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* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

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Beyond the zero lower bound: negative policy rates and bank lending*

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Abstract

How do banks operate in a negative policy rate environment? Bank profitability is threatened by policy rate cuts in negative territory because the zero lower bound on retail deposit rates prevents banks from benefiting from cheaper deposit funding costs. Contrary to some earlier research, this paper finds that banks most affected by negative rates through this retail deposits channel increase their lending relative to less affected banks. The response is limited to mortgage lending, and is driven by banks with high household deposit ratios and banks with high overnight deposit ratios. Overall, net interest margins are unaffected, which implies that the volume effect is large enough to offset the adverse impact on bank profitability. However, the positive effect on lending dissipates as negative rates persist. This suggests that although the "reversal rate" has not been breached, it may creep up over time as banks become more limited in their options to maintain profit margins. The results also point to an important role for bank capitalisation – net interest margins of relatively highly capitalised banks are squeezed, whereas the net interest margins of less capitalised banks are unaffected. This can be explained by differences in capacity for shock absorbency.

Keywords: negative rates, zero lower bound, bank lending channel, monetary policy Transmission.
JEL classifications: E43, E52, E58, G20, G21.

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1 Introduction

In a speech about the theory and practice of monetary policy, the then Deputy Governor of the Bank of England, Mervyn King, quipped, "... a successful central bank should be boring – rather like a referee whose success is judged by how little his or her decisions intrude into the game itself" (King, 2000, p. 6). On that front, central bankers in the developed world have certainly failed. Central bankers have become remarkably intrusive – since the Global Financial Crisis, a slew of unconventional monetary policy measures (many untried and untested at the time) have been adopted in attempts to shrug off the malaise of low inflation and sluggish growth (see Blinder et al., 2017). Given their novelty, the complex and potentially unintended effects that these unconventional measures exert on banks and the wider economy have not yet been resolved in the empirical literature.

This paper examines the impact of one these measures – negative policy rates – on bank lending behaviour. Negative policy rates are already operating in the euro area, Sweden, Switzerland, Denmark and Japan. With the secular decline in equilibrium real interest rates around the world, negative rates are likely to become a more prevalent feature of the financial landscape. Hence the question of whether and how negative rates transmit differently to the real economy is highly relevant to academics and policy-makers.

In some ways, the experience of most central banks with the transmission of policy rate cuts in negative territory has been similar to conventional experience with transmission in positive territory. With the pass-through to money market rates intact, easier financial conditions induce firms and households to bring forward spending and investment decisions. In addition, negative rates can be expected to strengthen standard monetary policy transmission in two respects. First, the introduction of negative rates eliminates any perceptions that policy rates are bounded at zero, prompting a (one-time) re-evaluation of market expectations of short- and long-term interest rates. Second, they disincentivise banks from hoarding excess liquidity, instead encouraging them to re-balance towards lending to the real economy.

However, concern has been raised about the impact of negative rates on bank balance sheets, and how this could distort or impair the bank lending channel. In the bank lending channel, a policy rate cut in positive territory leads to an expansion of bank deposit liabilities, thus enabling banks to increase their lending (Bernanke and Blinder, 1988).[1] Modern interpretations of the bank lending channel emphasise a risk-taking channel – the lower policy rate increases banks' net worth, which in turn reduces the external finance premium such that banks can expand their lending activities (Disyatat, 2011). But negative policy rates are different due to the zero lower bound on retail deposit rates – particularly household deposit rates. Banks are reluctant to transmit negative retail deposit rates because depositors can simply withdraw and hold their funds in cash, which carries zero nominal interest. Hence at the lower bound, banks that rely on deposit funding have to accept a lower reduction in their average cost of funding relative to banks less reliant on deposit funding.[2] Negative rates also constitute a direct charge for eligible excess reserves held at the central bank, which similarly adversely impacts bank profitability. Because holdings of excess liquidity are generally small relative to total assets, this direct effect is smaller than the indirect effect through the retail deposits channel, even in countries that have not implemented deposit tiering (Jobst and Lin, 2016).

On the other hand, banks benefit from rate cuts in negative territory in a number of ways. First, through capital revaluation gains on fixed income assets. Second, due to a more supportive macroeconomic environment stimulating loan demand and reducing the need for loan loss provisions due to easier financing conditions for borrowers. Third, rising asset prices

[1] Monetary policy in a textbook representation of the bank lending channel is typically modelled through changes in the quantity of bank reserves. In reality, most central banks implement monetary policy by targeting short-term interest rates.

