Life below Zero: Bank Lending under Negative Policy Rates*

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We show that negative policy rates affect the supply of bank credit in a novel way. Banks are reluctant to pass on negative rates to depositors, which increases the funding cost of high-deposit banks, and reduces their net worth, relative to low-deposit banks. As a consequence, the introduction of negative policy rates by the European Central Bank in mid-2014 leads to more risk-taking and less lending by euro-area banks with a greater reliance on deposit funding. Our results suggest that negative rates are less accommodative and could pose a risk to financial stability, if lending is done by high-deposit banks. (*JEL* E44, E52, E58, G20, G21)

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How does monetary policy transmit to the real sector once interest rates break through the zero lower bound? Negative monetary policy rates are unprecedented and controversial. Central banks around the world struggle to rationalize negative rates using conventional wisdom.[1]

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[1] To stimulate the economy in its post-crisis state with low growth and low inflation, the European Central Bank (ECB) and also the central banks of Denmark, Switzerland, Sweden and Japan have set their policy rates below zero. In contrast, the Bank of England and the Federal Reserve have refrained from setting negative rates amid

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This paper examines the transmission of negative policy rates to the real sector via the supply of bank credit. We find that when the European Central Bank (ECB) reduces the deposit facility (DF) rate from 0 to −0.10% in June 2014 and, shortly after, in September 2014, from −0.10 to −0.20%, banks with more deposits concentrate their lending on riskier firms in the market for syndicated loans. A 1-standard-deviation increase in banks' deposit ratio leads to the financing of firms with at least 16% higher return-on-assets volatility and to a reduction in lending of at least 13%.

The typical way to think about monetary policy transmission via bank lending—as described in, for example, Bernanke (2007)—cannot explain this pattern. First, bank deposits play no special role. Second, banks should generally lend more when the policy rate decreases. A lower (positive) policy rate lowers banks' cost of funding, and thereby increases bank net worth. More net worth, in turn, reduces banks' external finance premium, allowing banks to expand lending. And third, when the policy rate decreases, banks with higher net worth have more "skin-in-the-game" (or, equivalently, a higher franchise value) and should take less risk.

To explain our findings, we augment this standard view with a new effect that kicks in when the policy rate becomes negative. When the policy rate becomes negative, greater reliance on deposits (relative to market-based debt) has an adverse effect on bank net worth. This adverse effect on bank net worth explains why banks with more deposits should lend less and take more risk once the policy rate becomes negative.

Deposit funding hurts bank net worth because the lower negative policy rate does not transmit to lower negative deposit rates, while it does transmit to lower negative market rates. Normally, lower positive policy rates transmit to lower rates on both deposits and market-based debt. We show this is no longer the case for deposit rates once the ECB sets negative rates. Hence, banks relying more on deposit funding relative to market-based funding experience a lower reduction in their cost of funding, which adversely affects their net worth.

Negative policy rates do not transmit to lower deposit rates because banks appear reluctant to charge negative rates to their depositors. The distribution of deposit rates of euro-area banks is truncated at zero. Moreover, more deposit rates bunch at zero once the ECB lowers the policy rate to below zero.

The theoretical argument for not charging negative deposit rates is intuitive. As soon as deposits offer a negative nominal return, they become inferior to cash, which offers a zero nominal return, and depositors withdraw. Fearing deposit withdrawals, banks do not lower deposit rates to below zero.[2]

concerns about their effectiveness and adverse implications for financial stability. For the concerns of the Bank of England, see Carney (2016). Hilsenrath and Torry (2015) describe the Federal Reserve's reluctance.

[2] That holding physical currency may come with storage costs could, in theory, allow banks to charge negative deposit rates. These costs are, however, difficult to estimate, and banks appear reluctant to test this boundary by setting negative deposit rates, for which we provide evidence in our analysis.

Based on this logic, we examine the transmission of negative policy rates to the supply of bank credit using a difference-in-differences approach. We compare the lending behavior of banks with different deposit ratios before and after the ECB sets negative policy rates in mid-2014. Our identifying assumption therefore is that the lending behavior of low-deposit banks provides the counterfactual for the lending behavior of high-deposit banks in the absence of a negative policy rate.

The following example illustrates the essence of our identification strategy. A common problem of identifying the impact of monetary policy on the supply of bank credit is the endogeneity of monetary policy. The ECB sets negative rates because it is concerned about deteriorating economic conditions. At the same time, it is plausible that banks lend less and to riskier borrowers, because, when economic conditions deteriorate, the few lending opportunities available tend to be risky. In this case, the estimated impact of negative policy rates on banks' lending behavior is biased because the deteriorating economy drives both.

Comparing the lending behavior of high-deposit and low-deposit banks can address the endogeneity of monetary policy. If both types of banks face the same deterioration in economic conditions, the impact of deterioration is canceled out when we consider only the difference in the lending behavior of high-deposit and low-deposit banks around the setting of negative rates.

A main threat to our identification strategy is that the control group, low-deposit banks, may be inappropriate. This applies when a difference between high-deposit and low-deposit banks changes when the policy rate becomes negative (and matters for their lending behavior). Such a time-varying difference violates the parallel-trends assumption, which is key to the identification of a causal effect in a difference-in-differences setup.

Time-varying differences between high-deposit and low-deposit banks may occur when other bank characteristics that drive bank lending decisions, or indeed the deposit ratio itself, are not stable around the time of setting the negative policy rate.

In our most comprehensive attempt to address time-varying differences between high-deposit and low-deposit banks, we use confidential supervisory information to compare banks with a lot of household deposits to those with few household deposits. Because it is easier for households than for corporates to withdraw their deposits, banks should be more reluctant to charge negative rates on household rather than corporate deposits. This comparison is regardless of a bank's overall reliance on deposit funding. Hence, variation of the deposit ratio and its correlation with other bank characteristics do not matter. In line with this reasoning, we find that our difference-in-differences estimate is not only larger but also is more precisely estimated for banks with a greater reliance on household deposits.

Comparing banks with different reliance on household versus corporate deposits also limits the scope for other coincidental events driving our findings.

Central bank open-market operations, asset-purchase programs, and other regulatory changes could potentially affect the lending of certain banks more than others (although we argue that this is unlikely in our setting). It is, however, much less plausible that these other policy events affect banks differently according to whether their depositors are households or corporations.

An additional important source of potential bias in our setting is selection of firms and banks into lending relationships according to banks' deposit ratio. If high-deposit and low-deposit banks faced different investment opportunities following negative policy rates, then this would introduce time-varying differences between these two types of banks. To address this issue, we exploit the granularity of our transaction-level data on syndicated loans, and we compare the lending behavior of high-deposit and low-deposit banks to the same borrower. Including firm-time fixed effects eliminates any time-varying difference in lending opportunities (e.g., loan demand) between high-deposit and low-deposit banks. In line with our other results, we find that high-deposit banks reduce their loan shares for safe borrowers, but increase their loan shares for risky borrowers.

One may wonder whether negative policy rates are indeed special. Maybe we just identify a hitherto unknown role of bank deposits for the general transmission of policy rates. We examine this possibility by expanding our sample and including multiple policy rate changes, independent of their size or timing, or whether there are cuts or increases. We find that banks' deposit ratio does not matter for the pass-through of nonnegative rates to banks' risk-taking and lending volume. Instead, the transmission of policy rates to the supply of bank credit via deposits occurs only when policy rates become negative.

Our preferred explanation for our findings is that less skin-in-the-game exacerbates a bank's internal agency problem, which raises the external finance premium and gives less incentives to screen and monitor risky borrowers. In line with this reasoning, we find that the risk-taking of high-deposit banks is concentrated in banks with little equity, that is, those that have little skin-in-the-game.

While high-deposit banks lend to riskier firms, these riskier firms do not appear to be "zombie" firms. Firms receiving new loans from high-deposit banks have less leverage and the same profitability as firms receiving new loans from low-deposit banks. Moreover, the riskier lending of high-deposit banks is concentrated in private and, thus, potentially more financially constrained firms. High-deposit banks also engage in riskier lending if they previously lent to the same industry. Altogether, the evidence suggests more risk-taking but no obviously reckless lending behavior.

Finally, we assess the external validity of our findings. While syndicated loans account for a sizable portion of total bank lending, they do not necessarily capture overall bank lending behavior. Using market data, we show that high-deposit banks exhibit higher stock-return volatility and a stronger increase in their credit-default-swap spreads when the policy rate becomes negative, attesting to their risk-taking. Using annual balance-sheet data, we also show that while overall bank lending increases after the setting of negative policy rates, the lending of high-deposit banks increases less than the lending of low-deposit banks.

1. Related Literature

Our analysis makes the following contributions. First, negative policy rates truly are unchartered territory, both theoretically and empirically.[3] To the best of our knowledge, ours is the first paper to examine empirically how negative policy rates transmit to the real economy.[4]

Brunnermeier and Koby (2018) propose a theory of the "reversal interest rate" below which accommodative monetary policy becomes contractionary. Their theory, however, does not explicitly consider negative policy rates. Rognlie (2016) and Eggertsson, Juelsrud, and Wold (2017) present New Keynesian macroeconomic models to evaluate the impact of negative policy rates. In Rognlie (2016), a banking sector is absent, and negative rates are costly, because they subsidize holding currency, which offers a zero nominal return. In Eggertsson, Juelsrud, and Wold (2017), banks finance themselves only with deposits, the rate of which cannot become negative. The lack of pass-through of a negative policy rate to lower, that is, negative, deposit rates leads to a lack of pass-through to lower lending rates. Therefore, negative policy rates are not expansionary in their model.

Second, we contribute to an emerging literature on the role of deposit financing in banks' behavior. Drechsler, Savov, and Schnabl (2017b) examine the ability of U.S. bank branches to raise deposit rates and attract deposits when the policy rate increases. An increase in the policy rate transmits more to market rates than to deposit rates. Deposits become less attractive as a store of value and hence, banks lose deposit funding. This loss of stable funding causes banks to reduce lending. Drechsler, Savov, and Schnabl (2017a) show that banks' maturity transformation does not expose banks to interest-rate risk. Market power allows banks to keep deposit rates stable, which is then matched with stable income from long-term assets.

Third, by considering policy rate reductions into negative territory, we extend the literature on the bank lending channel, that is, how policy rate changes affect the supply of bank credit. This literature explores the role of bank size, holdings of liquid assets, and bank equity (Kashyap and Stein 2000; Kishan and Opiela

[3] Before the introduction of negative policy rates in Europe, Saunders (2000) laid out potential implications for bank behavior by considering the case of Japan in the late 1990s.

[4] Recently, Demiralp, Eisenschmidt, and Vlassopoulos (2018) and Basten and Mariathasan (2018) study banks' reaction to negative policy rates in the euro area and in Switzerland, respectively. Arseneau (2017) examines stress-testing data in which U.S. banks project losses in a hypothetical macro-financial scenario involving negative interest rates. None of these studies uses granular data on lenders and their borrowers (e.g., to control for loan demand).

2000; Jiménez et al. 2012). Recently, Gomez et al. (2016) examine the role of the interest-rate sensitivity of assets and liabilities, whereas Agarwal et al. (2018) show how asymmetric information between banks and their borrowers modifies the response of bank lending to funding cost shocks.

