Adapting lending policies when negative interest rates hit banks' profits[♣]

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Adapting lending policies when negative interest rates hit banks' profits

Abstract

What is the impact of negative interest rates on bank lending and risk-taking? To answer this question we study the changes in lending policies using the Euro area Bank Lending Survey and the Spanish Credit Register. Banks whose net interest income is adversely affected by negative rates are concurrently lowly capitalized, take less risk and adjust loan terms and conditions to shore up their risk weighted assets and capitalization. These banks also increase non-interest charges more. Importantly, we find no differences in banks' credit supply and credit standard setting, neither in Euro area nor in Spain, suggesting that negative rates do not necessarily contract the supply of credit, which can be interpreted in the sense that the so-called "reversal rate" has not been reached yet.

JEL Classification: G21, E52, E58

Keywords: negative interest rates; risk taking; lending policies

1. Introduction

A commonly shared view is that low interest rates maintained for an extended period may reduce banks' net lending margins. Very low short-term rates during the recent crisis and its aftermath have typically come hand in hand with a lower and flatter yield curve which renders maturity-transformation activities less profitable by pressing down net interest income. For a sufficiently low short-term rate, this latter effect, so the argument goes, will eventually dominate the positive effects of low rates on loan loss provisions and on non-interest income (see Borio *et al.*, 2015). Moreover, in an environment featuring negative policy rates – the one on which this paper focuses – the incidence of an effective lower bound on the remuneration of commercial banks deposits will exacerbate this negative loop between low rates and net lending margins (see Heider *et al.*, 2017 and Eisenschmidt and Smets, 2017).

A positive relation between the level of interest rates and bank profitability has been documented by Alessandri and Neleon (2012), Genay and Podjasek (2014), Borio *et al.* (2015), Busch and Memmel (2015), and Claessens *et al.* (2017), among others.[1,2] But, certainly, banks may mitigate the negative effect of falling interest rates by raising lending volumes, lowering interest expenses (Scheiber *et al.*, 2016), increasing loan spreads (Sääskilahti, 2016), lowering risk provisioning (Albertazzi and Gambacorta, 2009; Borio *et al.*, 2015), setting higher fees (Turk, 2106), or taking more risk (Albertazzi *et al.*, 2016; Heider *et al.*, 2017).[3] [4] How banks adjust the previous levers of their lending policies will ultimately determine the way in which negative rates affect the overall supply of credit to the economy and the profitability of banks.

Thus, identifying the channels through which interest rates shape bank profitability is a key piece to understand the reaction of banks in a context of

[1] This statement is not true if one attends to specific countries such as Denmark or Sweden (Turk, 2016) or the previous two countries plus Switzerland (Scheiber *et al.*, 2016). This view has also been recently challenged by Altavilla *et al.* (2017), who show that monetary policy easing is not associated with lower bank profits once they control for the endogeneity of the policy measures to expected macroeconomic and financial conditions. In other words, the positive correlation between interest rates and bank profits occurs because they are simultaneously determined by macroeconomic and financial conditions, but there is no causal relation between the two, at least not in the short run.

[2] For detailed descriptive evidence on the negative interest rate policy and bank profitability in the euro area see Jobst and Lin (2016).

[3] This empirical evidence is consistent with the one documented following the introduction of the large-scale asset purchase programs in US (see Kandrac and Schulsche, 2016 and Kurtzman *et al.*, 2017).

[4] A low interest rate environment could also affect banks' equity values (see Ampudia and Van den Heuvel, 2017).

persistently negative interest rates. The recent empirical literature has explored a wide array of channels through which negative rates may harm profitability. A first channel relates to the degree of the banks' reliance on retail deposit funding, on which they typically find difficult to charge negative interest rates (Heider *et al*., 2017).[5] Secondly, banks maintaining excess liquidity may face a negative return on reserves (Demiralp *et al.*, 2017; Basten and Mariathasan, 2018), whereas floating rate holdings may cause capital losses. Finally, a low net worth may lead to binding capital constraints and limit banks' risk taking ability, hence restraining their capacity to raise lending margins by charging higher spreads to riskier borrowers (Brunnermeier and Koby, 2017).

Banks with low net worth may initially benefit from decreasing interest rates through improved access to financing, and respond by lending more and taking more risks. However, as deposit funding costs at some point remain stuck above zero but lending yields continue to drop, the downward pressure on intermediation margin and, hence, on retained earnings (and capacity to build up capital organically) makes low net worth banks curtail lending and risk-taking more than high net worth banks. In addition, during the post crisis period low net worth banks were under particularly intense regulatory scrutiny about their lending policies and risk-taking behaviour.

Notice that the relationship between bank capital and risk taking is a priori ambiguous. The risk-shifting hypothesis (also called gambling for resurrection or asset-substitution) introduced by Jensen and Meckling (1976) implies stronger risk-taking by less capitalised banks. In short, as the skin in the game is low, banks may take high risks (Holmstrom and Tirole, 1997; Freixas and Rochet, 2008). By contrast, according to the risk-bearing capacity hypothesis (e.g., Adrian and Shin, 2011), higher bank capital allows more risk taking simply because of its loss-absorbing capacity. The relationship may also vary along the economic cycle and most evidence pertains to pre-crisis times when bank capital ratios were relatively low, and so were capital requirements. An exception on this account is recent work by Peydró, Polo and Sette (2017) who find evidence for Italy during the crisis supporting the risk-bearing capacity hypothesis.[6]

[5] There is in fact some evidence that banks have been reluctant to pass negative policy rates on to retail depositors (Bech and Malkohozov, 2016).

[6] They find that softer monetary policy makes less capitalized banks buy more securities (rather than increasing credit supply), but with lower yields in comparison to more capitalized banks, which constitutes evidence against risk shifting. Consistent with risk-bearing capacity, the effect is particularly

Our paper offers new empirical evidence on the relevance of the various channels through which negative interest rates affect banks' net lending margins in the context of the recent experience of the Euro area, where the European Central Bank (ECB) has set a negative deposit facility rate since 2014. To this aim, we exploit the non-anonymised answers to the Bank Lending Survey (iBLS) and the individual balance-sheet data and interest-rate data (IBSI and IMIR databases, respectively) of a wide sample of Euro area banks. The survey contains a question that deals explicitly with the effect of negative interest rates on banks' net interest income. More specifically, banks are asked whether the ECB's negative deposit facility rate (DFR) contributed to a decrease or an increase in their net interest income.

We then explore several banks' characteristics that may determine the way in which lending margins are affected by negative interest rates. Crucially, independently of the methodology or the sample period employed in the analysis, we find that those banks that report a negative incidence of negative rates on their net income (henceforth, *affected banks*) have capital ratios that on average are significantly lower than those that report to be unaffected.

Why are lending margins of banks with worse capital ratios more affected by negative interest rates? Following a drop in the interest rate, the negative effect of lower unit lending margins on a bank's profit can be partially offset by raising the supply of loans. But low capital ratios pose a limit on the loans supply, as emphasized by Brunnermeier and Koby (2017). As interest rates reach very low levels for a prolonged period of time, and bank capital is scarce and expensive – arguably, two prominent features of the current European banking landscape – the previous bank-profit eroding mechanism is likely to be more operational, giving rise to a link between the banks' capital position and the effect of negative rates on their profitability. As the argument goes, it is then reasonable to expect banks with lower capital ratios to rebalance their credit portfolio towards safer loans in the form of shorter maturities, smaller loan size and higher collateral requirements to improve their risk weighted assets and in turn their regulatory capital ratios. In parallel, low capital ratios may provide incentives to raise non-interest charges, like commissions and fees, as an alternative way to build up capital organically.

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strong in the portfolios where securities are marked to market, as in those portfolios unrealized changes in value are reflected in the income statement as profits or losses.

Our empirical results offer support to the previous mechanism. Exploiting data from a large sample of Euro area banks, we find that those banks that report a higher incidence of negative interest rates on their income tend to exhibit lower risk tolerance and grant loans with shorter maturity and lower average loan size. We report qualitatively consistent findings when we employ loan level data obtained from the Spanish Credit Register. In addition, we find that those European banks whose net interest income is adversely affected by the negative interest rates increase commissions and fees significantly more than unaffected banks.

Another important question is: How do negative interest rates affect the supply of bank credit? The answers in the previous literature are mixed. While there exists empirical evidence that supports the view that negative rates are effective in stimulating bank lending (Demiralp *et al.*, 2017; Rostagno *et al.*, 2016), other work documents a modest or even negligible expansion of credit (Borio and Gambacorta, 2017), whereas some recent work even finds a contraction in lending (Heider *et al.*, 2017). Brunnermeier and Koby (2017) argue that below a given policy rate (which they label as the "reversal rate"), which is not necessarily zero, further reductions in the rate will lower bank profitability and reduce capital generation via retained earnings, thereby eventually restricting lending. Our results obtained from the sample of European banks suggest that there are no significant differences in terms of the total amount of credit supplied by those banks whose net interest income is affected by negative interest rates and those that are not. Within the logic of Brunnermeier's and Koby's (2017), this result would provide support to the view that for the average euro area bank the reversal rate has not been reached (yet).