[2] By contrast, central banks that have implemented negative rates report that the pass-through to market rates has been relatively unimpeded.

help to ease collateral constraints.

Brunnermeier and Koby (2018) provide a useful theoretical framework to evaluate the transmission of negative rates to banks. If the negative effects of the rate cut dominate the positive effects, then bank profitability is damaged. This leads to a reduction in net worth, which increases the probability that banks hit their capital constraints.[3] If capital constraints become binding, then banks are forced to shrink their balance sheets, resulting in lower credit supply.[4] Brunnermeier and Koby (2018) call the policy rate associated with this effect the "reversal rate" – an endogenous, state-dependent, time-varying rate below which further rate cuts induce contractionary rather than expansionary effects. According to the authors, a "creeping up" effect also emerges due to the one-off revaluation gain on long-term fixed income assets when the rate cut occurs. As bank assets mature, the revaluation effect fades away, causing the reversal rate to inch upwards.

This paper contributes to the empirical literature on the impact of negative rates on bank lending behaviour by examining three outcomes implicated by the theory: 1) credit supply, the main outcome of interest, which measures monetary policy transmission through the bank lending channel; 2) lending rate spreads, which indicate risk-taking; and 3) profitability measures, which show whether negative rates filter through to the net worth of banks. For empirical identification, I focus on the euro area, which has implemented a negative deposit facility rate (DFR) since June 2014. I use high quality bank-level data collected by the European Central Bank (ECB) on lending volumes, bank balance sheet items and interest rates, supplemented by profitability and capitalisation measures from SNL Financial. My empirical methodology utilises a "difference-in-differences" approach around the ECB's first foray into negative rate territory in June 2014 *à la* Heider et al. (2019), who look at the

[3]Bank profitability and net worth are directly related insofar as some proportion of profits are held as retained earnings.

[4]In reality, banks have other options – for example they could issue new equity or make other changes to the compositional content of their balance sheets.

impact of negative rates on euro area lead-arrangers in the syndicated loan market. To limit the impact of confounding factors, I restrict the time period to a relatively short window around when the DFR became negative, from January 2013 to December 2015. The main identifying assumption is that banks with high retail deposit ratios as a percentage of total assets (henceforth, high deposit banks) are more affected by negative rates than banks with low retail deposit ratios (henceforth, low deposit banks). This arises from the zero lower bound on retail deposit rates, which implies a downward stickiness in the cost of funding for high deposit banks. Hence, low deposit banks can be considered the "control" group and provide for the counterfactual scenario for high deposit banks (the "treatment" group) in the absence of the negative policy rate environment. At its most refined, the regression is saturated with bank-specific control variables, entity fixed effects, time fixed effects and country-time fixed effects. Country-time fixed effects is used to control for time-varying, country-specific factors such as loan demand – importantly, this helps to isolate the effects on credit supply.

Unlike Heider et al. (2019), my sample is highly representative (encompassing around 70% of euro area bank assets) and examines total lending as opposed to syndicated loans, which only accounts for less than 5% of euro area loans and does not include lending to households.[5] However, the drawback is that I cannot control for borrower-specific characteristics. I also examine different measures of profitability and risk-taking, and exploit the granularity of my data set to pinpoint more precisely the types of lending and deposits that are impacted by negative rates.

Contrary to early empirical research from Heider et al. (2019) and Eggertsson et al. (2019), this paper finds that the banks most affected by negative rates through the retail

[5]Calculation based on a baseline sample from ECB bank-level data (see Section 3 for a full description of the data set). Demiralp et al. (2019) put the figure at 3% of euro area loans whereas syndicated loans in the sample of Heider et al. (2019) are at least 9%.

deposits channel *increase* their lending relative to less affected banks.[6] I conduct a variety of robustness tests to check that these results are not driven by the rate cut (as opposed to the negative rate environment), or by other measures which were operating concurrently, such as the ECB's public sector purchase programme (PSPP) and the new requirements from the liquidity coverage ratio (LCR) in Basel III.