Fourth, we extend the understanding of the bank risk-taking channel (Jiménez et al. 2014; Ioannidou, Ongena, and Peydró 2015; Dell'Ariccia, Laeven, and Suarez 2017; Paligorova and Santos 2017) and link it to the literature on the bank lending channel. The bank behavior we characterize—lending less and to riskier firms in response to a negative shock to bank net worth—is in line with theoretical models in which lower bank net worth increases agency problems when screening and monitoring risky, opaque borrowers (e.g., Keeley 1990; Holmström and Tirole 1997; Hellmann, Murdock, and Stiglitz 2000; Dell'Ariccia, Laeven, and Marquez 2014).[5]

Fifth, we contribute to the recent literature assessing the impact of nonstandard monetary policy measures, where existing work mainly focuses on the impact of asset-purchase programs and extraordinary liquidity provision. Chakraborty, Goldstein, and MacKinlay (2019), Rodnyansky and Darmouni (2017), Di Maggio, Kermani, and Palmer (2016), and Kandrac and Schlusche (2017) investigate the impact of quantitative easing in the United States. Carpinelli and Crosignani (2018) examine the ECB's 3-year long-term refinancing operations, which provided liquidity to euro-area banks. Lastly, Ferrando, Popov, and Udell (2017) and Acharya et al. (2018) analyze the ECB's outright monetary transactions program to buy (potentially unlimited) amounts of euro-area sovereign bonds.

2. Empirical Strategy and Data

We start by providing background information on the introduction of negative policy rates, and develop our hypothesis. We then lay out our identification strategy for estimating the effect of negative policy rates on bank lending behavior. Finally, we describe the data.

2.1 Institutional background and hypothesis development

On June 11, 2014, the ECB Governing Council lowered the deposit facility (DF) rate to −0.10%. Shortly after, on September 10, 2014, the DF rate was lowered again to −0.20%. With these actions, the ECB ventured into negative territory for the first time in its history.[6] The main goal of setting negative rates

[5] Angeloni, Faia, and Lo Duca (2015) offer a different take on the relationship between monetary policy and bank risk-taking and test it using aggregate time-series data when policy rates are positive. Lower policy rates induce banks to take on (long-term) risk on their liability side by substituting cheaper, but run-prone, deposits for equity.

[6] The DF rate is not the only policy rate of the ECB, but since the introduction of the "fixed-rate-full-allotment" regime in October 2008 after the Lehman bankruptcy, the DF rate is the relevant policy rate. For a review of how the ECB implements monetary policy before and after the financial crisis, see Garcia-de-Andoain et al. (2016).

was to provide monetary policy accommodation (Praet 2014). Setting negative rates in mid-2014 was seen as a bold and controversial move. Especially the cut in September came as a surprise. Since then, the ECB has lowered the DF rate two more times, on December 9, 2015, to −0.30%, and on March 16, 2016, to −0.40%.

Within Europe, euro-area banks are not the only ones exposed to negative policy rates. The Swedish Riksbank reduced the repo rate, its main policy rate, from 0% to −0.10% on February 18, 2015. The repo rate determines the rate of interest at which Swedish banks can borrow or deposit funds at the Riksbank. The Swedish experience is preceded by the Danish central bank, Nationalbanken, lowering the deposit rate to −0.20% on July 5, 2012. While the Danish deposit rate was raised to 0.05% on April 24, 2014, it was brought back to negative territory, at −0.05%, on September 5, 2014. Furthermore, the Swiss National Bank went negative on December 18, 2014, by imposing a negative interest rate of −0.25% on sight deposits exceeding a given exemption threshold (see Bech and Malkhozov 2016 for further details on the implementation of negative policy rates in Europe and the transmission to other interest rates).[7]

Our explanation of how policy rate changes transmit to the real economy via changes in the supply of bank credit is based on the standard external finance premium for banks (see Bernanke and Gertler 1995; Gertler and Kiyotaki 2010). Raising external funds is costly for banks because of agency conflicts between outside investors and inside decision makers (e.g., Holmström and Tirole 1997). The size of the external finance premium limits the amount of intermediation that banks can perform. The external finance premium depends on the balance sheet of banks. In particular, a smaller difference between a bank's assets and liabilities, that is, less net worth, increases the external finance premium. When bank net worth is small, insiders have little "skin-in-the-game," agency conflicts are severe, and banks can perform little intermediation. Moreover, insiders with little "skin-in-the-game" have less incentives to carefully screen and monitor risky loans in order to preserve future rents from intermediation (Keeley 1990; Hellmann, Murdock, and Stiglitz 2000; Dell'Ariccia, Laeven, and Marquez 2014).

In normal times—that is, when rates are positive—a lower policy rate increases the supply of bank credit because it reduces banks' external finance premium. A lower policy rate transmits to lower rates on short-term liabilities. This reduces banks' cost of funding because they finance their long-term assets with short-term liabilities. A lower cost of funding increases bank net worth and, thus, leads to more "skin-in-the-game" for insiders who extend more credit and screen as well as monitor borrowers more carefully. This is a joint description of the bank balance-sheet channel of monetary policy transmission (Boivin, Kiley, and Mishkin 2010), which focuses on the volume of bank lending, and

[7] We exploit these additional instances of negative policy rates as a robustness check.

the bank risk-taking channel (Adrian and Shin 2010; Borio and Zhu 2012), which focuses on the riskiness of bank lending.

Lowering the policy rate to below zero is special, because it affects the cost of deposit funding and the cost of market-based short-term debt funding differently. The standard description of how monetary policy affects the supply of bank credit does not assign a special role to deposit funding. A lower policy rate is typically seen to transmit both to lower rates on market-based short-term debt and to lower deposit rates.[8]

While lowering the policy rate to below zero transmits to lower, negative market rates on short-term debt, it does not transmit to lower, negative deposit rates. Figure 1 shows the ECB's deposit facility (DF) rate, the 3-month Euribor (a benchmark for the market rate of unsecured short-term debt), and the median rate of overnight deposits of euro-area banks. The vertical line indicates June 2014, when the ECB lowered the DF rate to below zero.

Prior to January 2013, increases and decreases in the DF rate transmit to increases and decreases in the 3-month Euribor and the median euro-area deposit rate. In our "pre-treatment period" from January 2013 to May 2014, the ECB keeps the DF rate stable and consequently, the 3-month Euribor and the median deposit rate are stable as well. After the lowering of the DF rate to below zero in June 2014, the paths of the 3-month Euribor and the median deposit rate diverge. While the 3-month Euribor decreases in line with the lower policy rate, the median deposit rate remains fairly stable. The median correlation between changes in the 3-month Euribor and changes in individual deposit rates for euro-area banks over a 12-month period after the June 2014 rate cut is only 0.01, whereas the correlation ranges from 0.14 to 0.18 for the rate cuts in positive territory in November 2011, December 2011, and July 2012.

The negative policy rate does not transmit to lower deposit rates because banks appear reluctant to charge negative rates to their depositors. Figure 2 shows the distribution of individual banks' rates on household and nonfinancial-corporation deposits before and after June 2014. A shift of the distribution to the left indicates banks' attempt to lower their cost of deposit funding, but the shift is limited by the truncation of the distribution at zero. Not a single bank charges negative deposit rates to households in December 2014 (top panel). A few banks charge negative deposit rates to nonfinancial corporations (NFCs, bottom panel), which is a feature that we will exploit in our empirical analysis.

The main argument for why banks are reluctant to charge negative deposit rates is based on the zero nominal return on cash. If a bank charged a negative rate to its depositors, they would withdraw their deposits and hold cash as an

[8] For the transmission of central bank policy rates to short-term market rates, see, for example, Kuttner (2001). The transmission to deposit rates is less strong than for market rates on average, but the average decomposes into a strong transmission when the policy rate decreases (which is of interest to us) and a weak transmission when the policy rate increases (Hannan and Berger et al. 1991; Driscoll and Judson 2013). Recently, Drechsler, Savov, and Schnabl (2017b, 2017a) explore the role of market power for banks' willingness to change deposit rates.

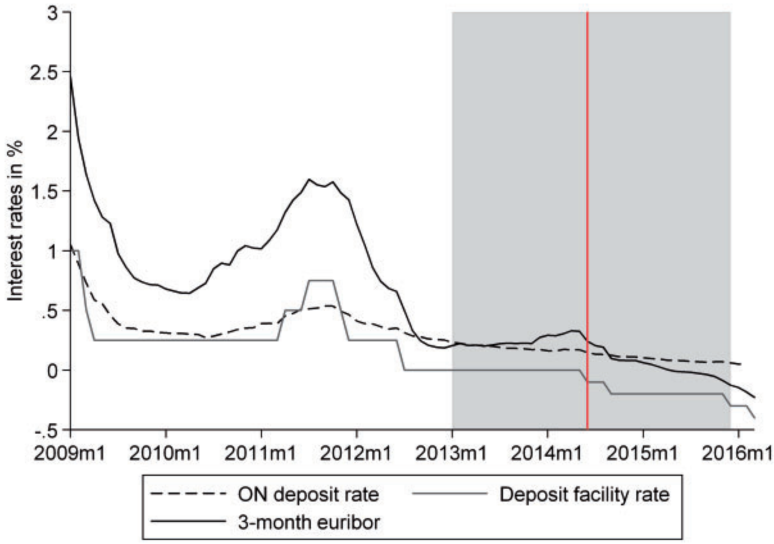

Figure 1
The deposit facility rate, the 3-month Euribor, and the overnight deposit rate
This figure shows the evolution of the median overnight deposit rate at euro-area banks between January 2009 and March 2016, in comparison to the 3-month Euro Interbank Offered Rate (Euribor) and the deposit facility (DF) rate. The Euribor and the DF rate are taken from the ECB Statistical Data Warehouse. Deposit rates are taken from the ECB IMIR database, which provides monthly interest-rate data for euro-area banks at the monetary financial institution (MFI) level. The monthly overnight deposit rate is calculated in two steps. We first calculate the average overnight deposit rate at the MFI level using the overnight rate on household deposits and the overnight rate on non-financial-corporation deposits. We then take the median rate over all MFIs for each month. The gray area represents the sample period for our main analysis (January 2013 to December 2015). The vertical line is drawn at June 2014.

alternative store of value and means of payment. This argument should apply more to household deposits than to corporate deposits. Households should find it easier to withdraw their deposits and hold cash than corporations, because they have fewer and much smaller deposit accounts. The evidence in Figure 2 that some banks can charge negative deposit rates to nonfinancial corporations is consistent with this logic.

The differential transmission of negative policy rates to market rates of short-term debt and to deposit rates exposes banks differently to negative policy rates depending on their liability structure. Relative to banks with little deposit funding, banks with a lot of deposit funding experience a lower reduction of their cost of funding and, thus, a negative shock to their net worth. Holding everything else constant, this assumption motivates our empirical strategy and its robustness throughout the analysis.

Banks with a lot of deposit funding indeed experience a negative shock to their net worth relative to banks with little deposit funding when the ECB sets a negative policy rate in June 2014. Figure 3 shows an (unweighted) stock price index for listed euro-area banks in the highest and the lowest tercile of the

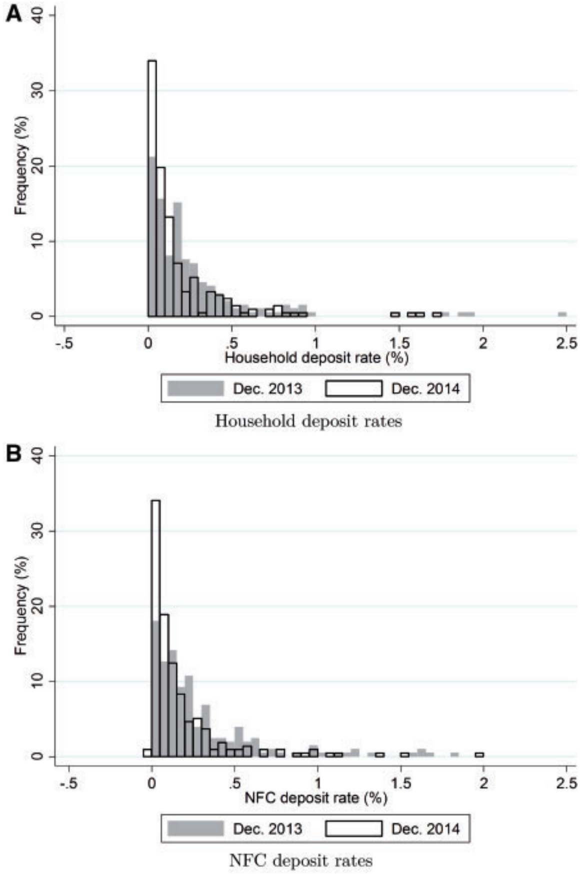

Figure 2
Distribution of deposit rates (households and nonfinancial corporations)
This figure shows the distribution of overnight deposit rates for households (in the top panel) and nonfinancial corporations (in the bottom panel) in December 2013 (gray bars) and December 2014 (white bars). The data are taken from the ECB IMIR database, which provides monthly interest-rate data for euro-area banks at the monetary financial institution (MFI) level.

deposits-to-assets-ratio distribution. The stock prices of high-deposit and low-deposit banks move in tandem between January 2013 and May 2014, prior to the introduction of negative policy rates. But there is a disconnect since June 2014: high-deposit banks perform worse, because the policy rate becomes negative. Within a couple of months, they lose around 10% of stock market value.[9]

Given that high-deposit banks experience a lower reduction of their cost of funding when the policy rate becomes negative and, thus, experience a negative

[9] Ampudia and Van den Heuvel (2018) provide complementary evidence using an event-study methodology. In normal times, a decrease in the policy rate increases banks' stock prices regardless of their deposits-to-assets ratio. When the policy rate becomes negative, a decrease in the policy rate decreases banks' stock prices, and more so for high-deposit banks.