Consistently with the previous finding for the whole European sample, based on detailed information at the loan level for Spain, we observe that there are no significant differences in the variation of lending by those banks whose net interest income was affected by negative interest rates as compared to those that were not affected. Interestingly, following the inception of a negative DFR in June 2014 affected banks cut (increased) their supply of credit to riskier (safer) firms by more than unaffected banks.

The remainder of the paper is organized as follows: Section 2 describes the main datasets employed in our analysis. Section 3 describes the channels through which negative interest rates affect bank profitability. In section 4 we study the effect of negative rates on credit supply. Section 5 contains several analyses on the rebalancing

of Euro area banks' credit portfolio to overcome the effects of negative interest rates. Section 6 provides further evidence based on loan level data obtained from the Banco de España's credit registry in line with previous results at the Euro area level. Section 6 concludes.

2. Data and variables

The data employed in the baseline analyses come from three sources: The Individual Bank Lending Survey (iBLS), the Individual Balance Sheet Items (IBSI) and the Individual MFI Interest Rate (IMIR) databases. The iBLS database contains confidential, non-anonymized replies to the ECB's Bank Lending Survey (BLS) for a subsample of banks participating in the BLS. The BLS is a quarterly survey through which euro area banks are asked about developments in their respective credit markets since 2003.[7] Currently the sample comprises more than 140 banks from 19 euro area countries, with coverage of around 60% of the amount outstanding of loans to the private non-financial sector in the euro area. However, there are six countries that do not share the confidential, non-anonymized replies to the BLS, so they are excluded from the iBLS (see Table 1 for a view of the distribution of observations per country).[8]

The BLS is especially designed to distinguish between supply and demand conditions in the euro area credit markets. Supply conditions are measured through credit standards (i.e., the internal guidelines or loan approval criteria of a bank), credit terms and conditions, and the various factors that may have caused them to change.[9] In fact, the credit standards measure contained in the BLS has been used as a proxy for

[7] For more detailed information about the survey see Köhler-Ulbrich, Hempell and Scopel (2016).Visit also https://www.ecb.europa.eu/stats/ecb_surveys/bank_lending_survey/html/index.en.html.

[8] Germany participates in the iBLS with a sub-sample of banks that have agreed to transmit their non-anonymized replies to the ECB.

[9] According to the BLS, *credit standards* are the internal guidelines or loan approval criteria of a bank. They are established prior to the actual loan negotiation on the terms and conditions and the actual loan approval/rejection decision. They define the types of loan a bank considers desirable and undesirable, the designated sectoral or geographic priorities, the collateral deemed acceptable and unacceptable, etc. Credit standards specify the required borrower characteristics (e.g., balance sheet conditions, income situation, age, employment status) under which a loan can be obtained. On the other side, *credit terms and conditions* refer to the conditions of a loan that a bank is willing to grant, i.e., to the terms and conditions of the individual loan actually approved as laid down in the loan contract which was agreed between the bank and the borrower. They generally consist of the agreed spread over the relevant reference rate, the size of the loan, the access conditions and other terms and conditions in the form of non-interest rate charges (i.e., fees), collateral or guarantees which the respective borrower needs to provide (including compensating balances), loan covenants and the agreed loan maturity.

banks' credit supply in some previous literature.[10] The BLS also contains information on the evolution of credit demand by firms and households and the factors underlying these developments. In addition, several ad hoc questions have been added in the recent years to analyze the impact of the main ECB's non-standard monetary policy measures, such as the negative DFR, on several dimensions such as banks' balance sheets, credit standards and terms and conditions.

IBSI and IMIR contain balance-sheet and interest rate information of the 300 euro area largest banks,[11] which is individually transmitted on a monthly basis from the national central banks to the ECB since July 2007. We have matched both datasets with the iBLS. We restrict the sample to the period spanning from 2014Q2 (i.e., when the negative DFR was introduced) to 2017Q3.[12] The resulting sample contains 1,694 observations corresponding to 123 banks from 13 countries (see Table 1 for a view of the distribution of observations per country).[13] However, the estimation sample will be generally smaller due to missing values.

The definitions of the variables used in this study are displayed in Table 2. The main dependent variables are changes in credit standards and non-price terms and conditions in the loans to enterprises, as reported in the BLS. In particular, the BLS asks banks on a quarterly basis about the evolution of the credit standards applied to their new loans or credit lines to enterprises, the margins charged on them and other non-price terms and conditions (non-interest charges, size of the loan, collateral requirements, loan covenants, and maturity). Banks must answer whether they have tightened them, kept them basically unchanged or eased over the past three months. While the BLS differentiates between "tightened considerably" and "tightened somewhat" and between "eased considerably" and "eased somewhat", we aggregate these categories into "tightened" and "eased", as done in the regular BLS reports

[10] See, for instance, Buca and Vermeulen (2017), who combine answers to the BLS and aggregate balance sheets from BACH to show that, following a tightening in credit supply, investment falls substantially more in bank-dependent industries.

[11] 55 monthly time series are required on the asset side, which include data on holdings of cash, loans, debt securities, MMF shares/units, equity and non-MMF investment fund shares/units, non-financial assets and remaining assets. On the liability side, the time series cover information on deposits, included and not included in M3, issuance of debt securities, capital and reserves and remaining liabilities.

[12] As most regressors are lagged one period, they are measured in the period spanning 2014Q1 to 2017Q2.

[13] The level of consolidation of the banking group differs between BLS and IBSI. Consequently, we have 123 banks in IBSI but 105 banks in BLS, because sometimes the head of the group is the one that answers to the BLS but we have unconsolidated balance sheets of the head and its subsidiaries in IBSI.

prepared by the ECB. In addition, in some of the analyses our dependent variable will be *risk tolerance*, i.e., the changes in the bank's risk tolerance in the past three months (decreased, remained unchanged or increased). Finally, in some analyses we will use the variable credit growth, which is the quarterly growth rate of outstanding loans to non-financial corporations.

Table 3, in which descriptive statistics of the dependent variables are presented, shows that most of the time (over 90% of the observations) credit standards remained unchanged. In addition, credit standards were more likely to ease (5%) than to tighten (around 2%), which is consistent with the phase of economic recovery observed during the sample period, as it is confirmed by an average quarterly credit growth of 0.20%. Terms and conditions were also very stable, and the probability of easing was somewhat larger than the probability of tightening during the sample period. Most observations (97%) are associated with a stable level of banks' risk tolerance.

Table 4 presents the descriptive statistics of the banks' characteristics. Our key regressor is *NDFR*, a dummy variable that equals 1 if the bank reported that the ECB's negative DFR contributed to a decrease of the bank's net interest income in the past six months and 0 otherwise. The variable is constructed using an ad-hoc question that has been asked four times on a semi-annual basis since April 2016.[14] According to Table 4, 73% of the observations correspond to banks affected by the negative DFR. The percentage of affected banks has risen over time, from 71% in April 2016 to 74% in October 2017.

In addition, we use balance sheet information and the interest rate data of IBSI and IMIR to construct several controls at the individual bank level. We proxy bank size with the natural logarithm of the bank's total assets (*size*). Leverage is defined as the ratio of capital and reserves over total unweighted assets (*capital ratio*). Liquidity is measured with a *liquidity ratio*, expressed as the sum of cash, holdings of government securities and Eurosystem deposits over total assets (%) and with a loan-to-deposit ratio. The importance of deposits as a funding source is captured with the *deposit ratio*, the

[14] The exact wording of the question is: "Given the ECB's negative deposit facility rate, did this measure, either directly or indirectly, contribute to a decrease / increase of your bank's net interest income over the past six months?" While the question refers to the last six months, it cannot be ruled out that banks reported the cumulative impact since the introduction of the negative DFR when answering the question by the first time in April 2016.

ratio between the deposits by households and non-financial corporations over total assets. An important control is the total borrowing from the Eurosystem over total assets (*Eurosystem borrowing).* This variable includes the amounts taken up by the banks in the first and second series of the targeted longer-term refinancing operations (TLTRO I and TLTRO II). As both the TLTRO I and the negative DFR were announced in June 2014,[15] as part of the credit easing package, it is important to take into account the liquidity obtained in the TLTRO when assessing the effect of negative interest rates on credit standards and loan terms and conditions. Finally, we also control for the bank's legal form (head institution, national subsidiary, foreign subsidiary, foreign branch). Around 75% of the observations belong to domestic banks (head institutions or national subsidiaries) while around 25% belong to foreign banks (mainly foreign subsidiaries).

In our empirical exercises we also use controls for the firms' demand for credit. In particular, the BLS asks banks about perceived changes in the demand for loans or credit lines to enterprises. Banks must answer whether the demand for their loans has decreased, has remained basically unchanged or has increased over the past three months. As with the supply indicators, we merge "decreased considerably" and "decreased somewhat" into "decreased" and "increased considerably" and "increased somewhat" into "increased". The descriptive statistics of the demand variables are displayed in Table 5. We differentiate between demand for loans from SMEs and large firms and also between short-term loans and long-term loans. We also distinguish the evolution of credit demand according to the purpose of the loan (loans for fixed investment, for inventories and working capital, for mergers and acquisitions and for debt refinancing). The demand indicators are also relatively stable, but they change more frequently than credit standards and terms and conditions. In addition, demand is more likely to increase than to decrease, as expected in a period of economic recovery.