The contrasting results with Heider et al. (2019) may be attributable to differences in sample characteristics and the type and measure of lending being analysed. In line with my findings, positive effects on lending have been found by other recent papers (see Demiralp et al., 2019; Basten and Mariathasan, 2018; Bottero et al., 2019; Lopez et al., 2018). Results from the euro area Bank Lending Survey (BLS) also indicate that banks respond to negative rates by increasing their lending volumes and decreasing their lending margins. My results show that the response is limited to household (mortgage) lending, and is driven by banks with high household deposit ratios and banks with high overnight deposit ratios. Overall, net interest margins are unaffected, which implies that the volume effect is large enough to offset the adverse impact on bank profitability. I also find limited evidence of a price effect – that is, some high deposit banks lower their lending spreads relative to low deposit banks in response to negative rates. This could imply increased risk-taking on the part of high deposit banks.

In an extension, I show that bank capitalisation (measured by Tier 1 capital ratio) plays an important role in the response to negative rates. I find that when restricted to a sample of relatively highly capitalised banks, the net interest margins of high deposit banks are squeezed, whereas the net interest margins of high deposit banks in the less capitalised sample are unaffected. My preferred explanation for this result is that more highly capitalised banks have a higher capacity for shock absorbency. In contrast, less capitalised banks need to find

[6] Early working paper versions of Heider et al. (2019) and Eggertsson et al. (2019) were released in 2016 and 2017 respectively.

other avenues to maintain their profitability in order to prevent erosion of relatively thinner capital cushions. This can also be viewed from a risk-shifting perspective – less capitalised banks have less "skin in the game" and are hence more likely to take on risk (Holmstrom and Tirole, 1997).

In a second extension that extrapolates the time period to 2018, I show that the positive effect on lending dissipates as negative rates persist. Viewed through the lens of the Brunnermeier and Koby (2018) framework, this is suggestive that although there is no evidence that the "reversal rate" has been breached, it may creep up over time as banks become more limited in their options to maintain profit margins. These results come with the caveat that extending the time period increases the risk of confounding factors and mis-identification of the treatment and control groups.

Overall, my results suggest that banks look for avenues to compensate for the hit on profitability due to negative rates. Although this is not evidence against the existence of a reversal rate, it does suggest something new – that policy rates can be lowered further, for as long as banks can find ways to shield their profits.

The remainder of this paper is organised as follows. Section 2 provides an overview of the related literature. Section 3 briefly describes the euro area context for negative policy rates; introduces the data set; and documents some stylised facts. Section 4 outlines my empirical strategy and approach to ensuring robustness. Section 5 presents the results, including robustness checks. Section 6 considers two small extensions on persistent negative rates and the role of bank capitalisation, given the main results. Section 7 discusses and attempts to rationalise the findings in the previous two sections, including policy implications for the euro area and avenues for future research. Section 8 concludes.

2 Related literature

This paper contributes to the small but burgeoning strand of literature examining the impact of negative policy rate environments on bank lending behaviour. More generally, this paper contributes to the vast body of work that concerns the role of banks in monetary policy transmission – in particular, the bank lending channel.

The bank lending channel, which focuses on the balance sheet effects of monetary policy on lending institutions, was conceptualised by Bernanke and Blinder (1988) and has since amassed a large body of empirical literature (see for example, Kashyap and Stein, 1994; Bernanke and Blinder, 1992; Gambacorta, 2005; Jiménez et al., 2014). A monetary policy contraction reduces the supply of deposit funding available to banks. Traditionally, this can be understood through a money multiplier view (tighter reserve requirements increase the opportunity cost of holding deposit liabilities) or through the borrower balance sheet perspective (higher interest rates induce households to allocate towards holding more interest-bearing bonds). If banks do not fully hedge their exposure to policy rates and cannot frictionlessly substitute to non-deposit funding sources, then bank lending will fall.[7] Bank size, liquid asset holdings and bank capitalisation have been shown to be important for monetary policy transmission through the bank lending channel (Kashyap and Stein, 2000; Kishan and Opiela, 2000; Jiménez et al., 2012). As the accessibility of non-deposit funding has increased, the traditional view of the bank lending channel, in which policy-induced changes in the quantity of deposits drive bank lending, has decreased in importance (Romer and Romer, 1990). Modern interpretations typically rationalise the propagation of monetary policy through banks by its impact on bank balance sheet strength and risk perceptions,

[7]This implies failure of the Modigliani-Miller theorem for banks, since the structure of liabilities matters for banks' supply of credit. In a similar way, the theorem must also fail for borrowers in order for the bank lending channel to transmit real effects – otherwise borrowers can easily substitute to other forms of financing (such as bonds).

which flows through to external finance premiums and finally, bank funding costs (Disyatat, 2011; Bernanke, 2007).