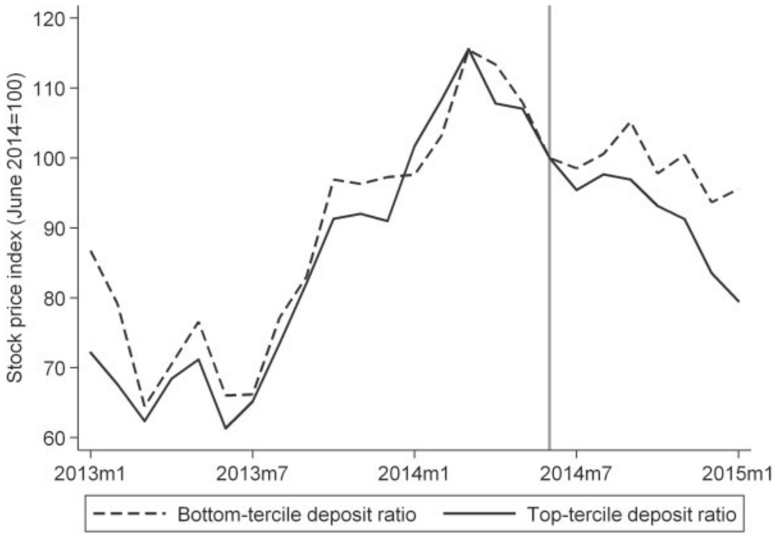

Figure 3
Stock price index of listed banks with high- versus low-deposit ratios
This figure shows the evolution of a monthly stock price index (June 2014 = 100) for listed euro-area banks in our sample between January 2013 and February 2015. We calculate a price index for each bank and plot the median index for banks in the top (solid line) and bottom tercile (dashed line) of the deposit-ratio distribution in 2013. Stock market data are taken from Thomson Reuters Datastream.

shock to their net worth, we expect this reduction of insiders' "skin-in-the-game" to lead to more risk-taking and less lending (all relative to low-deposit banks).

In sum, we aim to test the following hypothesis: negative policy rates lead to greater risk-taking and less lending by banks with more deposit funding.

2.2 Identification strategy

To test our hypothesis, we use a difference-in-differences strategy, which we implement by comparing the lending behavior of euro-area banks with different deposit ratios around the ECB's introduction of negative policy rates in June 2014.

We analyze banks' lending behavior in the syndicated loan market. In this market, different banks form a syndicate, which then lends to firms. We focus on the lead arrangers in a syndicate. Lead arrangers are those members of a syndicate typically responsible for traditional bank duties, including due diligence, payment management, and loan monitoring (Ivashina and Scharfstein 2010). They also tend to hold on to their loan share throughout its life. This is in contrast with other syndicate members, which may sell their shares in the secondary market.[10]

[10] In the subset of so-called "leveraged loans," even the lead arrangers may sell their shares. All results in our paper are robust to dropping leveraged loans, where we follow the definition of leveraged loans in Bruche, Malherbe, and Meisenzahl (2017).

To link lead arrangers and borrowers, and to obtain loan-level information, we use data on the issuance of syndicated loans from DealScan.[11] We match the DealScan data with Bureau van Dijk's Amadeus data on European firms and with SNL Financial's data on European banks.

Our baseline specification is

$$y_{ijt} = \beta Deposit\ ratio_j \times After(06/2014)_t + \gamma X_{ijt} + \delta_t + \eta_j + \epsilon_{ijt}, \qquad (1)$$

where y_{ijt} is an outcome variable reflecting, for instance, a firm/loan characteristic such as firm risk or loan terms associated with firm i's loan provided by loan syndicate j at time t. To directly infer percentage changes, we often use the dependent variable in logs. $Deposit\ ratio_j$ is equal to the 2013 deposit ratio of the euro-area lead arranger in syndicate j if there is only one lead arranger. If there are multiple lead arrangers, $Deposit\ ratio_j$ is equal to the average deposit ratio in 2013 across all euro-area lead arrangers of syndicate j. $After(06/2014)_t$ is a dummy variable for the period from June 2014 onward, X_{ijt} denotes firm-level and syndicate-level control variables, and δ_t denotes time fixed effects. η_j is a bank fixed effect in syndicates with only one lead arranger. If there are multiple lead arrangers, η_j denotes a vector of bank fixed effects containing one fixed effect for each lead arranger in syndicate j.

To minimize the influence of confounding factors, we use a relatively short window around the June 2014 event, from January 2013 to December 2015, in our baseline. We examine the robustness of our results by varying the estimation window by, for example, shortening the "post-treatment" period.

We cluster standard errors at the bank level. Bertrand, Duflo, and Mullainathan (2004) show that the persistence of the treatment variable in a difference-in-differences setup induces serial correlation in the regression error within treated units. To adjust for this serial correlation, they recommend to cluster standard errors at the level of the treated unit, which in our case is the bank.[12]

The key identifying assumption is that conditional on bank and time fixed effects, as well as potential control variables X_{ijt}, low-deposit banks provide the counterfactual for the lending behavior of high-deposit banks in the absence of a negative policy rate. In that case, the estimate of β in regression (1) gives the causal impact of the negative policy rate on the supply of bank credit via banks' cost of funding.

The main threat to the identifying assumption are time-varying differences across high-deposit and low-deposit banks. Such time-varying differences put

[11] We define lead arrangers as banks that provide 100% of the loan, or have any one of the following lender roles in DealScan: lead bank, lead manager, (mandated) lead arranger, joint arranger, colead arranger, coarranger, coordinating arranger, mandated arranger, (admin) agent, or bookrunner. Furthermore, we do not distinguish between different types of syndicated loans, for example, revolvers or term loans. This is because the hypothesis that we test has implications only for the granting of new loans in general, regardless of the type of loan.

[12] We have enough clusters (70 banks) to reliably obtain a cluster-robust variance estimator.

the lending behavior of high-deposit and low-deposit banks on different trends, which cannot be differenced out.

We assess the robustness of our difference-in-differences strategy in several ways. First, we examine whether the deposits-to-assets ratio changes differently across high-deposit and low-deposit banks, either in response to or in anticipation of the negative policy rate. If it did, low-deposit banks could become high-deposit banks and, therefore, would no longer provide the counterfactual for the lending behavior of high-deposit banks.

Next, we vary the set of control variables X_{ijt}, which essentially refines the comparison of our treatment group (high-deposit banks) and our control group (low-deposit banks). For instance, we include borrowers' country-time and borrowers' industry-time fixed effects. This controls for unobserved time-varying heterogeneity across banks caused by borrowers operating in different countries or industries. We also include bank characteristics that, according to the previous literature, matter for the transmission of (nonnegative) policy rates to the supply of bank credit.

In our most refined specification, we exploit the structure of syndicated loans, and explain the loan shares retained by high-deposit and low-deposit banks. This enables us to include firm-time fixed effects, so that we compare the lending of high-deposit and low-deposit banks to the same firm. This addresses the concern that high-deposit and low-deposit banks potentially face different changes in investment opportunities (e.g., loan demand) over time.

We also modify our measure of banks' exposure to the setting of negative policy rates in order to limit the possibility that some confound affects the lending of high-deposit and low-deposit banks differently. Instead of the ratio of overall deposits to total assets, we consider household (HH) and nonfinancial-corporation (NFC) deposits over total assets, and estimate the following regression specification:

$$y_{ijt} = \beta_1 \textit{HH deposit ratio}_j \times After(06/2014)_t + \beta_2 \textit{NFC deposit ratio}_j \times After(06/2014)_t + \gamma X_{ijt} + \delta_t + \eta_j + \epsilon_{ijt}. \quad (2)$$

According to the evidence shown in Figure 2, the zero lower bound is harder for household-deposit rates than for corporate-deposit rates. Therefore, we expect the effect of setting negative policy rates to be concentrated in banks with relatively more household deposits. Regression (2) compares banks with a lot of household deposits to those with few household deposits (and, thus, a lot of corporate deposits), regardless of the overall deposit ratio.

Another concern is that negative policy rates are not special. Even though we lay out a mechanism through which they are special—because of the zero lower bound on deposit rates—we could be picking up a hitherto unknown role of deposits for the transmission of policy rate cuts in general. To examine this possibility, we estimate the following regression:

$$y_{ijt} = \beta_1 Deposit\ ratio_j \times After(06/2014)_t + \beta_2 Deposit\ ratio_j \times After(07/2012)_t + \gamma X_{ijt} + \delta_t + \eta_j + \epsilon_{ijt}, \quad (3)$$

where $After(07/2012)_t$ is a dummy variable for the period from July 2012 onward.

In July 2012, the ECB cut the DF rate from 0.25% to zero.[13] If negative rates are special, then we expect the estimate of β_2 to be insignificant and the estimate of β_1 to be similar to the estimate of β from the baseline (1). If, however, the negative policy rates are not special, then the estimate of β_2 (as well as of β_1) would pick up a general role of deposits for the effect of policy rate cuts on the supply of bank credit.

This is also a useful placebo test in the following sense. Suppose it is not the difference in the deposits-to-assets ratio across banks that drives lending behavior but the difference in some other bank characteristic. If that other characteristic exposes banks differently to policy rate cuts in general, then one should observe a significant estimate of β_2.

To extend our test of whether negative policy rates are special, we estimate the following generalization of (3):

$$y_{ijt} = \beta_1 Deposit\ ratio_j \times DF\ rate_t \times After(06/2014)_t + \beta_2 Deposit\ ratio_j \times DF\ rate_t + \beta_3 Deposit\ ratio_j \times After(06/2014)_t + \beta_4 Deposit\ ratio_j + \delta_t + \eta_j + \epsilon_{ijt}, \quad (4)$$

where $DF\ rate_t$ is the ECB's deposit facility rate at the monthly level.

Regression (4) allows us to examine changes in the policy rate more generally, independent of their size, timing, or whether they are cuts or increases. We extend our sample to the time period from January 2009 to December 2015, during which the ECB's DF rate varies from +1% to −0.30%. The coefficient of interest in Equation (4) is on the triple interaction of banks' deposit ratio, the ECB's DF rate, and the dummy for the period of negative policy rates since June 2014. The estimate of β_1 shows whether the transmission of negative policy rates via deposits is different from the transmission of positive policy rates, which is captured by β_2. An insignificant estimate of β_2 indicates that the deposits-to-assets ratio does not affect the transmission of policy rates to the supply of bank credit in normal times.