Table 6 shows the distribution of affected and non-affected banks by country. Across the largest euro area countries, German banks account for more than 26% of the affected banks and Italian ones for 16%, while French and Spanish banks account for 8% and 7%, respectively.

3. Understanding the characteristics of banks adversely affected by negative interest rates

[15] The negative DFR was introduced on 11 June 2014, the TLTRO-I were announced on 5 June 2014.

A key identification challenge is to measure the shock implied by the introduction of the negative DFR. Although previous studies have used several proxies to identify this shock,[16] the negative DFR is likely to impact banks' profitability through several channels. First, affected banks may have high levels of excess liquidity, as the negative DFR implies a direct cost to those banks holding excess reserves. Second, these banks may have a high share of retail deposits, as the existence of cash as a zero-return store of value implies that banks are reluctant to charge negative interest rates to retail depositors. Third, affected banks may have a high share of floating-rate loans or short-term loans, which are repriced at a lower rate following a reduction in the interest rate. Those factors squeeze banks' net interest margins and erode banks' net worth via a reduction in retained earnings.

Confronted with these issues, we first exploit the answers to the BLS question about the incidence of negative rates on banks' profitability. Specifically, we consider that a bank has been negatively affected if it reports that the negative DFR contributed to a decrease in its net interest income. This allows us to abstract from the specific channel through which the negative DFR influences bank profitability (charge on excess liquidity, deposit rates floored at zero, floating-rate loans, short-term loans, lower risk-taking, etc.) and to focus on the final outcome, i.e., the decrease in net interest income. Table 7 reports the characteristics of banks affected and not affected by the negative DFR (*NDFR*=1 and *NDFR*=0, respectively). In particular, Panel A displays the means of both groups, the differences between the two and the p-values of a test of equality of means for the period 2014Q1. We consider the bank characteristics one quarter before the arrival of negative rates to guarantee that banks characteristics are not affected by this event. Panel B displays the equivalent information for the post-event period 2014Q2-2017Q3.

If one attends to the characteristics of affected banks immediately before the event, we observe that the only feature that distinguishes both affected and non-affected banks is the capital ratio. Concretely, affected banks are about 2.6 percentage points (pp) less capitalized than non-affected banks.

[16] For instance, Heider *et al.* (2017) measure the intensity of the exposure to the negative DFR with the deposit ratio (deposits over total assets). Demiralp *et al.* (2017) measure it with the ratio between excess liquidity and total assets.

As time passes and the question is formulated on a recurrent basis to banks, we observe that the proportion of banks that answer to be affected by negative rates increases slightly (74% in October 2017 as compared to 71% in April 2016). This fact, together with the potential effects of a prolonged period of negative rates on banks' profits and balance sheets, would motivate that not only initially low capitalized banks are in the end affected by negative rates. Particularly, Panel B shows that affected banks have a higher share of deposits than non-affected ones (42.7% vs. 38.6%), consistent with the findings of Heider *et al.* (2017). Affected banks also hold a higher fraction of liquid assets (8.2% of total assets) than non-affected ones (7%), which is in line with the arguments of Demiralp *et al.* (2017) and Basten and Mariathasan (2018). In addition, affected banks rely more on Eurosystem borrowing, have a larger market share and a slightly higher average maturity of their loan portfolio (however, the difference is just one month and a half and, in addition, there are not significant differences in terms of the proportion of short term loans). Crucially, affected banks are about 1 pp less capitalized than non-affected banks. By contrast, there are no significant differences in terms of size, loan-to-deposit ratio, average maturity of liabilities, and weight of overnight deposits.

To provide evidence on the bank characteristics adversely affected by negative interest rates beyond that contained in the previous unconditional tests, we estimate linear probability models based on the two previous periods but considering all bank characteristics jointly. Results are provided in Table 8. Panel A refers to the pre-event bank characteristics and strongly confirms those reported in Panel A of Table 7: Capital is the only factor correlated with the probability of being affected. Interestingly, when we perform a regression based on the post-event bank characteristics (Panel B), we observe that, besides the capital ratio, which remains highly significant, only the Eurosystem borrowing and the market share are statistically significant, whereas there is no significant role to be attributed to the other bank characteristics.

In sum, the capital ratio is the only factor that remains statistically significant in the four analyses previously implemented, which places the capital channel as the most relevant to understand the effect of negative rates on lending policies. In fact, if we restrict our analysis to the pre-shock information (2014Q1), the only bank characteristic that enables us to separate between affected and non-affected banks is the level of capital.

4. Negative interest rates and credit supply

4.1 Loan supply measured from credit growth

To identify the causal impact of the negative DFR on loan growth, we estimate the following diff-in-diff regression:

$$\Delta Credit_{ict} = \alpha_{ct} + \alpha_i + \beta NDFR_{it} + \gamma X_i' + \varepsilon_{ict} \quad (1)$$

The dependent variable, $\Delta Credit$, is the quarterly growth rate of the outstanding loans to non-financial corporations (NFCs)[17] by bank *i* in country *c* at quarter *t*. This variable is regressed on a dummy variable called *NDFR* that is equal to one for the banks affected by the negative DFR (i.e., those for which the negative interest rates lead to a decrease in their net interest income) and zero for all banks before 2014Q2. While we believe that we measure the negative DFR shock with precision, we cannot rule out the existence of other confounding factors that may have an impact on banks' lending policies. To ameliorate concerns about an omitted variable bias, we introduce several sets of controls. First, we include bank fixed effects to control for all time-invariant bank heterogeneity. Second, we include country-time fixed effects (i.e., a dummy for each country-quarter combination as denoted by α_{ct}) to eliminate variation in the dependent variable that is specific to a particular country in a particular period of time. This large set of dummies controls for all the time-varying country-specific factors that influence loan policies (e.g., business cycle). Third, the vector X_i' is a vector of bank-level variables. As the existing literature highlights the importance of banks' balance sheets for the transmission of monetary policy (e.g., Jiménez *et al.*, 2012), we include several indicators of banks' financial health (e.g., capital and liquidity ratios) as well as measures of banks' business models (loan-to-deposit ratio, deposit ratio), legal form, size and market share. Fourth, as differences in the composition of credit demand (i.e., borrowers' characteristics and loan purposes) can lead to different lending policies, we also control for them in our regressions using the answers to the BLS regarding demand developments. Fifth, as the introduction of the negative DFR took place concurrently with other non-standard policy measures such as the TLTROs, we deal with these confounding events by including the total borrowing from the Eurosystem over total assets. Finally, ε_{ict} is an error term.

[17] To reduce the effect of outliers, the variable has been winsorized at 90%.

The results reported in column (1) of Table 9 are obtained considering the quarterly credit growth for the period that spans from 2013Q2 to 2016Q1. The regressor of interest, NDFR, is constructed using the banks' answers to the first BLS question on the effects of negative rates on bank profitability. In column (2) we extend the sample period up to 2017Q3 and consider all the answers to the question of interest.

Independently from the sample period, our results show that there are not significant differences in the credit supply of both affected and non-affected banks. This conclusion can also be drawn after a graphical analysis (Figure 1): The average credit growth of affected and unaffected banks show similar evolutions over time. Hence, the results suggest that the reversal rate has not been reached.

4.2 Loan supply measured from credit standards

Another alternative to measure credit supply is through banks' credit standards. In fact, Lown and Morgan (2006) or Ciccarelli et al. (2015), among others, identify credit standards as reported in lending surveys as proxies for credit supply. Given that credit standards are defined from an answer to the BLS we consider a different methodology to identify the causal impact of the negative DFR on credit standards. We estimate an ordered probit model in which the dependent variable, ΔCS, measures changes in credit standards applied by bank *i* located in country *c* in loans granted to enterprises at quarter *t*. The ordered probit model is specified in terms of a continuous latent variable, *latent credit standards,* ΔCS^*:

$$\Delta CS^*_{ict} = \alpha_{ct} + \beta NDFR_{it} + \gamma X'_i + \varepsilon_{ict} \quad (2)$$

Observed changes in credit standards ΔCS_{ict}, as reported to the BLS, are then related to latent changes in *credit standards* ΔCS^*_{ict} in the following way:

$$\begin{aligned} \Delta CS_{ict} &= \text{"}eased\text{"} \quad \text{if} \quad \Delta CS^*_{ict} \leq \mu_1 \\ \Delta CS_{ict} &= \text{"}remained\ unchanged\text{"} \quad \text{if} \quad \mu_1 < \Delta CS^*_{ict} \leq \mu_2 \\ \Delta CS_{ict} &= \text{"}tightened\text{"} \quad \text{if} \quad \Delta CS^*_{ict} > \mu_3 \end{aligned} \quad (3)$$

where the parameters μ_1, μ_2, μ_3 are thresholds to be jointly estimated with the slope parameters by maximum likelihood. We then compute the marginal effects of *NDFR*. For instance, for the probability that credit standards are eased, the corresponding marginal effect is:

$$P(\Delta CS_{ict} = \text{"}eased\text{"}/NDFR_i = 1) - P(\Delta CS_{ict} = \text{"}eased\text{"}/NDFR_i = 0) \quad (4)$$

To compute (4) we first need to find the response probability in terms of the error term:

$$P(\Delta CS_{ict} = \text{"}eased\text{"}) = P\left(\Delta CS^{*}_{ict} \leq \mu_1\right) = P(\varepsilon_{ict} \leq \mu_1 - \alpha_{ct} - \beta NDFR_i - \gamma X_i') =$$

$$= F(\varepsilon_{ict} \leq \mu_1 - \alpha_{ct} - \beta NDFR_i - \gamma X_i') \quad (5)$$

where F(.) is the standard normal cumulative distribution function.