The theoretical literature on negative policy rate environments is scant. Brunnermeier and Koby (2018) propose an endogenous lower bound, which they call the "reversal rate", that is state-dependent and time-varying. Below this endogenous rate, further policy rate cuts become contractionary. The reversal rate is determined by bank balance sheet characteristics, capital regulatory requirements and the degree of pass-through to retail deposit rates. Banks benefit from rate cuts due to revaluation gains on holdings of long-term fixed income assets. On the other hand, net interest income is squeezed as rates fall due to increasing competition with cash (that is, the elasticity of deposit supply increases). The damage to profitability increases the probability that capital constraints become binding, which itself is a function of banks' initial capitalisation. When these capital constraints do bind, further deterioration of profitability forces banks to reduce their lending. In persistently negative policy rate environments, a "creeping up" effect emerges as fixed income holdings mature and the capital gains effect dissipates, causing the reversal rate to incrementally inch up. A key contribution of this paper is to examine the effects of negative rates on banks within the framework of the reversal rate.

Apart from Brunnermeier and Koby (2018), Eggertsson et al. (2019) construct a model with paper currency whereby the storage costs of money generate a natural bound on deposit rates. They similarly show that bank lending may actually contract in response to rate cuts in negative territory due to competitive pressure from cash. In a New Keynesian model without bank intermediaries, Rognlie (2016) argues that negative rates are most effective when cash demand is relatively inelastic, as this causes less distortion from violating the Friedman rule.[8]

[8]The Friedman rule states that the optimal nominal interest rate is zero, and any deviation from the optimal rate results in welfare loss.

In the empirical literature, the evidence is conflicting as to how bank lending is affected when policy rates turn negative. Heider et al. (2019) examine the effects of negative rates through their impact on retail deposit funding. They take a "difference-in-differences" approach around the ECB's first venture into negative policy rate territory in June 2014, using syndicated loan micro data. They find that in response to the negative rate cut, banks with more deposit funding reduced their lending and further, concentrated their lending to riskier firms. Eggertsson et al. (2019) find similar results on reduced lending volumes using bank-level data in Sweden.

Other recent empirical work find contrary effects. Schelling and Towbin (2018) use a similar methodology to Heider et al. (2019) to show that high deposit Swiss banks increased their lending (relative to low deposit banks) in response to a large and unexpected rate cut into negative territory. They hypothesise that banks respond to the negative shock to deposit funding costs by extending more generous lending terms in an effort to capture market shares and maintain profits. Lopez et al. (2018) take a cross-country approach, comparing banks in countries with negative rates to those in countries with low but still positive rates. They find that for banks in the former group, lending activity increases relative to the latter group, and losses in interest income are almost exactly offset by gains in non-interest income and savings on deposit expenses. Altavilla et al. (2019) find that the pass-through of negative rates to corporate deposits is preserved for sound banks, and overall, the transmission of monetary policy is not hampered.

Negative rates also constitute a direct charge on eligible excess reserves held at the central bank. Papers examining negative rates through the lens of banks' relative exposure to charged reserves have generally found expansionary effects in the form of increased lending and risk-taking (Basten and Mariathasan, 2018; Schelling and Towbin, 2018; Bottero et al., 2019). Some studies conclude that the indirect effects of the retail deposits channel are more important for negative rates than the direct effects of the excess reserves channel (Schelling and Towbin, 2018; Jobst and Lin, 2016). Demiralp et al. (2019) exploit joint variation in deposit funding and excess liquidity holdings in euro-area banks, and find that the most affected banks convert their excess liquidity into increased lending volumes.

Finally, this paper relates to the role that deposit financing plays in determining bank behaviour. Drechsler et al. (2017) find evidence of a "deposits channel", where monetary policy affects the deposit spread through changes in banks' market power. When policy rates are low, deposits become competitive with cash and banks are forced to lower deposit spreads.

3 Data description

3.1 Bank data

This paper primarily makes use of two proprietary bank-level data sets regularly maintained by the ECB – Individual Balance Sheet Items (IBSI) and Individual MFI Interest Rates (IMIR), where MFI refers to monetary financial institution. These data sets report granular statistics on interest rates, lending to households and non-financial corporations (NFCs), and balance sheet characteristics at a monthly frequency for individual euro area banks from July 2007. From 2015, the full sample consists of 300 MFIs. The sample is biased towards larger banks and covers approximately 70% of euro area MFIs by total assets.