Finally, we exploit geographic variation. We limit our sample to non-euro-area borrowers in order to (at least partially) filter out any effect of negative policy rates on the demand for bank credit. We also show that only the deposit

[13] We choose the DF rate cut in July 2012 because it is the last cut prior to going negative. To estimate (3), we extend our sample to the period from January 2011 to December 2015. The rate reductions in early 2009 and late 2011 are somewhat unusual because they occurred at the height of the financial crisis and the sovereign debt crisis. However, we include them when we estimate Equation (4).

ratio of euro-area lead arrangers, but not that of non-euro-area ones, matters. In the Online Appendix, we also report the results of a staggered difference-in-differences estimation that includes the instances of negative rates in Denmark, Sweden, and Switzerland.

2.3 Data description

In the top panel of Table 1, we present summary statistics for our baseline sample of syndicated loans with any euro-area lead arrangers from January 2013 to December 2015. European syndicated loans in our sample have a 5-year maturity on average, and all loans are floating-rate loans. More than one-quarter of the loans in our sample have a unique lead arranger, and the average number of lead arrangers is 3.6.

The bottom panel of Table 1 presents separate bank-level summary statistics for all euro-area banks in our baseline sample (for a list of banks and their 2013 deposit ratios, see Table B.1 in the Online Appendix).[14] Bank assets mainly consist of loans and securities, making up 57.2% and 26.5% of total assets, respectively. Customer deposits are a main source of bank funding, at 43.1% of total assets. Other main funding sources are debt issuances (21.5%), bank deposits (16.2%), other liabilities (13.6%), and equity (6.2%).

The upper part of panel A in Table 2 examines potential differences in bank characteristics between high-deposit and low-deposit banks, that is, our treatment and control groups. High-deposit (low-deposit) banks are defined as banks in the highest (lowest) tercile of the deposit-ratio distribution in 2013. The average deposit ratio in the high-deposit group is almost 3 times as high as in the low-deposit group (61.1% vs. 21.6%). High-deposit banks are also smaller, have higher equity ratios (6.2 % vs. 5.0%), higher loans-to-assets ratios (68.4% vs. 39.9%), and higher net interest margins (1.5% vs. 0.8%).

The threat to our identification does not, however, come from cross-sectional differences across high-deposit and low-deposit banks (these are differenced out), but from time-varying differences. We conduct a number of formal robustness tests to address this concern in depth. Nevertheless, it is useful to examine briefly raw bank characteristics of high-deposit and low-deposit banks over time (Figures A.1a–A.1d in the Online Appendix).

First, the deposit ratio, our treatment-intensity variable, is fairly stable across high-deposit and low-deposit banks over time. Next, banks' equity and securities ratios, both potentially important determinants of how banks adjust their lending behavior to changes in the policy rate (e.g., Kashyap and Stein 2000), move roughly in parallel since 2011. Finally, the fee income of high-deposit and low-deposit banks also moves in parallel before 2014. High-deposit banks are not "undoing" the (relative) negative shock to their net worth by charging higher fees.

[14] The loan-level deposit ratio in the upper panel of Table 1 is different from the bank-level customer-deposit ratio in the bottom panel, because the former is calculated as an average across lead arrangers in the same syndicate.

Table 1
Summary statistics

Loans sample	Mean	SD	Min	Max	N
$\sigma(ROA_i)^{5y}$	0.04	0.05	0.00	0.49	1,576
$\sigma(return_i)^{36m}$	0.09	0.04	0.03	0.33	665
ROA (%)	4.35	9.14	−98.06	80.01	1,576
Leverage (%)	35.90	20.15	0.00	99.99	1,569
No. of employees in thousands	21.69	56.34	0.00	610.99	1,456
Deposit ratio (%)	40.79	9.45	0.49	64.53	2,450
Equity ratio (%)	5.37	1.09	3.40	13.61	2,450
Euro-area firm $\in \{0,1\}$	0.78	0.41	0	1	2,450
All-in-drawn spread in bps	264.33	157.04	10	850	791
Loan size in 2016 €billion	0.74	1.93	0.00	68.48	2,426
Secured $\in [0,1]$	0.69	0.46	0	1	986
Avg. loan share lead arrangers $\in [0,100]$	23.29	18.60	0	100	591
Financial covenants $\in \{0,1\}$	0.03	0.18	0	1	2,450
Maturity of loan in months	58.78	27.33	1	345	2,386
No. of lead arrangers	3.64	2.86	1	20	2,450
Bank-level sample	Mean	SD	Min	Max	N
Assets					
Total assets (in bill. eur)	309.83	409.11	1.17	1,810.52	70
Loans-to-assets ratio (%)	57.21	17.6	2.03	87.40	66
Securities-to-assets ratio (%)	26.53	12.64	7.82	80.23	69
Other financial assets ratio (%)	11.56	17.53	−9.12	73.39	69
Other assets ratio (%)	7.24	6.03	0.09	27.91	66
Liabilities					
Customer deposits-to-assets ratio (%)	43.05	18.69	0.49	78.39	70
Bank deposits-to-assets ratio (%)	16.18	12.67	0.88	69.78	69
Debt-to-assets ratio (%)	21.54	17.82	0.00	83.44	69
Equity-to-assets ratio (%)	6.16	2.88	1.46	22.64	70
Other fin. liabilities-to-assets ratio (%)	6.76	7.35	−0.34	36.82	70
Other liabilities-to-assets ratio (%)	6.85	11.45	0.13	85.33	70

In the top panel, the baseline sample consists of all completed syndicated loans (package level) of both private and publicly listed firms i at date t granted by any euro-area lead arranger(s) from January 2013 to December 2015. $\sigma(ROA_i)^{5y}$ is the 5-year standard deviation of firm i's ROA (using P&L before tax) from year $t-5$ to $t-1$. $\sigma(return_i)^{36m}$ is the standard deviation of firm i's monthly stock returns in the 36 months before t. $ROA_{i,t-1}$ is firm i's ROA (using P&L before tax) in year $t-1$. $Leverage_{i,t-1}$ is firm i's leverage in year $t-1$. *Deposit ratio* is the average ratio (%) of deposits over total assets in 2013 across all euro-area lead arrangers of syndicate j. *Euro-area firm*$_i$ is an indicator for whether firm i is headquartered in the euro area. The all-in-drawn spread is the sum of the spread over LIBOR and any annual fees paid to the lender syndicate. The bottom panel presents the bank-level summary statistics for all euro-area banks included in the baseline sample. All bank-level variables are calculated using annual balance-sheet and P&L data for the year 2013.

The lower part of panel A in Table 2 shows no significant differences between high-deposit and low-deposit banks in terms of their role in the syndicated loan market. On average, low-deposit banks are lead arrangers of 151 syndicated loans during our sample period, whereas high-deposit banks are lead arrangers of 71 syndicated loans (this difference is not statistically significant). Both types of banks are equally likely to serve as lead arrangers for the loans included in our sample. Furthermore, neither the average loan size nor the average loan share retained by high-deposit and low-deposit banks (in any capacity, i.e., as lead arrangers or participants) are significantly different.

Table 2
Characteristics of high- versus low-deposit banks and loan market shares of top lead arrangers

	High- versus low-deposit banks				
Panel A	Tercile	N	Mean	SD	*t*-stat
Deposit ratio (%)	Bottom	23	21.58	12.60	13.82
	Top	23	61.13	6.04	
Equity ratio (%)	Bottom	23	4.98	2.26	1.94
	Top	23	6.19	2.04	
ln(total assets)	Bottom	23	12.22	1.61	2.00
	Top	23	11.46	0.94	
Loans-to-assets ratio (%)	Bottom	23	39.92	17.97	6.75
	Top	23	68.44	8.56	
ROA (%)	Bottom	23	0.04	0.44	0.54
	Top	23	0.17	1.05	
Net interest margin (%)	Bottom	23	0.78	0.44	4.98
	Top	23	1.53	0.57	
Number of loans as lead arranger	Bottom	23	150.65	231.35	1.47
	Top	23	71.26	116.96	
Proportion of loans as lead arranger	Bottom	23	0.87	0.15	1.20
	Top	23	0.81	0.18	
Average loan size in 2016 €billion	Bottom	23	1.19	0.68	0.97
	Top	23	1.02	0.53	
Average loan share (%)	Bottom	23	16.68	18.15	0.32
	Top	23	14.99	17.02	
Proportion of leveraged loans $\in [0,1]$	Bottom	23	0.16	0.21	0.41
	Top	23	0.14	0.12	

	Loan market shares – top-15 banks		
Panel B	Deposit ratio (%)	Market share	Total assets (€m)
BNP Paribas	30.57	0.102	1,810,521
Banco Santander	54.48	0.098	1,115,762
Société Générale	27.52	0.069	1,214,193
ING Bank	64.53	0.067	787,566
Deutsche Bank	25.67	0.062	1,611,400
Crédit Agricole	37.95	0.054	1,688,264
Fundacion Bancaria La Caixa	50.16	0.049	351,269
Intesa Sanpaolo	36.71	0.048	624,179
BBVA	51.57	0.046	582,697
UniCredit	48.61	0.041	825,919
Groupe BPCE	40.72	0.035	1,124,857
Commerzbank	50.30	0.034	549,654
BFA Sociedad Tenedora Acciones	40.33	0.031	269,159
Rabobank	49.21	0.030	669,095
Banco de Sabadell	60.76	0.028	163,523

Panel A of this table compares the characteristics of banks with high and low deposit ratios. High-deposit (low-deposit) banks are defined as banks that are in the top (bottom) tercile of the deposit-ratio distribution in 2013. The deposit ratio is defined as total deposits over total assets. The last column shows the absolute value of the t-statistic for a test whether the difference in means between both groups is equal to zero. The sample period for the summary statistics in the upper part of Panel A is the year 2013. The summary statistics in the lower part of Panel A are based on the sample of all completed syndicated loans of both private and publicly listed firms granted by any euro-area (participating or lead) bank from January 2013 to December 2015. Panel B lists the top-15 banks with the highest market share in our syndicated-loans sample. Market shares are calculated using loan volumes granted by banks in their function as lead arrangers in syndicated loans, on the basis of the respective loan shares. Together, these 15 banks provide 80% of the syndicated-loan volume in our sample. We also report their 2013 deposit ratio (in %) and total assets (in €m). Deposit ratios and total assets are taken from SNL Financial, market shares are calculated using DealScan data.

Panel B indicates that the European syndicated loan market is concentrated. Fifteen banks make up 80% of the market share in our sample. The deposit ratio within this group strongly varies, with a range from 25.7% to 64.5%.

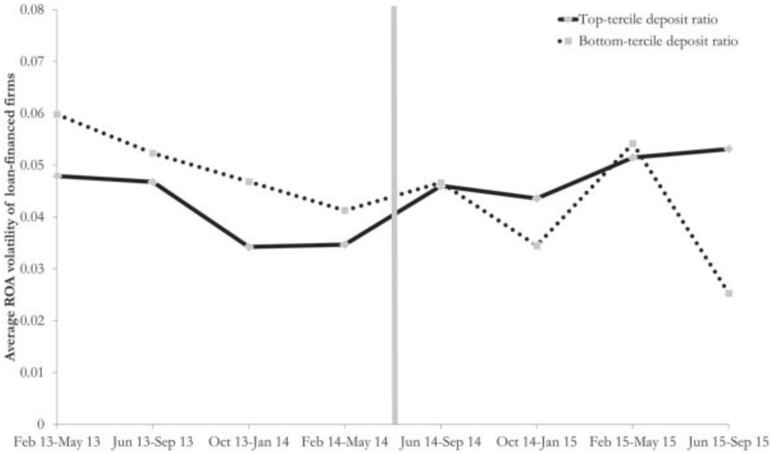

Figure 4
ROA volatility of firms associated with loans granted by banks with high- versus low-deposit ratios
This figure plots the 4-month forward-looking (e.g., the June 2014 data point uses data from June to September 2014) average of ROA volatility of both private and publicly listed firms that received loans from euro-area lead arrangers in the top (solid line) and bottom tercile (dashed line) of the distribution of the average ratio of deposits over total assets in 2013. We plot the 4-month average of ROA volatility to ensure that we have enough observations for the calculation of the mean. For a given loan at date t, the associated ROA volatility is measured as the 5-year standard deviation of the borrower firm's ROA (using P&L before tax) from year $t-5$ to $t-1$. The sample is aligned with that from Table 3.