Then we must evaluate the response probabilities at the values of *NDFR*. Plugging $NDFR_{it} = 0{,}1$ into (5):

$$P(\Delta CS_{ict} = \text{"}eased\text{"}/NDFR_{it} = 1) = F(\varepsilon_{ict} \leq \mu_1 - \alpha_{ct} - \beta - \gamma X_i') \quad (6)$$

$$P(\Delta CS_{ict} = \text{"}eased\text{"}/NDFR_{it} = 0) = F(\varepsilon_{ict} \leq \mu_1 - \alpha_{ct} - \gamma X_i') \quad (7)$$

Finally, we subtract (7) from (6) to obtain the marginal effect.

Our empirical strategy implies the comparison of changes in credit standards between *affected* and *non-affected* banks *after* the introduction of the negative DFR in June 2014. An alternative approach would be to compare those changes between affected and non-affected banks *before* and *after* June 2014, i.e., a differences-in-difference analysis similar to the one in the previous section. The particular nature of our data makes us select the first strategy. Specifically, in the BLS banks are asked to report whether their credit standards and their terms and conditions have eased, remained unchanged or tightened in the past three months. The answers are qualitative, so banks do not provide exact figures (e.g., growth rates) on these developments to quantify the intensity of the changes.[18] Consider for instance a bank that tightened credit standards *slightly* in the quarter just before the introduction of the negative DFR, 2014Q1. If the bank tightens them *substantially* as a consequence of the negative DFR in the quarter just after its introduction, 2014Q2, then the after-before difference will be zero. However, the same would be true for another bank that leaves credit standards unchanged during that period, so that two banks with very different policies caused by the negative DFR would be assigned the same value of the dependent variable. Hence, to avoid this problem we focus on the period after the introduction of the negative DFR and compare the outcomes of treatment and control banks.

[18] This notwithstanding, the BLS allows banks to differentiate between "tightened/eased considerably" and "tightened/eased somewhat". However, the low number of answers in those categories, relative to the answers that report "unchanged", makes us avoid that distinction and simply analyze "tightened", "eased" and "unchanged".

The results reported in Table 10 confirm that, independently from the sample period used in the analysis, the negative DFR had no significant impact on banks' credit standards, which suggests that bank did not expand their loan supply. We next study the effect of the negative DFR on loan terms and conditions which, as the credit standards, are contained in the BLS.

5. The effect of negative interest rates on loan terms and conditions.

As credit standards, loan terms and conditions refer to the bank answers to several questions included in the BLS. Thus, the methodology used to obtain the effect of negative rates on loans terms and conditions is the one described in Section 4.2. The results are contained in panels A–E of Table 11. Each panel corresponds to a specific loan term or condition and its structure is analogous to that of Table 10. We display the estimations using only the first answer to the question on the negative DFR (2014Q2-2016Q1) and combining the four answers to the question (2014Q2-2017Q3). Recall that, when analyzing the answers to the first question, the only bank characteristic that differentiated affected and non-affected banks was the capital ratio, while there were other characteristics, such as the deposit rate and the liquidity ratio, which distinguished the two groups of banks when combining all the answers (Table 7).

In view of Panel A, we sustain that the negative DFR did not have an impact on collateral requirements. By contrast, negative rates reduced loan maturity (Panel B). The reduction of loan maturity is more sizeable when we focus on the answers to the first question (2014Q2-2016Q1), according to which the most affected banks are those with low capital ratios. As reported in columns (1) and (2) of Table 11, affected banks had a 9.2 pp lower probability of increasing loans' maturity and a 2.9 pp higher probability of decreasing it. This finding suggests that banks affected by the introduction of the negative DFR aimed to reduce the effective risk of their loan portfolio by reducing average loan maturity.[19] In fact, a lower maturity also helps reduce the regulatory risk-weighted assets and, hence, the need for capital (see Basel Committee of Banking Supervision, 2011).

We interpret the two previous findings (no effect on collateral, strong effect on maturity) by noticing that collateral requirements and loan maturity may be strategic

[19] Ortiz-Molina and Penas (2008) and Kirschenmann and Norden (2012), among others, document that the probability of default falls as loan maturity is reduced.

substitutes in reducing the risk of the loan portfolio, in the sense that, as borrowers are less likely to default on short-term loans, there is less need to collateralize them. For instance, Boot *et al.* (1991) argue that the longer the maturity, the more likely that the bank will request collateral to align the borrower and the lender incentives. Consistent with this view, Mayordomo *et al.* (2017), in their study of personal and real guarantees, find that collateral is increasingly prevalent at longer maturities and larger loans.

The connection between loan terms and conditions and risk taking is corroborated by Panel C, which shows the estimation results of an ordered probit model in which the dependent variable is *risk tolerance*. As this variable is only available since 2015Q1, the reduced number of observations forces us to substitute (additive) country and time dummies for country-time dummies. Consistently with Panel B, the effects of negative rates on risk taking are stronger when we focus on the responses to the first question in columns (1) and (2), according to which affected banks are those lowly capitalized. In view of the estimates referred to the first question, banks affected by the negative DFR had a 6.9 pp lower probability of increasing their risk tolerance and a 5.4 pp higher probability of decreasing it. These findings confirm our hypothesis that low capital limits banks' risk taking, following the negative shock to net worth implied by the negative DFR.

As a complementary view of the lower risk taken by affected banks, we next have a closer look at the evolution of the risk-weighted assets (RWA) of affected and non-affected banks, classified from their answers to the BLS question the first time it was included in the survey. According to the argument about the central role played by bank capital, a negative DFR erodes the affected banks' profitability and in turn their capacity to generate capital via retained earnings and, hence, it can be interpreted as a negative shock to banks' net worth. If net worth decreases to the point where the capital constraint binds, then a bank's ability to take on additional risk becomes limited. The lower risk-taking would go hand on hand with lower RWA. Given that this optimization was not accomplished through a cut in the supply of credit, lending policies aimed at lowering risk taking represent the main channel to optimize RWA. Figure 2 depicts the evolution of the ratio of RWA to total assets for the two groups of banks during the period 2012-2017, and documents that those negatively affected by negative rates reduce that ratio by more than unaffected banks. Hence, this evidence is in agreement with results contained in Table 11 and provides further support to the idea that the

negative DFR makes affected banks take comparatively less risk probably due to the existence of (regulatory and economic) capital constraints.[20]

The negative DFR also implied a reduction of loan size (Panel D) but only in the shorter sample period (i.e., columns (1) and (2)). Thus, affected banks had a 7.7 pp lower probability of increasing loan size and a 1.9 pp higher probability of decreasing it.[21] By reducing their average loan size and keeping the overall size of their loan portfolio unchanged, affected banks may diversify more their loan portfolio in an attempt to reduce non-systematic risk. This hypothesis seems to be supported by the fact that the introduction of the negative DFR had no significant impact on banks' credit growth and credit standards, which suggests that banks did not expand their loan supply.

Finally, the negative DFR led to an increase of non-interest charges (Panel E) in the two sample periods. Considering the average marginal effects in columns (1) and (2), banks affected by the negative DFR had a 4.8 pp lower probability of reducing non-interest charges than non-affected competitors and a 2.4 pp higher probability of increasing them. This suggests that banks tried to offset the reduction in net interest income by increasing commission and fees.

6. Analysis based on loan-level data

The previous results suggest that those banks more affected by negative interest rates tend to react by diminishing the risk of their loan portfolio without reducing their credit supply. In this section we take advantage of the Credit Register of the Bank of Spain (CRR) to dig deeper on this issue using information at loan level.

The CCR contains information on every loan given to non-financial institutions above 6,000 euros, including the size of the credit instrument and other characteristics such as maturity, guarantees and creditworthiness. The fact that these data are available at the firm-bank level enables us to better control for demand effects and so to isolate the specific effect of negative interest rates on the supply of credit.

We conduct a set of analyses similar to the ones undertaken above for the Euro area banks. As before, we classify banks as affected and non-affected. The ten Spanish banks that participate in the BLS account around 60% of the total amount of credit

[20] For a distinction between the two see Elizalde and Repullo (2007).
[21] The lower size of the loans granted by affected banks also suggests that there is less need to collateralize them, as in Mayordomo *et al.* (2017).

outstanding by June 2014. According to the answers to the first BLS question (April 2016), five of these ten banks stated that their net interest income had not been affected by the negative interest rates, whereas the other five indicated that they had been adversely affected by this measure. Importantly, as in the case of the sample of European banks, we also find that the Spanish banks affected by negative interest rates have a capital ratio that on average is 1 pp lower than those that report to be unaffected.