Following the lead of other papers analysing euro area banks in a similar time period, banks from Cyprus and Greece are excluded due to domestic economic and banking crises (see for example, Holton and d'Acri, 2018). Branches and banking groups are also removed to avoid double-counting, as are subsidiaries of non-EMU banks, small entities (defined as banks with total assets in the first percentile) and banks with frequently large jumps in total assets.[9] Large jumps are defined as observations where the monthly growth rate of total assets are above the 99th percentile. Banks with five or more of these large jumps are dropped. This helps to remove structural breaks in the data – for example, due to major restructuring.

Finally, I restrict my analysis to deposit-taking institutions, and (mostly) focus on the time period between 2013 and 2015. This leads to a baseline sample of 189 banks. The baseline sample retains its representativeness, comprising around 78% of the total assets in the full sample. Table 1 reports bank balance sheet statistics for the baseline sample and subsamples of high and low deposit banks. High (low) deposit banks are banks with deposit ratios above (below) the median in May 2014. The statistics are based on outstanding amounts, and paint a picture of the typical bank balance sheet in the baseline sample.

In the baseline sample, loans make up close to half of total assets. Retail deposits – specifically, household deposits – are the main source of funding for banks, although funding from other MFIs (which includes central bank financing) and issuance of securities are also important. Interestingly, retail deposit funding has been increasing over time, probably because it is viewed as a relatively safe source of funding (see Appendix B.1).[10] The difference between household deposit ratios in high and low deposit banks is large (48.7% vs 11.4%), but is less evident with respect to NFC deposit ratios (9.7% vs 5.7%). On average, high deposit banks tend to be smaller, hold more loans on their portfolio and are less reliant on funding from securities and other MFIs. Finally, excess liquidity in both high and low deposit banks is relatively low (below 1% on average). This is because the ECB's asset purchase programme was only launched during the latter half of the sample period.[11]

[9] Branch losses are also ultimately covered by the head institution, which implies that the lending behaviour of bank branches are not necessarily reflected by their balance sheets.

[10] Developments in deposit insurance guarantees also make retail deposit financing more attractive.

[11] The low amount of excess liquidity during the sample period makes it even more unlikely that negative rates were significantly propagated through the direct charge on excess reserves (as opposed to the retail deposits channel). This is shown more formally in Section 5.4.

Table 1: Bank balance sheet characeristics

		2013-2015					
Assets		N	Mean	Median	St. Dev.	p5	p95
Total assets (in mill. euro)	*Baseline sample*	6804	105146	40351	169414	4416	483385
	Below median	3384	156072	65506	206808	13810	626876
	Above median	3384	55004	17737	98890	3313	250731
Loans (% total assets)	*Baseline sample*	6804	43.51	45.50	21.31	4.37	75.89
	Below median	3384	31.56	30.30	18.05	4.00	61.24
	Above median	3384	55.34	58.29	17.41	23.40	78.70
Securities holdings (% total assets)	*Baseline sample*	6670	19.94	18.53	12.49	2.33	39.98
	Below median	3313	21.80	21.29	11.47	4.19	41.64
	Above median	3321	18.04	14.46	13.23	1.04	37.11
Excess liquidity (% total assets)	*Baseline sample*	5180	0.72	0.04	1.92	-0.44	4.41
	Below median	2681	0.67	0.03	1.81	-0.34	4.27
	Above median	2463	0.77	0.05	2.05	-0.52	4.52
External assets (% total assets)	*Baseline sample*	6678	7.43	3.81	8.53	0.18	26.92
	Below median	3311	11.15	8.49	9.87	0.45	32.16
	Above median	3331	3.79	1.94	4.67	0.13	13.85
Liabilities							
Household deposit ratio (% total assets)	*Baseline sample*	6804	30.08	28.56	22.71	0.03	70.76
	Below median	3384	11.41	9.40	11.08	0.00	30.51
	Above median	3384	48.72	46.49	14.76	26.77	75.17
NFC deposit ratio (% total assets)	*Baseline sample*	6804	7.66	7.10	5.89	0.08	17.77
	Below median	3384	5.65	5.04	4.86	0.02	14.04
	Above median	3384	9.65	8.84	6.18	0.43	21.95

Table 1 (continued)