3. Results

We present our results in four steps. First, we document the effect of negative policy rates on bank risk-taking and on the volume of bank lending. We then further examine the robustness of our results. Next, we characterize the changes in the supply of bank credit in order to assess the underlying mechanism. Finally, we evaluate the external validity of our results.

3.1 Effect of negative policy rates on bank risk-taking and bank lending

In the first two columns of Table 3, we present the results from estimating Equation (1) when the dependent variable y_{ijt} is a measure of banks' ex ante risk-taking. Our baseline measure of ex ante risk-taking is $\sigma(ROA_i)^{5y}$, the 5-year standard deviation of loan-financed firm i's ROA (using profit & loss before tax) from year $t-5$ to $t-1$.

The first column shows the basic difference-in-differences specification with bank and month-year fixed effects only. We find a positive and significant treatment effect. Banks with more deposits finance riskier firms when rates become negative. In terms of economic significance, a 1-standard-deviation increase in *Deposit ratio* (=9.45 percentage points) translates into a 16% increase in ROA volatility ($9.45 \times 0.017 = 0.161$).

Figure 4 graphically represents our baseline result. In the period leading up to the introduction of negative policy rates, risk-taking by both high-deposit banks

Table 3
ROA volatility of firms financed by banks following negative policy rates

	$\ln(\sigma(ROA_i)^{5y})$						
Sample	2013 − 2015				2011 − 2015	2011 − 2015 Non-euro-area borrowers, Euro-area lenders	Non-euro-area lenders
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Deposit ratio × After(06/2014)	0.017*** (0.005)	0.020*** (0.005)		0.018*** (0.006)	0.020*** (0.006)	0.033** (0.014)	0.009 (0.020)
HH deposit ratio × After(06/2014)			0.029*** (0.009)				
NFC deposit ratio × After(06/2014)			0.010 (0.010)				
GDP p.c. growth				−2.682 (2.916)			
ESI growth				0.025 (0.040)			
Credit-demand index				0.001 (0.003)			
Assets_{t-1}				0.088 (0.071)			
$\text{Equity ratio}_{t-1}$				0.036 (0.060)			
$\text{Securities ratio}_{t-1}$				0.011* (0.006)			
Deposit ratio × After(07/2012)					−0.007 (0.004)	−0.012 (0.010)	−0.009 (0.012)
Bank FE	Y	Y	Y	Y	Y	Y	Y
Month-year FE	Y	Y	Y	Y	Y	Y	Y
Country-year FE	N	Y	Y	Y	Y	Y	Y
Industry-year FE	N	Y	Y	Y	Y	Y	Y
R^2	.053	.153	.200	.162	.159	.213	.125
N	1,576	1,576	763	1,538	2,490	542	666

The sample consists of all completed syndicated loans j (package level) of both private and publicly listed firms i at date t granted by any euro-area lead arranger(s), from January 2013 to December 2015 in the first four columns and from January 2011 to December 2015 in the last three columns. The sample in the last column consists of all completed syndicated loans j (package level) of both private and publicly listed firms i at date t granted by any non-euro-area lead arranger(s) from January 2011 to December 2015. In the last two columns, we furthermore limit the sample to non-euro-area borrowers. The dependent variable is the logged 5-year standard deviation of firm i's ROA (using P&L before tax) from year $t-5$ to $t-1$. In the last column, *Deposit ratio* is the average ratio (in %) of deposits over total assets in 2013 across all non-euro-area lead arrangers of syndicate j. In all remaining columns, *Deposit ratio* is the average ratio (in %) of deposits over total assets in 2013 across all euro-area lead arrangers of syndicate j. In the third column, *HH deposit ratio* (*NFC deposit ratio*) is the average ratio (in %) of household (non-financial-corporation) deposits over total assets in the fourth quarter of 2014 across all euro-area lead arrangers of syndicate j, as there is no decomposition of deposits available before that quarter. The sample in the third column is limited to syndicated loans for all lead arrangers of which we have the respective deposit-decomposition data from the Single Supervisory Mechanism. In the fourth column, we control for the quarter-on-quarter growth rates in GDP per capita and the European Sentiment Indicator (ESI), as well as an index based on the country-level answers to the question on loan demand from the ECB's Bank Lending Survey, all for a bank's country of origin in the euro area and averaged across all euro-area lead arrangers of syndicate j. Assets_{t-1} is the logged average value of total assets in year $t-1$ across all euro-area lead arrangers of syndicate j. $\text{Equity ratio}_{t-1}$ is the average ratio (in %) of equity over total assets in year $t-1$ across all euro-area lead arrangers of syndicate j. $\text{Securities ratio}_{t-1}$ is the average ratio (in %) of securities over total assets in year $t-1$ across all euro-area lead arrangers of syndicate j. $After(06/2014)$ is a dummy variable for the period from June 2014 onward. $After(07/2012)$ is a dummy variable for the period from July 2012 onward. Bank fixed effects are included for all euro-area and, if applicable, non-euro-area lead arrangers. Country-year fixed effects are based on the firm's country of origin. Industry-year fixed effects are based on two-digit SIC codes. Public service, energy, and financial services firms are dropped. Robust standard errors (clustered at the bank level) are in parentheses.

and low-deposit banks move in parallel. It decreases, with high-deposit banks lending to less risky firms than low-deposit banks. This gap closes when policy rates become negative, and the previous trend is eventually reversed, implying significantly greater risk-taking by high-deposit banks after June 2014.

In Column 2 of Table 3, we add fixed effects to control for borrower characteristics. By removing unobserved time-varying country and industry factors of borrowers, we increase the difference-in-differences estimate from 0.017 to 0.020.

One possible concern is that the introduction of negative policy rates in June 2014 coincides with other events that might affect the risk-taking of banks. As long as other coincidental events affect high-deposit and low-deposit banks in the same way, these other concurrent policy measures are differenced out. However, if they affect high-deposit and low-deposit banks differently, then our results could be biased.

Potential candidates for confounding, coincidental events are the introduction of the Basel III liquidity coverage ratio (LCR) and the ECB's first series of targeted longer-term refinancing operations (TLTROs). The LCR requires banks to hold a buffer of liquid assets against net short-term outflows under stress, which could plausibly affect high-deposit and low-deposit banks differently (although it would hurt low-deposit banks more as nondeposit funding requires a higher buffer). The timing of the LCR, however, does not fully coincide with the negative policy rate because it was introduced on January 1, 2015, with a 4-year rollout period.

The first series of TLTROs, in which the ECB lends long term and at a discount to banks that provide credit to firms, was announced in June 2014 and subsequently executed in two separate stages in September and December 2014. However, it is not clear ex ante why the TLTRO take-up would differ according to the deposit ratio of banks. Additionally, the take-up was below expectations and mainly used to substitute liquidity from other ECB operations.[15] As a result, it seems implausible that TLTROs are driving our findings.

To rule out such confounds more formally, we estimate Equation (2), using confidential data from the Single Supervisory Mechanism (SSM). In Column 3 of Table 3, we compare banks with different exposure to negative rates according to whether their deposits are held by households or by nonfinancial corporations.[16] Because of the harder zero lower bound on household deposits, we expect a stronger effect for banks with more household deposits than

[15] Only €212.4 billion was allotted during the September 2014 and December 2014 TLTROs, which amounts to roughly half of the available funding. About one-third of this amount was used to substitute existing liquidity from other ECB operations, leading to a net take-up of €143 billion in these 2 months. Additionally, the December 2011 and February 2012 3-year LTROs both matured in January and February 2015, potentially leading to even larger substitution effects.

[16] We consider only syndicates in which all lead arrangers come from the group of 43 euro-area lead arrangers for which we have the supervisory data to decompose lead-arranger deposits. Note that if we run the specification from Column 2 on this smaller sample, the estimated difference-in-differences estimate is 0.022 (significant at the 1% level). Our results are robust to using a less strict criterion, by limiting the sample to syndicated loans with

for banks with more corporate deposits. In contrast, neither the LCR nor the TLTROs should affect household and corporate deposits differently. As hypothesized, the difference-in-differences estimate is much more precisely estimated, and also larger in size, for banks that rely more on household deposits.

More generally, this result addresses the concern that banks' deposit ratio may be correlated with bank characteristics that are not stable around the time of setting the negative policy rate. To the extent that these characteristics affect banks' credit-supply decisions, this could introduce time-varying differences between high-deposit and low-deposit banks. As the comparison of banks with a lot of household deposits to those with few household deposits is independent of the overall level of the deposit ratio, the estimation in Column 3 of Table 3 sidesteps this concern.

In Column 4 of Table 3, we add control variables to refine the comparison of high-deposit and low-deposit banks. We include three time-varying variables at the level of the banks' country of origin to control for lenders' local economic conditions. In particular, we use quarter-on-quarter growth rates in gross domestic product (GDP) per capita and the European Sentiment Indicator (ESI),[17] as well as an index based on the country-level answers to the question on loan demand from the ECB's Bank Lending Survey.[18] In addition, we control for banks' size, their equity ratio, and their securities ratio. The previous literature identifies these balance-sheet characteristics as relevant for the transmission of monetary policy, even though they add little explanatory power in our empirical setting (R^2 increases from .153 to .162). Adding all these control variables leaves the difference-in-differences estimate virtually unchanged.

In Column 5, we show the results from estimating Equation (3), which tests whether the transmission of the negative rate cut via deposits is special. We apply the same difference-in-differences approach also to the rate cut in July 2012, when the ECB lowers the DF rate from 0.25% to zero. The estimate of β_2, the coefficient on the interaction *Deposit ratio* $\times$ $After$(07/2012), is insignificant, while the estimate of β_1, the coefficient on the interaction *Deposit ratio* $\times$ $After$(06/2014), is unchanged. Different deposit ratios expose banks differently to lower, negative rates, but not to lower, nonnegative rates.

In Column 6 of Table 3, we reduce the sample to European borrowers outside the euro area. The majority of these firms (70%) are U.K. firms. The loan

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any one of the 43 euro-area lead arrangers for which we have the supervisory data to decompose lead-arranger deposits.

[17] The European Sentiment Indicator is a composite indicator comprising five sectoral confidence indicators. It is meant to capture the confidence in the economy and is a more forward-looking measure than GDP growth.

[18] We use the following survey question: "Over the past 3 months, how has the demand for loans or credit lines to enterprises changed at your bank, apart from normal seasonal fluctuations?" Banks can respond "decreased considerably," "decreased somewhat," "unchanged," "increased somewhat," or "increased considerably." We use the net percentage at the country level reported by the ECB, that is, the percentage of banks whose answer implied that loan demand increased minus the percentage of banks whose answer implied that loan demand decreased.

demand of these non-euro-area firms should be less affected by economic conditions and policies in the euro area. The coefficient on our treatment *Deposit ratio* $\times$ $After$(06/2014) is stronger, while the coefficient on *Deposit ratio* $\times$ $After$(07/2012) remains insignificant. This suggests that our results are unlikely to be driven by monetary policy reacting to the economic condition of firms or by monetary policy affecting loan demand.

In Column 7, we perform a falsification test using non-euro-area lenders to non-euro-area borrowers.[19] As non-euro-area lenders are not directly affected by euro-area monetary policy, we expect to find no effect of setting negative policy rates on the risk-taking of those banks. In line with this reasoning, the coefficient on the treatment *Deposit ratio* $\times$ $After$(06/2014) is insignificant.