6.1 Loan supply

We first study whether affected banks modified their flow of new credit activity. To this aim, we propose a regression analysis in which the dependent variable ($\Delta ln(Credit_{ib})$) is the change in the logarithm of credit committed by bank *j* to firm *i* (in thousands of euros plus one, to deal with zeros), both drawn and undrawn, between June 2013 and June 2015 (i.e., the pre- and post-event periods depart one year from the date of the event):[22]

$$\Delta ln(Credit_{ij})_{ib} = \alpha_i + \beta_1 \cdot NDFR_b + \gamma X_b' + \varepsilon_{ib} \qquad (8)$$

where the coefficient β_1 indicates whether affected banks increase or diminish the amount of loans granted to NFC after the event as compared to non-affected banks. The parameter α_i denotes the use of firm fixed effects to capture demand factors. The vector X_b contains bank characteristics as of 2013 (i.e., before the event). Concretely, we use proxies for bank credit risk (non-performing loans over total loans), size (logarithm of total assets), profitability (ROA), leverage (total liabilities over total assets), and liquidity (liquid assets over total assets. We have 210,862 bank-firm observations in total.[23]

The results contained in column (1) of Table 12 suggest that there are not significant differences in the credit supply of the two types of banks. The results are fully consistent with those obtained for Europe and suggest that affected Spanish banks were not operating below their "reversal rate". The analysis is implemented computing the credit growth up to June 2015 and at that moment, the DFR was at -0.2% suggesting

[23] Notice that (8) is a diff-in-diff estimation in first-differences. We prefer this approach, rather than estimating a long panel of credit in levels (i.e., monthly values of the credit stock between June 2013 and June 2015), to eliminate the serial correlation problem of diff-in-diff estimates (Bertrand et al, 2014), as in Kwaja and Mian (2008) and Ponticelli and Alencar (2016). We avoid this by eliminating the time-series dimension of the data via first-differencing a panel of time dimension T=2. Notice that first-differencing also removes the bank fixed effects.

that the reversal rate is lower than -0.2%. However, the current DFR is -0.4% since March 2016 and so, the previous results do not provide enough evidence to conclude that the "reversal rate" has not been reached yet. For this reason, in column (2) we extent the post-event period up to June 2016 to obtain the growth rate of credit and conduct a similar analysis to that summarized in equation (8). The coefficient associated to the dummy denoting the banks adversely affected by negative interest rates is not statistically different from zero suggesting that the reversal rate would fall below -0.4%.

To get a deeper understanding of how affected and unaffected banks adjust their supply of loans to different firms' segments of risk, we extend equation (8) by including an interaction term capturing firms' risk. We measure firm risk by means of a dummy variable, denoted as $DIST_i$, that is equal to one if a firm is in the "distress zone" according to the Altman's Z-score corresponding to December 2012 and zero otherwise.[24] This variable is interacted with the dummy variable $NDFR_b$:

$$\Delta Log(Credit)_{ib} = \alpha_i + \beta_1 NDFR_b + \beta_2 NDFR_b \cdot DIST_i + \gamma X_b' + \varepsilon_{ib} \quad (9)$$

where coefficient β_1 indicates whether the increase in the supply of credit of affected banks to safer firms after June 2014 exceeds that of non-affected banks. The linear combination of coefficients β_1 and β_2 indicates whether the increase in the supply of credit of affected banks to riskier firms after June 2014 exceeds that of non-affected banks to the same type of firms.

Results are reported in column (3) of Table 12. The number of observations of this estimation decreases around 60% because of the lack of the balance-sheet information required for computing the Z-score for all the firms for which we observe the bank-firm credit exposure. The positive and significant coefficient β_1 indicates that the supply of credit of affected banks to safer firms increases significantly more than that of non-affected banks. On the contrary, affected banks reduce their credit supply to riskier firms by more than non-affected banks such that the linear combination of coefficients β_1 and β_2 is negative (-0.019) and statistically different from zero. On average, the supply of credit of an affected bank to the average riskier firm in the

[24] The Z-score is estimated based on the specification for private firms according to which the safe zone is the one in which the Z-score is lower than 1.23. For more details, see Altman (1968).

sample decreases by 1.9 % more than that of non-affected banks. It confirms that affected banks decrease their credit supply to the segment of riskier firms more than non-affected banks after the date in which the DFR turns into the negative territory.

6.2 Maturity and collateral

We next study whether the propensity to reduce the risk of the loan portfolios of affected banks also lead them to shorten the maturity of their loans. For that aim, we propose an analysis similar to the one summarized in equation (8) and conducted on the same sample period. The dependent variable in this analysis is the change between June 2013 and June 2015 in the proportion of firm *i's* outstanding short-term loans (i.e., maturity lower than one year) with bank *b* over the total amount of loans outstanding of that firm with the same bank ($\Delta ShortRunCr_{ib}$). We regress this variable on a dummy variable that is equal to one if the bank declares being affected by the negative rate ($NDFR_b$), firm fixed effects and pre-shock bank variables In total, we have 190,655 bank-firm observations. The regression equation is as follows:

$$\Delta ShortRunCr_{ib} = \alpha_i + \beta_1 NDFR_b + \gamma X_b' + \varepsilon_{ib} \qquad (10)$$

where the coefficient β_1 indicates whether affected banks increase or diminish the amount of short-run loans after the event as compared to non-affected banks.

The results obtained from the estimation of equation (10) for the variable Δ*ShortRunCr* are reported in column (1) of Table 13. They support the lower risk appetite of affected banks and their tendency to shorten the maturity of their loans. More specifically, the proportion of short-term loans in the portfolio of affected banks increases by 3.3 % more than that for non-affected banks.

To check whether the negative DFR contributed to alter the requirement of collateral by affected banks, we perform a regression analysis similar to that in equation (10) but using as a dependent variable the change in the proportion of loans of firm *i* in bank *b* with collateral. This proportion is obtained by means of a weighted average in which the weights are proportional to the size of each loan. The results are reported in column (2) of Table 13. We observe that, after the introduction of a negative DFR, affected banks require collateral to a higher extent than non-affected banks.

Putting things together, the previous results reveal the preference of banks affected by the negative DFR towards a safer loans portfolio, presumably as a way to optimize their relatively lower capital ratios, as supported by Figure 2. The reduction in

the level of risk of the loans given by affected banks' would have been accomplished through a shortening of the maturity of new loans and a higher demand for collateral, both as compared to non-affected banks.

7. Conclusions

This paper offers new empirical evidence on the relevance of the various channels through which negative interest rates affect banks' net interest income in the context of the recent experience of the Euro area. To this aim, we exploit survey data at the bank-level. We find that those banks that report a negative impact of negative rates on their net interest income have capital ratios that on average are significantly lower than those banks that report to be unaffected.

Banks reporting a higher incidence of negative interest rates on their net interest incomes tend to exhibit lower risk tolerance and grant loans with shorter maturity and lower average loan size. As affected banks are less capitalized, these results could probably reflect the limitation of those banks to expand their risk weighted assets as a way to compensate for lower unit lending margins. We report qualitatively consistent findings when we use very detailed loan level data obtained from the Spanish official credit registry.

In addition, we find that those European banks whose net interest income is adversely affected by the negative interest rates attempt to offset the adverse effect on net interest income by increasing non-interest charges, so that the generated revenue can be used to build capital organically. Finally, the results obtained from both the Euro area and Spanish datasets suggest that there are no significant differences in terms of the supply of credit by those banks whose net lending margins are affected by negative interest rates and those that are not. Within the logic of hypothesis recently put forward by Brunnermeier's and Koby (2017) about the so-called reversal rate, our results provide support to the view that for the average bank the interest rates are not sufficiently low so as to exert a negative effect on the supply of credit.

