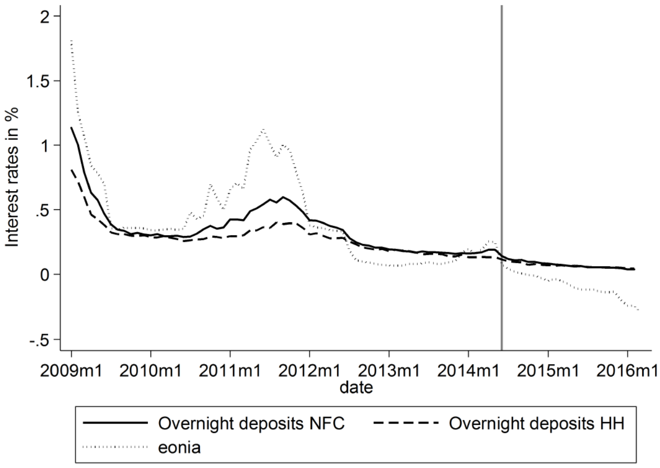
Source: SHSG

Figure B.13: ECB key policy rates and interbank lending rate



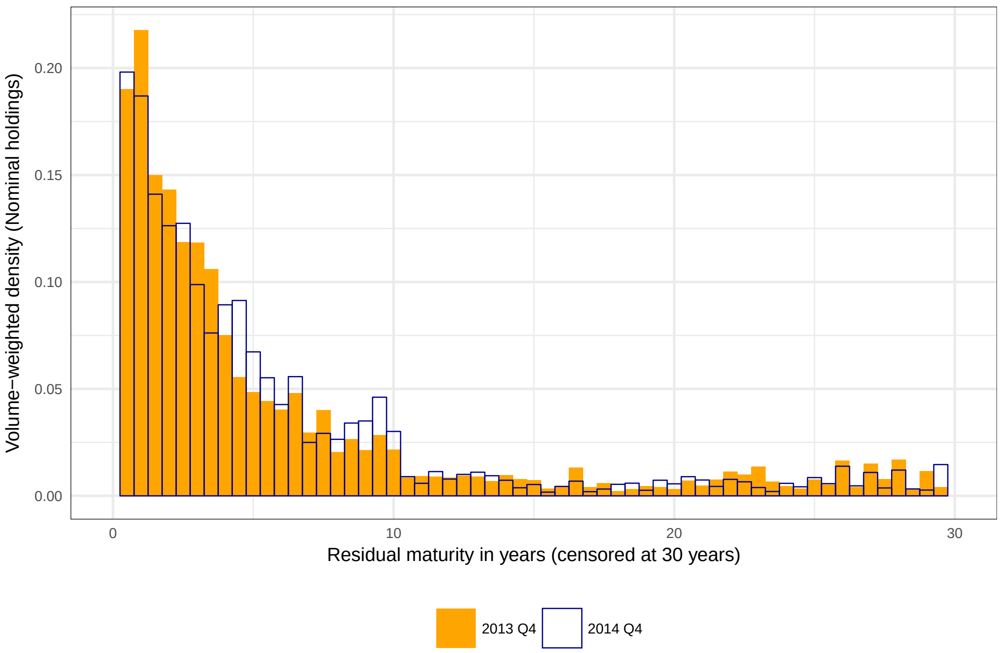
Source: ECB SDW

Figure B.14: Rates on Overnight Deposits by House-holds (HH) and Non-financial Corporations (NFC)



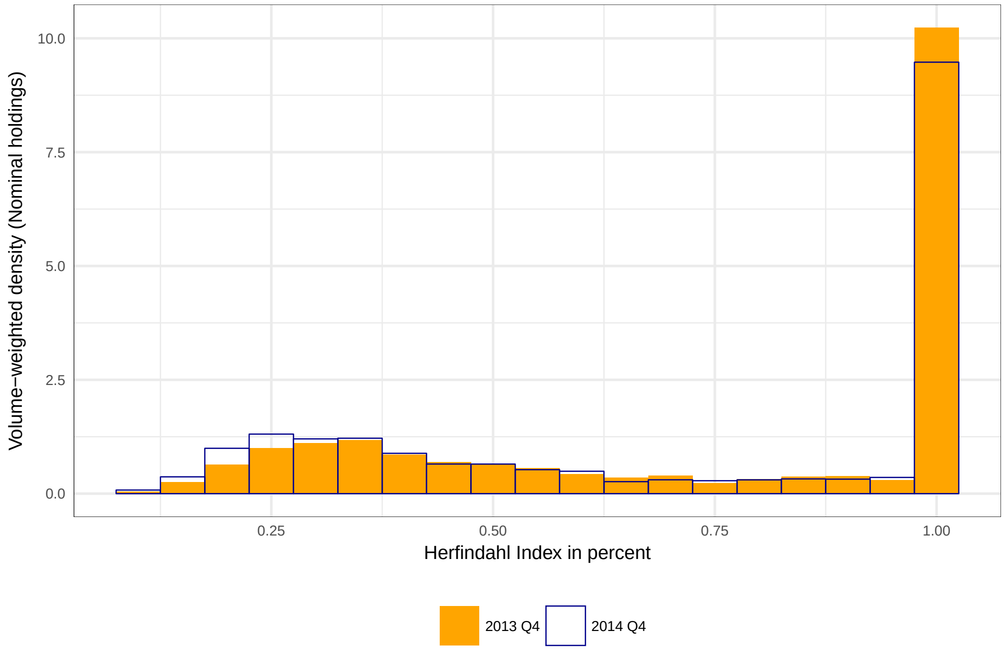
Source: Heider, Saidi and Schepens (2017), ECB IMIR interest rate statistics database

Figure B.15: Distribution of residual maturity in years before and after negative policy rates



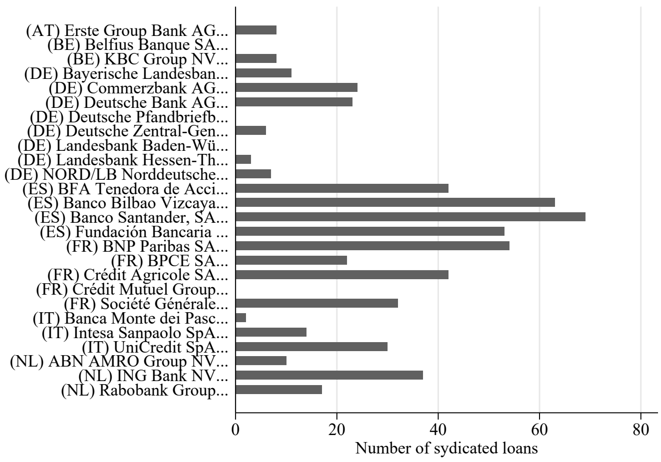
Source: ECB calculations, SHSG

Figure B.16: Distribution of asset concentration before and after negative policy rates



Source: ECB calculations, SHSG

Figure B.17: Overall number of syndicated loans by sample banks



Source: Dealogic