Next, we examine the impact of negative policy rates on the volume of bank lending. In Table 4, we move the estimation from the loan to the bank level, and rerun as many of the specifications from Table 3 as possible (while accounting for the reduced number of observations when aggregating the loans of a bank in a given month).

In the first column of Table 4, we present the basic difference-in-differences specification with bank and month-year fixed effects. In the second column, we replace the bank fixed effects with the actual deposit ratio for robustness. The estimate of the coefficient on *Deposit ratio* $\times$ $After$(06/2014) is negative and significant (at the 5% level in Column 2 and at the 10% level in Column 1). Taking the estimate from the first column, a 1-standard-deviation increase in a bank's deposit ratio (=14.76 percentage points in this particular sample) leads to an economically relevant reduction in lending of 13% ($14.76 \times 0.009 = 0.133$).[20]

In Column 3, we estimate Equation (2). Our difference-in-differences estimate is more than 6 times larger (in absolute terms) for banks relying on household deposits, on which they are more reluctant to charge negative rates. The estimate is, however, significant only at the 19% level.

In Column 4, we add the same controls for local economic conditions and bank characteristics used in Column 4 of Table 3. In Column 5, we also add the placebo treatment in July 2012 (Equation (3) at the bank level). Doing so leaves our difference-in-differences estimate unaltered, while the coefficient on the placebo treatment remains insignificant. As before, adding control variables does not increase the explanatory power much relative to our baseline with bank and time fixed effects.

[19] Non-euro-area borrowers are likely to contract with non-euro-area lead arrangers, even if the latter join forces with euro-area lead arrangers in the syndication process. This enables us to rerun the specification from Column 6 by adding non-euro-area lead arrangers. The respective sample in Column 7 overlaps with the syndicated loans in Column 6, but additionally comprises loans with only non-euro-area lead arrangers. We redefine *Deposit ratio* as the average deposit ratio of all non-euro-area lead arrangers in syndicate j.

[20] The effect is also visible in the raw data when plotting lending by high-deposit and low-deposit banks over time (Figure A.2 in the Online Appendix).

Table 4
Impact of negative policy rates on banks' lending volume

	ln(syndicated loan volume)					
Sample	2013−2015				2011−2015	2011−2015
						Non-euro-area lenders
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Deposit ratio × After(06/2014)	−0.009* (0.004)	−0.010** (0.005)		−0.009** (0.004)	−0.009** (0.004)	−0.004 (0.007)
Deposit ratio		−0.003 (0.009)				
HH deposit ratio × After(06/2014)			−0.013 (0.010)			
NFC deposit ratio × After(06/2014)			−0.002 (0.010)			
GDP p.c. growth				−3.715 (6.244)		
ESI growth				0.047 (2.451)		
Credit-demand index				−0.000 (0.003)		
$Assets_{t-1}$				−3.197*** (1.112)		
Equity $ratio_{t-1}$				−0.255*** (0.069)		
Securities $ratio_{t-1}$				0.048 (0.032)		
Deposit ratio × After(07/2012)					0.008 (0.006)	0.001 (0.011)
Bank FE	Y	N	Y	Y	Y	Y
Month-year FE	Y	Y	Y	Y	Y	Y
R^2	.424	.216	.442	.451	.393	.498
N	759	759	592	733	1,371	399

The level of observation is a bank's month-year, based on all completed syndicated loans j granted by euro-area lead arrangers at date t, from January 2013 to December 2015 in the first four columns and from January 2011 to December 2015 in the last two columns. In the last column, the sample is based on all completed syndicated loans granted by non-euro-area lead arrangers from January 2011 to December 2015. The sample of banks is limited to those that consistently—at least for 30 months during the respective sample period—act as lead arrangers in syndicated loans. The dependent variable is the logged total loan volume granted by a bank in its function as lead arranger in syndicated loans, calculated on the basis of the respective loan shares. *Deposit ratio* is a bank's ratio (in %) of deposits over total assets in 2013. In the third column, *HH deposit ratio* (*NFC deposit ratio*) is a bank's ratio (in %) of household (non-financial-corporation) deposits over total assets in the fourth quarter of 2014, as there is no decomposition of deposits available before that quarter. In the fourth column, we control for the quarter-on-quarter growth rates in GDP per capita and the European Sentiment Indicator (ESI), as well as an index based on the country-level answers to the question on loan demand from the ECB's Bank Lending Survey, all for a bank's country of origin in the euro area. $Assets_{t-1}$ is the natural logarithm of a bank's total assets in year $t-1$. *Equity* $ratio_{t-1}$ is a bank's ratio (in %) of equity over total assets in year $t-1$. *Securities* $ratio_{t-1}$ is a bank's ratio (in %) of securities over total assets in year $t-1$. $After$(06/2014) is a dummy variable for the period from June 2014 onward. $After$(07/2012) is a dummy variable for the period from July 2012 onward. Robust standard errors (clustered at the bank level) are in parentheses.

We also conduct a falsification test and rerun the regression from Column 5 for all non-euro-area lead arrangers. As can be seen in the last column, we find no effect, as should be the case for non-euro-area banks that are not directly affected by the ECB's policy rates.

In Table 5, we move our analysis to the loan-bank level to include firm-time fixed effects. By comparing the lending behavior of high-deposit and low-deposit banks to the same borrower, we address the concern that high-deposit

Table 5
Impact of negative policy rates on loan shares: Borrower-time fixed effects

	Loan share $\in [0,1]$ Intensive margin				Any involvement $\in \{0,1\}$ Extensive margin		
Sample	2013−2015	2011−2015	Bottom-half ROA volatility	Top-half ROA volatility	2011−2015	Bottom-half ROA volatility	Top-half ROA volatility
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Deposit ratio × After(06/2014)	−0.032*	−0.037**	−0.129**	0.026*	0.019	−0.038	0.055**
	(0.019)	(0.016)	(0.064)	(0.014)	(0.024)	(0.045)	(0.028)
Deposit ratio × After(07/2012)		0.071	0.169*	−0.115*	−0.004	0.026	−0.010
		(0.052)	(0.096)	(0.065)	(0.019)	(0.033)	(0.035)
Firm-time FE	Y	Y	Y	Y	Y	Y	Y
Bank-firm FE	Y	Y	Y	Y	N	N	N
Bank FE	N	N	N	N	Y	Y	Y
Bank-country -time FE	Y	Y	Y	Y	Y	Y	Y
R^2	.681	.651	.742	.554	.758	.763	.785
N	1,712	3,045	467	429	162,650	30,756	31,214

The sample consists of all completed syndicated loans j of both private and publicly listed firms i at date t granted by any euro-area (participating or lead) bank, from January 2013 to December 2015 in the first column and from January 2011 to December 2015 in all remaining columns. In the first four columns, observations are at the loan-bank level; that is, each loan comprises multiple observations, but only one observation per (participating or lead) bank. In the last three columns, the sample is extended so as to represent a balanced panel of all borrower-bank pairs at the semiannual frequency. All singletons are dropped from the total number of observations N. In the third (sixth) and fourth (seventh) columns, the sample is limited to borrower firms in the bottom and top halves, respectively, of the distribution of the 5-year standard deviation of firms' ROA (using P&L before tax) from year $t-5$ to $t-1$. In the first four columns, the dependent variable is the loan share (between 0 and 1) retained by a (participating or lead) bank. In the last three columns, the dependent variable is an indicator for any involvement by a (participating or lead) bank. *Deposit ratio* is a bank's ratio (in %) of deposits over total assets in 2013. $After$(06/2014) is a dummy variable for the period from June 2014 onward. $After$(07/2012) is a dummy variable for the period from July 2012 onward. In the first four (last three) columns, time refers to the annual (semiannual) level. Bank-country-time fixed effects are based on the bank group's country of origin in the euro area. Public service, energy, and financial services borrower firms are dropped. Robust standard errors (clustered at the bank level) are in parentheses.

and low-deposit banks face different investment opportunities (e.g., different loan demand) after the setting of negative policy rates.

For each syndicated loan, we have multiple observations that record each (participating or lead) bank's loan share.[21] The dependent variable now is the share of a syndicated loan retained by a bank. We also add bank-firm fixed effects to compare the lending of the same banks to the same firm before and after June 2014, as well as banks' country-time fixed effects to control for time-varying differences across banks driven by factors at the level of their home countries.

In the first column of Table 5, we estimate this within-borrower version of our baseline Equation (1) and find a negative and significant difference-in-differences estimate. High-deposit banks not only reduce the total volume of syndicated loans they grant once the policy rate becomes negative (Table 4), but

[21] We go beyond the sample of lead arrangers when adding firm-time fixed effects because firms typically do not receive new loans from multiple syndicates in a given year. If we did not use the loan shares of other syndicate participants, we would lose syndicated loans with only one single lead arranger.

they also reduce their share in syndicated loans to the same firm. In Column 2, we reestimate Equation (3). As before, the difference-in-differences estimate is unchanged, and the coefficient on the placebo is insignificant.

In Columns 3 and 4 of Table 5, we use the within-borrower specification to test the robustness of our results on bank risk-taking. To do this, we sort borrowers into the bottom and top halves according to their ROA volatility (our baseline measure of ex ante risk). Within safe borrowers, high-deposit banks reduce their loan shares (Column 3), while within risky borrowers, they increase their loan shares (Column 4).

In Columns 5, 6, and 7, we consider the extensive margin, that is, the event that a bank participates (in any capacity) in any syndicated loan of firm i in a given time period. For this purpose, we replace the bank-firm fixed effects by bank fixed effects and construct a balanced panel of all borrower-bank pairs at the semiannual frequency, that is, from the first half of 2011 to the second half of 2015. As the dependent variable, we use an indicator for any involvement by a (participating or lead) bank.[22] In Column 5, we see that high-deposit banks are more likely to participate in syndicated loans overall, but the effect is not statistically significant. After splitting the sample into safe (Column 6) and riskier borrowers (Column 7), it becomes, however, clear that the higher participation rate of high-deposit banks is driven by their lending to risky borrowers. The difference-in-differences estimate is positive and significant in Column 7, but not in Column 6.

Overall, these within-borrower results using loan shares and syndicate participation confirm our previous findings on bank lending and bank risk-taking: high-deposit banks lend less, and the average riskiness in their loan portfolio increases when the policy rate becomes negative.[23]

3.2 Further robustness

In this section, we provide further robustness checks for our results on bank risk-taking and the volume of bank lending. Table 6 shows the results of estimating Equation (4). In Columns 1 and 2, we consider bank risk-taking at the loan level used in Table 3. In Columns 3 and 4, we consider the lending volume at the bank level used in Table 4.

The coefficient on $\textit{Deposit ratio} \times \textit{DF rate}_t$ is never significant and close to zero. Banks with different extent of deposit funding do not respond differently to policy rate changes when the policy rate is *not* negative. This is different when the policy rate becomes negative, as indicated by the significant coefficient on $\textit{Deposit ratio} \times \textit{DF rate}_t \times \textit{After}(06/2014)$. Only negative lower rates lead to more risk-taking (Columns 1 and 2) and less lending (Columns 3 and 4).

[22] One advantage of considering the extensive margin is that the sample no longer depends on the (poor) availability of loan share data in DealScan.

[23] In line with this, we also find that while on average, high-deposit banks do not grant larger loans than low-deposit banks, they do grant larger loans to riskier borrowers (Table B.2 in the Online Appendix).