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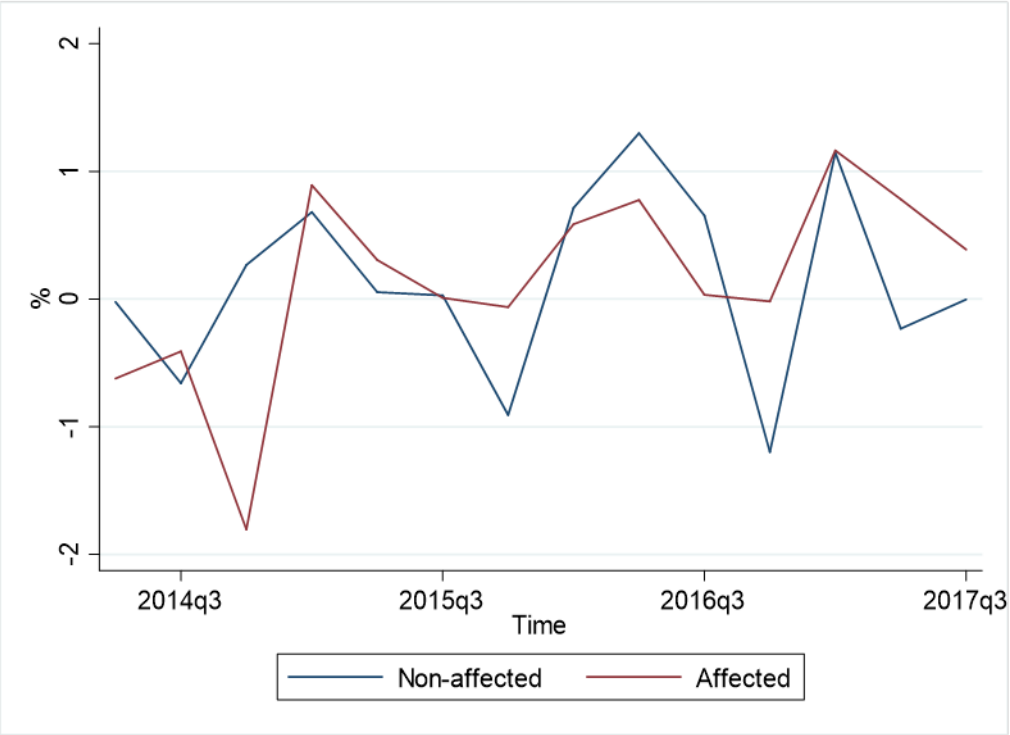

Figure 1: average credit growth. This figure summarizes the evolution of the average quarterly growth rate of loans to NFCs for affected banks and non-affected banks.

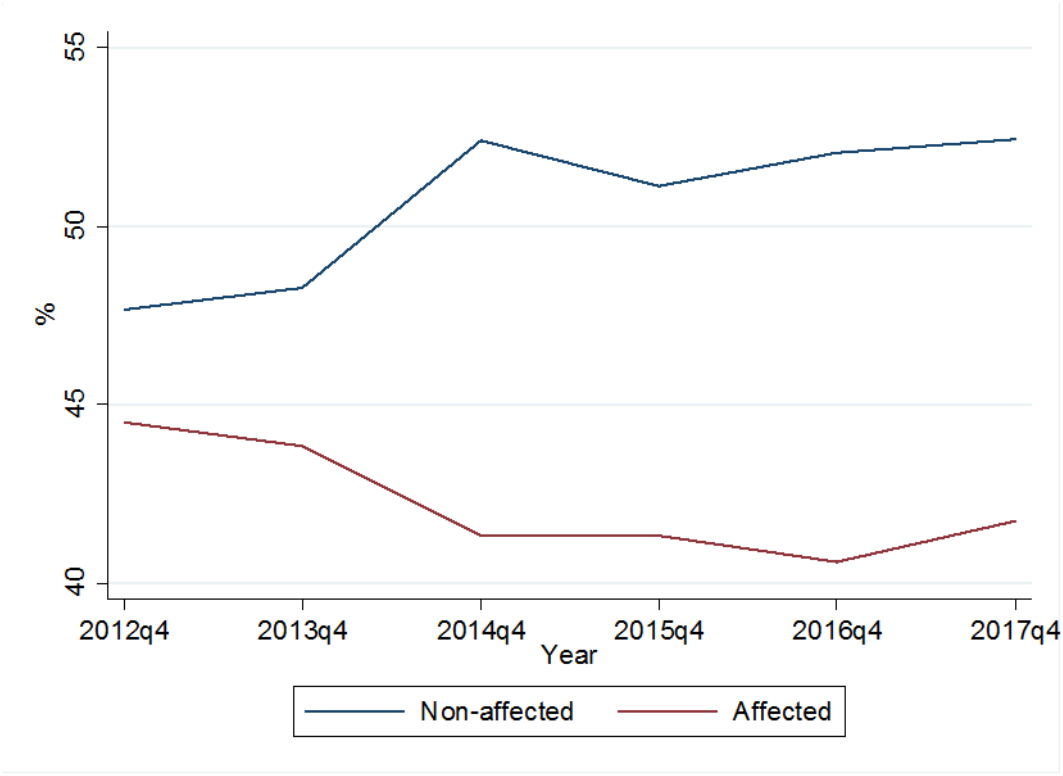

Figure 2: RWA over total assets. This figure summarizes the evolution of the median ratio of RWA over total assets at the end of each year for affected banks and non-affected banks.

Table 1: Number of banks and number of observations by country

This table summarizes the number of banks in our sample for each country as of 2017Q3 and the number of observations corresponding to each country for the whole sample period 2014Q2-2017Q3.

	Number of banks (2017Q3)		Number of observations (2014Q2-2017Q3)	
Country	Freq.	Percent	Freq.	Percent
AT	8	6.5	109	6.43
BE	4	3.3	56	3.3
DE	26	21.1	375	22.1
EE	5	4.1	70	4.1
ES	10	8.1	140	8.3
FR	14	11	196	12
IE	7	5.69	98	5.79
IT	22	17.9	284	16.8
LT	4	3.3	44	2.6
LU	5	4.1	70	4.1
NL	8	6.5	112	6.6
PT	5	4	70	4
SK	5	4.07	70	4.13
Total	123	100	1,694	100

Table 2: Definition of variables

This table contains the definition of the dependent variables used in the analyses implemented along the paper plus the set of control variables used to measure demand and bank characteristics.

Dependent variables	
credit standards	Change in the overall credit standards applied to new loans or credit lines to enterprises.
credit growth	Quarterly growth rate of loans to non-financial corporations.
non_interest_charges	Change in the non-interest charges for new loans or credit lines to enterprises.
loan_size	Change in the size of the loans or credit lines to enterprises.
collateral	Change in the collateral requirements of the loans or credit lines to enterprises.
maturity	Change in the maturity of the loans or credit lines to enterprises.
risk tolerance	Change in the level of the bank's risk tolerance.
Demand variables	
demand_sme	Change in the demand for loans or credit lines to small and medium enterprises.
demand_large	Change in the demand for loans or credit lines to large firms.
demand_short_term	Change in the demand for short-term loans or credit lines to enterprises.
demand_long_term	Change in the demand for long-term loans or credit lines to enterprises.
demand_investment	Change in the demand for loans or credit lines to enterprises for fixed investment.
demand_inventories	Change in the demand for loans or credit lines to enterprises for inventories and working capital.
demand_mergers	Change in the demand for loans or credit lines to enterprises for mergers/acquisitions and corporate restructuring.
demand_debt_refinancing	Change in the demand for loans or credit lines to enterprises for debt refinancing/restructuring and renegotiation.

Table 2: Definition of variables (cont'd)

Bank variables	
NDFR	Dummy that equals 1 if the negative deposit facility rate contributed to a decrease in the bank's net interest income.
size	Logarithm of the bank's total assets.
capital ratio	Capital and reserves over total assets (%)
liquidity ratio	Cash + government securities + Eurosystem deposits over total assets (%)
loan-to-deposit ratio	Loans to non-financial corporations and households over deposits by non-financial corporations and households.
deposit ratio	Deposits by households and non-financial corporations over total assets (%).
eurosystem borrowing	Total borrowing from the Eurosystem (marginal lending facility + main refinancing operations + fine-tuning operations) over total assets (%)
market_share	Ratio between a bank's total assets and the total assets of the country's banking sector (%).
legal_form: foreign branch	Dummy that equals 1 if the bank is a branch of a foreign bank.
legal_form: foreign subsidiary	Dummy that equals 1 if the bank is a subsidiary of a foreign bank.
legal_form: head institution	Dummy that equals 1 if the bank is the head institution of the banking group.
legal_form: national subsidiary	Dummy that equals 1 if the bank is a subsidiary of a domestic bank.

Table 3: Descriptive statistics of dependent variables

This table contains the descriptive statistics of the dependent variables referred to credit standards, credit growth, loan terms and conditions and bank risk tolerance that are used along the analyses implemented in the paper for the sample period 2014Q2-2017Q3.

Variable	Obs	Mean	Std. Dev.	Min	Max
Credit					
credit standards: eased	1,630	0.05	0.22	0	1
credit standards: unchanged	1,630	0.93	0.26	0	1
credit standards: tightened	1,630	0.02	0.13	0	1
credit growth	1,502	0.20	3.64	-7.93	7.49
Terms and conditions					
non_interest_charges: eased	1,621	0.04	0.20	0	1
non_interest_charges: unchanged	1,621	0.93	0.26	0	1
non_interest_charges: tightened	1,621	0.03	0.17	0	1
loan_size: eased	1,622	0.06	0.24	0	1
loan_size: unchanged	1,622	0.93	0.26	0	1
loan_size: tightened	1,622	0.01	0.10	0	1
collateral: eased	1,621	0.05	0.21	0	1
collateral: unchanged	1,621	0.95	0.23	0	1
collateral: tightened	1,621	0.01	0.10	0	1
maturity: eased	1,619	0.07	0.25	0	1
maturity: unchanged	1,619	0.92	0.27	0	1
maturity: tightened	1,619	0.02	0.12	0	1
Risk tolerance					
risk tolerance: increased	1,259	0.02	0.13	0	1
risk tolerance: unchanged	1,259	0.97	0.18	0	1
risk tolerance: decreased	1,259	0.02	0.13	0	1

Table 4: Descriptive statistics of bank characteristics

This table contains the descriptive statistics of the bank characteristics that are used as independent variables along the analyses implemented in the paper for the sample period 2014Q2-2017Q3.