Table 6
Effect of changes in the deposit facility rate on banks' risk-taking and lending volume

	$\ln(\sigma(ROA_i)^{5y})$		ln(syndicated loan volume)	
Sample	2009 − 2015			
Variable	(1)	(2)	(3)	(4)
Deposit ratio × DF rate$_t$ × After(06/2014)	−0.094***	−0.091***	0.062**	0.050*
	(0.029)	(0.029)	(0.028)	(0.030)
Deposit ratio × DF rate$_t$	0.017	0.014	−0.005	−0.002
	(0.011)	(0.011)	(0.010)	(0.012)
Deposit ratio × After(06/2014)	−0.008*	−0.007	0.013	0.008
	(0.005)	(0.005)	(0.008)	(0.005)
Deposit ratio	0.003		−0.009	
	(0.004)		(0.008)	
Bank FE	N	Y	N	Y
Month-year FE	Y	Y	Y	Y
R^2	.027	.065	.174	.407
N	3,005	3,005	2,330	2,330

In the first two columns, the sample consists of all completed syndicated loans j (package level) of both private and publicly listed firms i at date t granted by any euro-area lead arranger(s) from January 2009 to December 2015. In the last two columns, the level of observation is a bank's month-year, based on all completed syndicated loans j granted by euro-area lead arrangers at date t from January 2009 to December 2015. Furthermore, in the last two columns, the sample of banks is limited to those that consistently—at least for 30 months—act as lead arrangers in syndicated loans. The dependent variable in the first two columns is the logged five-year standard deviation of firm i's ROA (using P&L before tax) from year $t-5$ to $t-1$. The dependent variable in the last two columns is the logged total loan volume granted by a bank in its function as lead arranger in syndicated loans, calculated based on the respective loan shares. In the first two columns, *Deposit ratio* is the average ratio (in %) of deposits over total assets in 2013 across all euro-area lead arrangers of syndicate j. In the last two columns, *Deposit ratio* is a bank's ratio (in %) of deposits over total assets in 2013. *DF rate$_t$* is the ECB's deposit facility rate (in %) at the monthly level. $After$(06/2014) is a dummy variable for the period from June 2014 onward. Bank fixed effects are included for all euro-area lead arrangers. Robust standard errors (clustered at the bank level) are in parentheses.

In Table 7, we check that our results on risk-taking are not driven by how we measure the ex ante risk of borrowers. As an alternative to ROA volatility, we use a firm's interest rate (all-in-drawn spread) of the most recent syndicated loan obtained prior to our estimation period (Columns 1 and 2). For the subsample of public firms, we also use their stock-return volatility, derived from monthly stock returns (Columns 3 and 4). Finally, lenders may care more about the risk of their debt claim rather than the risk of the overall firm. To examine this possibility, we multiply the standard deviation of the ROA of the borrowing firm with its leverage in year t-1 (last two columns). None of these alternative risk measures change our main finding.

In Table 8, we consider alternative definitions of the deposit ratio. First, we exclude government entities and one insurance company from our sample of lenders (Columns 1 and 4). They have very low deposit ratios and may behave differently than banks. Second, we use the ratio of deposits over total liabilities, rather than assets (Columns 2 and 5). This way we examine whether our results do indeed reflect the different funding structure of banks and are not driven by variation in bank size. And third, we replace our treatment-intensity variable *Deposit ratio* with the average deposit ratio across all euro-area lead

Table 7
Alternative risk measures of firms financed by banks following negative policy rates

	ln(spread before sample period)		$\ln(\sigma(return_i)^{36m})$		$\ln(\sigma(ROA_i)^{5y} \times Leverage_{i,t-1})$	
Sample	2013−2015	2011−2015	2013−2015	2011−2015	2013−2015	2011−2015
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Deposit ratio × After(06/2014)	0.010*	0.007	0.009***	0.006*	0.008**	0.009**
	(0.006)	(0.008)	(0.003)	(0.004)	(0.003)	(0.003)
Deposit ratio × After(07/2012)		−0.003		0.002		−0.004
		(0.007)		(0.003)		(0.003)
Bank FE	Y	Y	Y	Y	Y	Y
Month-year FE	Y	Y	Y	Y	Y	Y
Country-year FE	Y	Y	Y	Y	Y	Y
Industry-year FE	Y	Y	Y	Y	Y	Y
R^2	.242	.222	.328	.361	.097	.099
N	1,218	1,746	665	1,061	1,569	2,478

The sample consists of all completed syndicated loans j (package level) of both private and publicly listed firms i at date t granted by any euro-area lead arranger(s), from January 2013 to December 2015 in the first, third, and fifth columns, and from January 2011 to December 2015 in the remaining columns. The dependent variable is the log of the all-in-drawn spread (in bps), which is the sum of the spread over LIBOR and any annual fees paid to the lender syndicate, associated with the most recent syndicated loan of firm i before 2013 in the first column, and before 2011 in the second column, but no earlier than January 2003. In Columns 3 and 4, the dependent variable is the logged standard deviation of firm i's monthly stock returns in the 36 months before t. In Columns 5 and 6, the dependent variable is the log of the 5-year standard deviation of firm i's ROA (using P&L before tax) from year $t-5$ to $t-1$ multiplied by firm i's leverage in year $t-1$. *Deposit ratio* is the average ratio (in %) of deposits over total assets in 2013 across all euro-area lead arrangers of syndicate j. $After(06/2014)$ is a dummy variable for the period from June 2014 onward. $After(07/2012)$ is a dummy variable for the period from July 2012 onward. Bank fixed effects are included for all euro-area lead arrangers. Country-year fixed effects are based on the firm's country of origin. Industry-year fixed effects are based on two-digit SIC codes. Public service, energy, and financial services firms are dropped. Robust standard errors (clustered at the bank level) are in parentheses.

arrangers in 2010 (rather than in 2013) in order to render our exposure-to-treatment variable well predetermined (Columns 3 and 6). In all cases, the difference-in-differences estimate for both risk-taking and lending volume is robust.

Relatedly, Figure 5 confirms the validity of using banks' deposit ratio as our exposure-to-treatment variable. During our sample period (2013−2015), bank-level deposit growth and banks' deposits-to-assets ratio in 2013 are not correlated. We also fail to find formal time-varying differences in deposits across high-deposit and low-deposit banks when we estimate specification (1) at the bank level, with deposit growth as the dependent variable over the period from 2011 to 2015.[24]

Another potential concern might be that the ECB started its PSPP on March 9, 2015. From this date onward, the ECB expanded its existing, rather limited, asset purchase programs (of covered bonds and asset-backed securities) to include public sector bonds (for a total monthly amount of initially €60 billion). Although it is not clear why the PSPP would affect banks' credit supply differently according to their deposit ratio, we address this potential confound

24 Interestingly, banks' deposit ratios increase overall. This finding is in line with the argument of Drechsler, Savov, and Schnabl (2017b) that market-based investments have become less attractive than deposits. These results are available on request.

Table 8
ROA volatility of firms financed and volume of syndicated lending by banks following negative policy rates: Robustness to the definition of deposit ratio

	$\ln(\sigma(ROA_i)^{5y})$			ln(syndicated loan volume)		
Robustness	No low deposits	Alternative deposit ratio	Deposit ratio in 2010	No low deposits	Alternative deposit ratio	Deposit ratio in 2010
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Deposit ratio	0.020***	0.018***	0.017**	−0.011*	−0.009*	−0.012**
× After(06/2014)	(0.006)	(0.005)	(0.007)	(0.006)	(0.005)	(0.005)
Bank FE	Y	Y	Y	Y	Y	Y
Month-year FE	Y	Y	Y	Y	Y	Y
Country-year FE	Y	Y	Y	N	N	N
Industry-year FE	Y	Y	Y	N	N	N
R^2	.153	.153	.154	.430	.425	.425
N	1,571	1,576	1,576	739	759	759

In the first three columns, the sample consists of all completed syndicated loans j (package level) of both private and publicly listed firms i at date t granted by any euro-area lead arranger(s) from January 2013 to December 2015. In the last three columns, the level of observation is a bank's month-year, based on all completed syndicated loans j granted by euro-area lead arrangers at date t from January 2013 to December 2015. Furthermore, in the last three columns, the sample of banks is limited to those that consistently—at least for 30 months—act as lead arrangers in syndicated loans. The dependent variable in the first three columns is the logged 5-year standard deviation of firm i's ROA (using P&L before tax) from year $t-5$ to $t-1$. The dependent variable in the last three columns is the logged total loan volume granted by a bank in its function as lead arranger in syndicated loans, calculated based on the respective loan shares. In the first column, *Deposit ratio* is the average ratio (in %) of deposits over total assets in 2013 across all euro-area lead arrangers of syndicate j, with the exception of government entities—Bank Nederlandse Gemeenten (with a deposit ratio of 7.65% in 2013), European Investment Bank (0.49%), Instituto de Credito Oficial (1.78%), and KfW (2.43%)—and the insurance company Allianz Group (1.57%). In the second column, *Deposit ratio* is the average ratio (in %) of deposits over total liabilities in 2013 across all euro-area lead arrangers of syndicate j. In the third column, *Deposit ratio* is the average ratio (in %) of deposits over total assets in 2010 across all euro-area lead arrangers of syndicate j. In the fourth column, we drop from the sample all government entities and the insurance company Allianz Group, like in the first column, and *Deposit ratio* is a bank's ratio (in %) of deposits over total assets in 2013. In the fifth column, *Deposit ratio* is a bank's ratio (in %) of deposits over total liabilities in 2013. In the sixth column, *Deposit ratio* is a bank's ratio (in %) of deposits over total assets in 2010. $After(06/2014)$ is a dummy variable for the period from June 2014 onward. Bank fixed effects are included for all euro-area lead arrangers. Country-year fixed effects are based on the firm's country of origin. Industry-year fixed effects are based on two-digit SIC codes. Public service, energy, and financial services firms are dropped from the first three columns. Robust standard errors (clustered at the bank level) are in parentheses.

by shortening our sample period and setting its end to February 2015. We find that our results are robust to excluding months with large-scale asset purchases by the ECB (Table B.3 in the Online Appendix).

Finally, we modify our sample to add the introduction of negative rates in Denmark, Sweden, and Switzerland.

The extra, staggered number of treatments makes it less likely that, despite our numerous robustness tests, there still may be some omitted factor in June 2014 that drives the risk-taking of high-deposit banks. Again, high-deposit banks finance riskier firms when policy rates become negative (Table B.4 in the Online Appendix).

3.3 Characterizing the nature of bank lending

We now characterize the nature of bank lending by examining the role of bank capitalization and the characteristics of firms financed by high-deposit versus low-deposit banks after the introduction of negative policy rates.

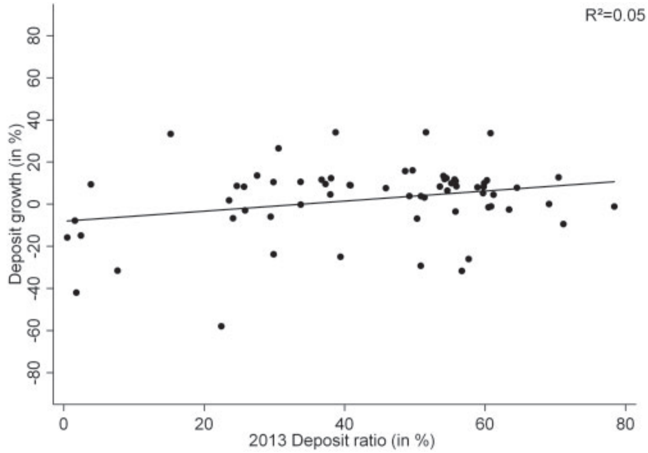

Figure 5
Deposit growth (2013–2015) versus deposit ratio (2013)
This figure shows the growth rate of deposits (in %, *y*-axis) between 2013 and 2015 for each bank in our sample, relative to the bank's deposit ratio (in %, *x*-axis) in 2013. Data are taken from SNL Financial.

With less capital, a bank's agency problem is worse, and it has less incentives to refrain from risk-taking once its net worth is hit by a negative shock. In the first two columns of Table 9, we rerun our baseline specification from Column 2 in Table 3 on two subsamples: banks in the bottom and the top tercile of the distribution according to their equity-to-assets ratio. The difference-in-differences estimate is positive and significant only for the group of poorly capitalized banks in Column 1. This is also the case when we add the placebo treatment in the last two columns.