Variable	Obs	Mean	Std. Dev.	Min	Max
NDFR	1,694	0.73	0.45	0	1
size	1,644	10.69	1.54	2.77	13.88
capital ratio	1,640	10.69	6.05	0.25	100.00
liquidity ratio	1,487	7.67	6.19	0.00	32.38
loan-to-deposit ratio	1,596	18.56	191.26	0.21	3804.00
deposit ratio	1,644	40.80	22.45	0.00	87.00
eurosystem borrowing	1,644	1.03	2.51	0.00	17.39
market_share	1,651	6.05	7.64	0.00	41.92
legal_form: foreign branch	1,694	0.04	0.19	0	1
legal_form: foreign subsidiary	1,694	0.21	0.41	0	1
legal_form: head institution	1,694	0.49	0.50	0	1
legal_form: national subsidiary	1,694	0.26	0.44	0	1

Table 5: Descriptive statistics of demand variables

This table contains the descriptive statistics of the demand variables that are used as control variables along the analyses implemented in the paper for the sample period 2014Q2-2017Q3.

Variable	Obs	Mean	Std. Dev.	Min	Max
demand_sme: decreased	1,566	0.12	0.33	0	1
demand_sme: unchanged	1,566	0.65	0.48	0	1
demand_sme: increased	1,566	0.23	0.42	0	1
demand_large: decreased	1,561	0.11	0.31	0	1
demand_large: unchanged	1,561	0.68	0.47	0	1
demand_large: increased	1,561	0.21	0.41	0	1
demand_short_term: decreased	1,627	0.10	0.31	0	1
demand_short_term: unchanged	1,627	0.71	0.45	0	1
demand_short_term: increased	1,627	0.18	0.39	0	1
demand_long_term: decreased	1,627	0.10	0.29	0	1
demand_long_term: unchanged	1,627	0.64	0.48	0	1
demand_long_term: increased	1,627	0.26	0.44	0	1
demand_investment: decreased	1,626	0.11	0.32	0	1
demand_investment: unchanged	1,626	0.69	0.46	0	1
demand_investment: increased	1,626	0.20	0.40	0	1
demand_inventories: decreased	1,605	0.06	0.24	0	1
demand_inventories: unchanged	1,605	0.76	0.43	0	1
demand_inventories: increased	1,605	0.18	0.38	0	1
demand_mergers: decreased	1,608	0.03	0.17	0	1
demand_mergers: unchanged	1,608	0.85	0.35	0	1
demand_mergers: increased	1,608	0.12	0.32	0	1
demand_debt_refinancing: decreased	1,621	0.03	0.16	0	1
demand_debt_refinancing: unchanged	1,621	0.85	0.36	0	1
demand_debt_refinancing: increased	1,621	0.12	0.33	0	1

Table 6: Number of observations of affected and non-affected banks by country

This table summarizes the number of observations in our sample for each country for the group of affected banks (NDFR=1) and non-affected banks (NDFR=0) for the period 2014Q2-2017Q3.

	NDFR=1		NDFR=0	
Country	Freq.	Percent	Freq.	Percent
AT	85	6.8	24	5.2
BE	40	3.2	16	3.4
DE	326	26.3	63	13.5
EE	44	3.5	26	5.6
ES	82	6.6	58	12.5
FR	99	8.0	97	20.8
IE	44	3.5	54	11.6
IT	204	16.4	80	17.2
LT	38	3.1	6	1.3
LU	64	5.2	6	1.3
NL	94	7.6	18	3.9
PT	68	5.5	2	0.4
SK	54	4.4	16	3.4
Total	1,242	100	466	100

Table 7: Descriptive statistics of bank characteristics for affected and non-affected banks

This table contains the number of observations and means of bank characteristics for the banks that are affected (NDFR=1) and non-affected by the negative DFR (NDFR=0). It also includes the difference in means between the two groups and the p-value associated with a two-sample t-test of equality of means.

Panel A: 2014 Q1

	NDFR=1		NDFR=0		Difference in means	
Variable	Obs	Mean	Obs	Mean	Diff	P-value
Size	78	10.82	27	10.31	0.50	0.11
Capital ratio	78	9.85	27	12.43	-2.58	0.06
Liquidity ratio	71	8.06	27	6.23	1.83	0.17
Loan-to-deposit ratio	78	38.63	27	41.37	-2.74	0.86
Deposit ratio	77	7.95	25	6.84	1.11	0.60
Eurosystem borrowing	78	2.60	27	1.65	0.95	0.21
Market_share	78	6.31	27	4.26	2.05	0.15
Legal_form: foreign branch	80	0.03	27	0.04	-0.01	0.77
Legal_form: foreign subsidiary	80	0.20	27	0.15	0.05	0.53
Legal_form: head institution	80	0.58	27	0.44	0.13	0.25
Legal_form: national subsidiary	80	0.20	27	0.37	-0.17	0.11
Loan maturity	77	61.09	27	59.44	1.65	0.64
Weight overdraft loans	77	0.16	27	0.17	-0.02	0.60
Weight loans up to 1 year	77	0.24	27	0.25	-0.02	0.65
Deposit maturity	78	5.55	25	4.95	0.61	0.65
Weight overnight deposits	78	0.56	25	0.61	-0.05	0.29

Panel B: 2014Q2-2017Q3

	NDFR=1		NDFR=0		Difference in means	
Variable	Obs	Mean	Obs	Mean	Diff	P-value
Size	1,206	10.69	570	10.68	0.01	0.87
Capital ratio	1,206	10.34	566	11.35	-1.00	0.00
Liquidity ratio	1,081	8.17	523	7.03	1.13	0.00
Loan-to-deposit ratio	1,191	16.96	533	14.76	2.20	0.76
Deposit ratio	1,206	42.70	570	38.60	4.10	0.00
Eurosystem borrowing	1,206	1.16	570	0.53	0.63	0.00
Market_share	1,209	6.52	575	4.98	1.53	0.00
Legal_form: foreign branch	1,242	0.04	591	0.04	0.00	0.71
Legal_form: foreign subsidiary	1,242	0.22	591	0.22	0.00	1.00
Legal_form: head institution	1,242	0.54	591	0.38	0.16	0.00
Legal_form: national subsidiary	1,242	0.21	591	0.36	-0.15	0.00
Loan maturity	1,199	60.13	557	58.63	1.50	0.05
Weight overdraft loans	1,199	0.15	557	0.15	0.00	0.58
Weight loans up to 1 year	1,199	0.23	557	0.24	0.00	0.55
Deposit maturity	1,197	4.12	545	4.15	-0.03	0.90
Weight overnight deposits	1,197	0.65	545	0.66	-0.01	0.49

Table 8: Bank characteristics correlated with being affected by the negative interest rates.

This table shows the bank characteristics that are correlated with being affected by the negative interest rates. The dependent variable is NDFR. In particular, banks are affected by the negative interest rates (NDFR=1) if they answer that the negative deposit facility rate contributed to a decrease in their net interest income in the 6 months prior to the survey, and unaffected otherwise (NDFR=0). The sample period is shown in each panel. The model is estimated by OLS. Robust standard errors in parentheses are clustered at bank level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	2014Q1	2014Q2-2017Q3
VARIABLES		
Size	-0.024	-0.025
	(0.050)	(0.028)
Capital ratio	-0.032***	-0.017**
	(0.011)	(0.007)
Liquidity ratio	0.002	0.000
	(0.008)	(0.005)
Deposit ratio	-0.004	0.000
	(0.004)	(0.002)
Loan-to-deposit ratio	-0.001	0.000
	(0.001)	(0.000)
Eurosystem borrowing	0.010	0.019**
	(0.010)	(0.007)
Market share	0.009	0.009***
	(0.007)	(0.003)
Loan maturity	0.303	0.001
	(0.428)	(0.002)
Deposit maturity	0.275	-0.002
	(0.439)	(0.007)
Legal_form: foreign branch	0.210	0.115
	(0.456)	(0.214)
Legal_form: foreign subsidiary	-0.000	0.232
	(0.004)	(0.211)
Legal_form: head institution	-0.000	0.067
	(0.009)	(0.221)
Constant	1.170*	0.869**
	(0.691)	(0.382)
Observations	94	1,445

Table 9: Negative interest rates and credit supply. Diff-in-diff analysis.