We explain this risk-taking with lower net worth giving less "skin-in-the-game" and, thus, giving less incentives to screen and monitor risky borrowers. An alternative explanation could be that high-deposit banks engage in a "search-for-yield" (see Rajan 2005).

However, we find no effect of the introduction of negative policy rates on the all-in-drawn spread (and also the total cost of borrowing) charged by high-versus low-deposit banks. Other loan terms, such as collateral, the lead share (as a measure of monitoring incentives, see Ivashina (2009)), financial covenants, and maturity, are not affected either (Table B.5 in the Online Appendix). That is, the risk-taking of high-deposit banks is not accompanied by stricter loan terms that could mitigate the increase in the risk of these banks' loan portfolio.

Thus far, we characterize banks' risk-taking using the riskiness of their borrowers. In Table 10, we examine the impact of negative rates on banks' loan portfolio using other borrower characteristics. In the first two columns, we partition the sample into privately held and publicly listed firms, and rerun our baseline specification from Column 2 in Table 3. The risk-taking of high-deposit banks is significant only for private firms. Private firms are typically

Table 9
Negative policy rates and firms' ROA volatility: Interaction of treatment with bank capitalization

	$\ln(\sigma(ROA_i)^{5y})$			
Sample	2013 − 2015		2011 − 2015	
Variable	Bottom tercile (1)	Top tercile (2)	Bottom tercile (3)	Top tercile (4)
Deposit ratio × After(06/2014)	0.033***	−0.010	0.031***	−0.010
	(0.010)	(0.014)	(0.010)	(0.015)
Deposit ratio × After(07/2012)			−0.007	−0.006
			(0.008)	(0.016)
Bank FE	Y	Y	Y	Y
Month-year FE	Y	Y	Y	Y
Country-year FE	Y	Y	Y	Y
Industry-year FE	Y	Y	Y	Y
R^2	.270	.153	.261	.156
N	527	534	819	832

The sample consists of all completed syndicated loans j (package level) of both private and publicly listed firms i at date t granted by any euro-area lead arranger(s), from January 2013 to December 2015 in the first two columns and from January 2011 to December 2015 in the last two columns. In the first and third (second and fourth) column, the sample is limited to euro-area banks in the bottom (top) tercile of the distribution of the average ratio of equity over total assets in 2013. The dependent variable is the logged 5-year standard deviation of firm i's ROA (using P&L before tax) from year $t-5$ to $t-1$. *Deposit ratio* is the average ratio (in %) of deposits over total assets in 2013 across all euro-area lead arrangers of syndicate j. $After$(06/2014) is a dummy variable for the period from June 2014 onward. $After$(07/2012) is a dummy variable for the period from July 2012 onward. Bank fixed effects are included for all euro-area lead arrangers. Country-year fixed effects are based on the firm's country of origin. Industry-year fixed effects are based on two-digit SIC codes. Public service, energy, and financial services firms are dropped. Robust standard errors (clustered at the bank level) are in parentheses.

seen as more credit constrained and, thus, more exposed to variation in the supply of bank credit than public firms that have access to other sources of financing.

In the next three columns of Table 10, we provide evidence that the risk-taking of high-deposit banks does not lead to "zombie" lending, that is, lending to firms with low profitability or those that are already heavily indebted. The dependent variable in Column 3 is the borrower's ROA, measured in the year before receiving the loan. The difference-in-differences estimate is insignificant. The firms receiving loans from high-deposit banks have the same profitability as firms receiving loans from low-deposit banks after June 2014. In Column 4, the dependent variable is the leverage (debt-to-assets ratio) of borrowers. The difference-in-differences estimate is negative and significant. High-deposit banks lend more to low-leverage firms than do low-deposit banks once the policy rate becomes negative.

The risk-taking of high-deposit banks is stronger if they know more about the borrower, which also sheds a more positive light on their risk-taking. In Column 5 of Table 10, we interact the treatment *Deposit ratio* × $After$(06/2014) with an indicator variable *Exposure* equal to 1 if lead arrangers have significant prior lending activity in the borrower's SIC2 industry. The positive and significant coefficient on the triple interaction shows that the treatment effect is 1.58 (= 0.019/0.012) times stronger for banks with prior exposure to the borrower's industry.

Table 10
Impact of negative policy rates on banks' loan portfolio

Sample	$\ln(\sigma(ROA_i)^{5y})$ Private firms	$\ln(\sigma(ROA_i)^{5y})$ Public firms	$ROA_{i,t-1}$	$Leverage_{i,t-1}$ Private and public firms	$\ln(\sigma(ROA_i)^{5y})$
Variable	(1)	(2)	(3)	(4)	(5)
Deposit ratio	0.027***	0.011	−0.036	−0.238**	0.012*
× After(06/2014)	(0.009)	(0.007)	(0.083)	(0.110)	(0.007)
Deposit ratio × Exposure					0.019*
× After(06/2014)					(0.011)
Deposit ratio					−0.006
× Exposure					(0.006)
Exposure ×					−0.923**
After(06/2014)					(0.451)
Exposure					0.328
					(0.274)
Bank FE	Y	Y	Y	Y	Y
Month-year FE	Y	Y	Y	Y	Y
Country-year FE	Y	Y	Y	Y	Y
Industry-year FE	Y	Y	Y	Y	Y
R^2	.142	.271	.088	.174	.154
N	904	672	1,576	1,569	1,576

The sample consists of all completed syndicated loans j (package level) of only private (in the first column), only publicly listed (in the second column), and both private and publicly listed firms i (in the remaining columns) at date t granted by any euro-area lead arranger(s) from January 2013 to December 2015. The dependent variable in the first, second, and fifth column is the logged 5-year standard deviation of firm i's ROA (using P&L before tax) from year $t-5$ to $t-1$. The dependent variable in the third column is firm i's ROA (using P&L before tax) in year $t-1$, measured in % ($\in [0,100]$). The dependent variable in the fourth column is firm i's leverage in year $t-1$, measured in % ($\in [0,100]$). *Deposit ratio* is the average ratio (in %) of deposits over total assets in 2013 across all euro-area lead arrangers of syndicate j. *Exposure* is an indicator for whether the proportion of loans granted to firms in the same SIC2 industry as firm i in the total loan portfolio in 2013 of all euro-area lead arrangers of syndicate j is above the sample median. $After(06/2014)$ is a dummy variable for the period from June 2014 onward. Bank fixed effects are included for all euro-area lead arrangers. Country-year fixed effects are based on the firm's country of origin. Industry-year fixed effects are based on two-digit SIC codes. Public service, energy, and financial services firms are dropped. Robust standard errors (clustered at the bank level) are in parentheses.

3.4 External validity

So far, we have characterized banks' lending behavior under negative policy rates using syndicated loans, which allows us to link borrowers and lenders as well as to analyze individual loan terms. However, syndicated lending represents only a fraction of banks' total lending. In our sample, outstanding syndicated loans on average make up at least 9% of a bank's total loan portfolio.

We examine the external validity of our results on bank risk-taking using the market's view of overall bank behavior. In Columns 1 and 2 of Table 11, we estimate our baseline specification (1) as well as specification (3) at the bank level, using the log of the (unlevered) monthly standard deviation of daily bank stock returns as the dependent variable. In Columns 3 and 4, we repeat this exercise with banks' credit default swap (CDS) returns. Both market-based risk measures confirm that high-deposit banks become riskier (relative to low-deposit banks) after lower, negative policy rates in June 2014, but not after lower, nonnegative rates in July 2012.

To examine the external validity with respect to the volume of lending, we are forced to fall back on annual SNL balance-sheet data, which is not plentiful

Table 11
Bank-level stock-return volatility and CDS returns

	$\ln(\sigma(return_j)^{1m})$		$CDS\ return_j^{1m}$	
Sample	2013−2015	2011−2015	2013−2015	2011−2015
Variable	(1)	(2)	(3)	(4)
Deposit ratio × After(06/2014)	0.012*	0.013**	0.141**	0.126**
	(0.007)	(0.005)	(0.062)	(0.058)
Deposit ratio × After(07/2012)		−0.006		−0.043
		(0.016)		(0.047)
Bank FE	Y	Y	Y	Y
Month-year FE	Y	Y	Y	Y
R^2	.655	.414	0.494	.588
N	775	1,471	898	1,689

The level of observation is a bank's month-year. We use stock-market data on 30 listed banks, from January 2013 to February 2015 in the first and from January 2011 to February 2015 in the second column. The dependent variable in the first two columns is the logged unlevered monthly standard deviation of bank stock returns. For each bank, the monthly standard deviation is calculated using daily stock returns. Standard deviations are unlevered by multiplying them with the ratio of bank equity over total assets. In the last two columns, we use monthly CDS-spread returns (in %) for 36 banks. The sample period runs from January 2013 to February 2015 in the third column, and from January 2011 to February 2015 in the last column. *Deposit ratio* is a bank's ratio (in %) of deposits over total assets in 2013. $After(06/2014)$ is a dummy variable for the period from June 2014 onward. $After(07/2012)$ is a dummy variable for the period from July 2012 onward. Robust standard errors (clustered at the bank level) are in parentheses.

enough for a regression analysis. In Figure 6, we inspect these data on total bank lending, and build an annual lending index (December 2013 = 100) for the top, middle, and bottom terciles of banks in the deposit-ratio distribution (in 2013).

High-deposit banks generally lend less than other banks, and this lending gap increases further in 2014, when the policy rate is reduced to negative. This confirms our negative difference-in-differences estimate for the volume of lending in the syndicated loan market. While total lending increases in 2014 and 2015 for all groups, the recovery is markedly slower for high-deposit banks (solid line). Negative rates are less accommodative for high-deposit banks.

4. Conclusion

When central banks charge negative policy rates, they enter unchartered territory. We identify negative policy rates to lead to less lending and more risk-taking by high-deposit banks, as compared to low-deposit banks, in the market for syndicated loans. We show how the conventional view of monetary policy transmission through bank net worth and the associated external financial premium, when augmented with banks' reluctance to charge negative rates on deposits, can explain the transmission of negative policy rates.

Our results suggest potential costs of negative policy rates in terms of limited stimulus and financial instability. Normally, one views high-deposit banks as traditional intermediaries providing most of the lending and being most stable. Negative policy rates have the potential to change the role of these banks for the supply of credit to the real economy.

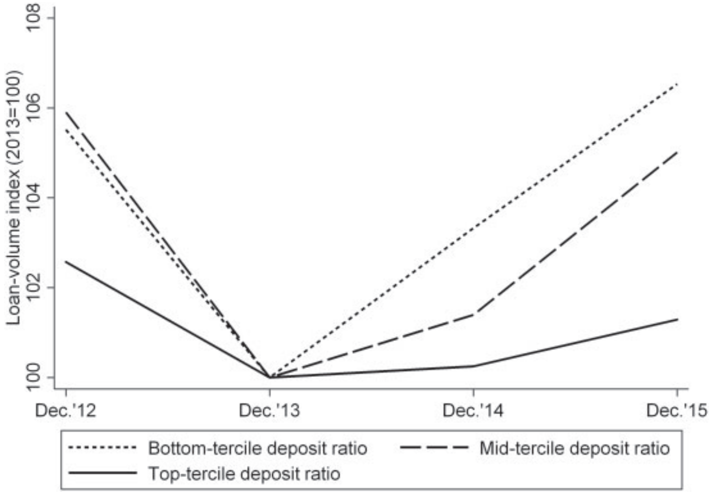

Figure 6
Total bank lending by banks as a function of their deposit ratio
This figure shows the evolution of an annual lending index (December 2013 = 100) for euro-area banks in our sample between 2012 and 2015. We split our sample in terciles based on the deposit-ratio distribution in 2013. For each tercile, we calculate the annual total loan volume. We then index the total loan volumes such that December 2013 = 100 and plot the index for the top (solid line), middle (long-dashed line), and bottom terciles (short-dashed line). All data series are taken from SNL Financial.

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