This table shows the effect of the negative deposit facility rate (NDFR) on the supply of loans to non-financial corporations. The results are obtained from a within-group estimator of a model with bank fixed effects. The dependent variable is the quarterly growth rate of loans to NFCs. It is regressed on bank and demand controls. As for the former we use size, capital ratio, liquidity ratio, loan-to-deposit ratio, deposit ratio, Eurosystem borrowing, market share and legal form of the bank. As for the latter group of controls we use dummy variables for changes (decrease, unchanged, increase) in the demand of credit by non-financial corporations in the following segments: SMEs and large firms, short-term loans and long-term loans, loans for fixed investment, loans for inventories, loans for mergers and acquisitions and loans for debt refinancing/restructuring. In addition, we use country-time fixed effects. The sample period is shown in each panel. Robust standard errors in parentheses are clustered at bank level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	2013Q2-2016Q1	2013Q2-2017Q3
	(1)	(2)
Variables	credit growth	credit growth
NDFR	-0.089	0.101
	(0.390)	(0.214)
Bank controls	YES	YES
Demand controls	YES	YES
Bank FE	YES	YES
Country-Time FE	YES	YES
Observations	1,063	1,578
Number of banks	105	112
R-squared	0.279	0.259

Table 10: Negative interest rates and credit standards

This table shows the marginal effect of the negative deposit facility rate (NDFR) on the standards of loans to non-financial corporations of those banks whose net interest income was adversely affected by negative interest rates. The results are obtained from a pooled ordered probit as detailed in equations (2) - (7). The dependent variable, which refers to the standards, takes the values 1 (eased), 2 (remained unchanged) and 3 (tightened) and is regressed on bank and demand controls. As for the former we use size, capital ratio, liquidity ratio, loan-to-deposit ratio, deposit ratio, Eurosystem borrowing, market share and legal form of the bank. As for the latter group of controls we use dummy variables for changes (decrease, unchanged, increase) in the demand of credit by non-financial corporations in the following segments: SMEs and large firms, short-term loans and long-term loans, loans for fixed investment, loans for inventories, loans for mergers and acquisitions and loans for debt refinancing/restructuring. In addition, we use country-time fixed effects. Columns (1) and (3) ((2) and (4)) contain the results referred to the effect of the NDFR on the probability that credit standards (CS) are eased and tightened, respectively. The sample period is shown in each panel. Robust standard errors in parentheses are clustered at bank level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	2014Q2-2016Q1		2014Q2-2017Q3	
	(1)	(2)	(3)	(4)
Variables	P(CS=eased)	P(CS=tightened)	P(CS=eased)	P(CS=tightened)
NDFR	0.011	-0.003	0.020	-0.006
	(0.029)	(0.008)	(0.016)	(0.006)
Bank and Demand Controls	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES
Observations	698	698	1,334	1,334
Number of banks	98	98	110	110

Table 11: Negative interest rates and terms & conditions

This table shows the marginal effect of the negative deposit facility rate (NDFR) on several terms and conditions of loans to non-financial corporations of those banks whose net interest income was adversely affected by negative interest rates. The results are obtained from a pooled ordered probit as detailed in equations (2) - (7). The dependent variable, which refers to the terms and conditions and standards, takes the values 1 (eased), 2 (remained unchanged) and 3 (tightened) and is regressed on bank and demand controls. As for the former we use size, capital ratio, liquidity ratio, loan-to-deposit ratio, deposit ratio, Eurosystem borrowing, market share and legal form of the bank. As for the latter group of controls we use dummy variables for changes (decrease, unchanged, increase) in the demand of credit by non-financial corporations in the following segments: SMEs and large firms, short-term loans and long-term loans, loans for fixed investment, loans for inventories, loans for mergers and acquisitions and loans for debt refinancing/restructuring. In addition, we use country-time fixed effects. Panel A refers to the probability that collateral requirements (Col) are eased (columns (1) and (3)) or tightened (columns (2) and (4)). Panel B contain the results referred to the effect of the NDFR on the probability that the maturity is eased (lengthened) in columns (1) and (3) or tightened (shortened) in column (2) and (4). The results in Panel C refer to the effect of the NDFR on the probability that the risk tolerance increased (column (1) and columns (3)) and decreased (column (2) and column (4)). Columns (1) and (3) of Panel D contain the results referred to the effect of the NDFR on the probability that the loan size increased whereas columns (3) and (4) show the results associated to a decrease in the loan size. Finally, the results in Panel E refer to the effect of the NDFR on the probability that the non-interest decreased (columns (1) and (3)) and increased (columns (2) and (4)). The sample period is shown in each panel. Robust standard errors in parentheses are clustered at bank level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A	2014Q2-2016Q1		2014Q2-2017Q3	
	(1)	(2)	(3)	(4)
Variables	P(Col=eased)	P(Col=tightened)	P(Col=eased)	P(Col=tightened)
NDFR	0.003	-0.001	-0.003	0.001
	(0.014)	(0.007)	(0.013)	(0.005)
Bank and Demand Controls	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES
Observations	698	698	1,329	1,329
Number of banks	98	98	110	110
Panel B	2014Q2-2016Q1		2014Q2-2017Q3	
	(1)	(2)	(3)	(4)
Variables	P(Mat=eased)	P(Mat=tightened)	P(Mat=eased)	P(Mat=tightened)
NDFR	-0.092***	0.029***	-0.039***	0.017**
	(0.024)	(0.009)	(0.013)	(0.007)
Bank and Demand Controls	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES
Observations	697	697	1,329	1,329
Number of banks	98	98	110	110

Table 11: Negative interest rates and terms & conditions (cont'd)

Panel C	2015Q1-2016Q1		2015Q1-2017Q3	
	(1)	(2)	(3)	(4)
Variables	P(RT=increased)	P(RT=decreased)	P(RT=increased)	P(RT=decreased)
NDFR	-0.069***	0.054***	-0.013*	0.014**
	(0.020)	(0.016)	(0.007)	(0.007)
Bank and Demand Controls	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Observations	427	427	1,027	1,027
Number of banks	93	93	103	103

Panel D	2014Q2-2016Q1		2014Q2-2017Q3	
	(1)	(2)	(3)	(4)
Variables	P(Siz=increased)	P(Siz=decreased)	P(Siz=increased)	P(Siz=decreased)
NDFR	-0.077***	0.019***	-0.022	0.005
	(0.018)	(0.006)	(0.014)	(0.003)
Bank and Demand Controls	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES
Observations	698	698	1,329	1,329
Number of banks	98	98	110	110

Panel E	2014Q2-2016Q1		2014Q2-2017Q3	
	(1)	(2)	(3)	(4)
Variables	P(Fee=decreased)	P(Fee=increased)	P(Fee=decreased)	P(Fee=increased)
NDFR	-0.048**	0.024**	-0.025**	0.019**
	(0.019)	(0.010)	(0.010)	(0.008)
Bank and Demand Controls	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES
Observations	697	697	1,328	1,328
Number of banks	98	98	110	110

Table 12: Negative interest rates and credit supply. Evidence from Spain

This table contains the coefficients estimated for a regression analysis in which the dependent variable is the first-difference of the logarithm of credit committed by bank j to firm i (in thousands of euros plus one, to deal with zeros), both drawn and undrawn. In column (1) we use a pre- and a post-event period that departs one year from the date of the event (i.e., June 2013 and June 2015) to obtain the variation in credit whereas in column (2) the post-event period is extended up to June 2016. Columns (1) and (2) report the result obtained when the corresponding dependent variable is regressed on a variable that is equal to one if the negative DFR (NDFR) contributed to a decrease of the net interest margin of bank b and zero otherwise plus bank characteristics and firm fixed effects as detailed in equation (8). In column (3) we report the results obtained from the estimation of equation (9) in which we extend the analysis in column (1) by including an interaction term capturing firms' risk. We measure firm risk by means of a dummy variable, denoted as DIST, that is equal to one if a firm is in the "distress zone" according to the Altman's Z-score corresponding to December 2012 and zero otherwise. This variable is interacted with the dummy variable NDFR.The number of observations of this estimation decreases around 60% with respect to column (1) because the lack of the balance-sheet information required for computing the Z-score for all the firms for which we observe the bank-firm credit exposure. Standard errors in brackets are robust to heteroscedasticity. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)
NDFR	-0.002	0.009	0.028**
	[0.006]	[0.009]	[0.012]
NDFR * DIST			-0.047***
			[0.011]
Bank Characteristics	YES	YES	YES
Firm FE	YES	YES	YES
Observations	210,862	170,410	89,260
R-squared	0.432	0.457	0.436

Table 13: Negative interest rates and loan maturity and collateral. Evidence from Spain

This table summarizes the effect of negative interest rates on the loan maturity and collateral for a sample of Spanish banks and firms. The dependent variable in column (1) is the change between June 2013 and June 2015 in the proportion of firm i's outstanding short-term loans (i.e., maturity lower than one year) with bank b at time t over the total amount of loans outstanding of that firm with the same bank at that time. The dependent variable in (2) is the change in the proportion of loans of firm i in bank b with collateral between the same two years. Both dependent variables are regressed on a dummy variable that is equal to one if the negative DFR contributed to a decrease of the net interest margin of bank b, and zero otherwise, plus bank characteristics and firm fixed effects. Standard errors in brackets are robust to heteroscedasticity. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1) SR Maturity (1-year)	(2) Guarantee
Post * NDFR	0.033***	0.031***
	[0.003]	[0.002]
Bank Characteristics	YES	YES
Firm FE	YES	YES
Observations	210,861	210,862
R-squared	0.413	0.439