		2013-2015					
		N	Mean	Median	St. Dev.	p5	p95
MFI deposit ratio (% total assets)	*Baseline sample*	6804	16.84	13.77	14.38	1.52	40.95
	Below median	3384	22.26	17.90	17.16	4.39	56.86
	Above median	3384	11.42	10.73	7.92	0.83	26.01
Capital ratio (% total assets)	*Baseline sample*	6804	8.58	7.56	4.63	2.81	16.35
	Below median	3384	8.75	7.36	5.33	2.68	17.73
	Above median	3384	8.42	7.71	3.82	2.98	14.93
Securities issued (% total assets)	*Baseline sample*	6804	13.66	8.74	14.83	0.00	42.67
	Below median	3384	21.05	18.80	16.67	0.34	49.88
	Above median	3384	6.19	3.52	7.30	0.00	21.17
Profitability							
Net interest margin (% average interest-earning assets)	*Baseline sample*	1551	0.84	0.64	0.71	0.09	2.21
	Below median	839	0.75	0.55	0.70	0.03	2.24
	Above median	700	0.93	0.74	0.70	0.20	2.19
Net fee income (% average assets)	*Baseline sample*	1599	0.34	0.23	0.34	-0.01	1.08
	Below median	875	0.33	0.20	0.35	-0.00	1.10
	Above median	712	0.35	0.29	0.31	-0.03	0.94

Note: N; St. Dev.; p5; and p95 refer to number of observations, standard deviation, 5th percentile and 95th percentile respectively. The MFI deposit ratio is inclusive of central bank financing. Above (below) median banks are banks above (below) the median deposit ratio in May 2014. See the Glossary for definitions and data sources of variables.

3.2 Regression variables

The main data sets are supplemented with statistics from a variety of sources. Additional bank-level information on profitability and capitalisation is obtained by matching data from SNL Financial, which is available at a quarterly frequency. Macro-level variables are obtained from Bloomberg, Eurostat and the BLS. The BLS is a euro area survey of bank lending behaviour administered by the ECB. Descriptive statistics for the regression variables used in this paper can be found in Appendix A.1.

For the purposes of this paper, lending is defined as a flow variable comprising new business loan volumes granted by banks. New business refers to any new agreement between a household or NFC and the bank, including new negotiations over existing contracts. The ideal measure of lending would only include new agreements – however the data set does not allow for this level of granularity. Lending rate variables are similarly based on new business. For convenience, a Glossary can be found at the end of the paper, which includes definitions and data source descriptions of the regression variables used.

From the baseline sample, further sample shrinkage occurs in regression analyses mostly due to missing values of the dependent variable. For consistency, I keep my cleaning strategy identical where the dependent variables are of similar type (see Appendix C for a full description). However, the strategy differs slightly depending on, for example, the source of the data, or whether the dependent variable is a stock or flow. Finally, in order to omit the influence of outliers, all bank-specific control variables are winsorised at the first and 99th percentiles.

4 Empirical strategy

4.1 Institutional background and hypothesis development

On June 11, 2014, the ECB for the first time ventured in negative policy rate territory, lowering the DFR from 0% to -0.1%. This move was part of a broader strategy with explicit aims of price stability, monetary policy accommodation and support for lending to the real economy (Draghi, 2014a). The DFR has remained negative ever since – three subsequent rate cuts (in September 2014, December 2014 and March 2016) have brought the DFR to its present rate of -0.4%.[12] Currently, the negative DFR applies only to excess reserves held at the ECB – required reserves earn the main refinancing operations (MRO) rate.

Apart from the euro area, negative policy rates have been implemented in Denmark, Sweden, Switzerland and Japan, although the motivations for doing so were not all the same. In particular, the introduction of negative rates was linked to price stability objectives for the ECB, the Riksbank and the Bank of Japan (BoJ), whereas for the Swiss National Bank (SNB) and Danmarks Nationalbank (DN), it was in response to currency appreciation pressures. Tiered deposit schemes which effectively exempt some excess reserves from the headline negative policy rate have also been implemented by the BoJ, SNB, DN, and the Riksbank. In this way, tiered deposits attempt to mitigate the direct charge of negative rates on bank holdings of excess reserves.

In Europe, rate cuts into negative territory have thus far largely been deemed successful in providing monetary policy accommodation, incentivising banks to shift their portfolios from liquid assets to lending (see *inter alia*, Jobst and Lin, 2016; Altavilla et al., 2019). The transmission of policy rates to short-term money market rates and wholesale deposit rates has remained intact. The exception, however, has been transmission to retail deposit rates. The

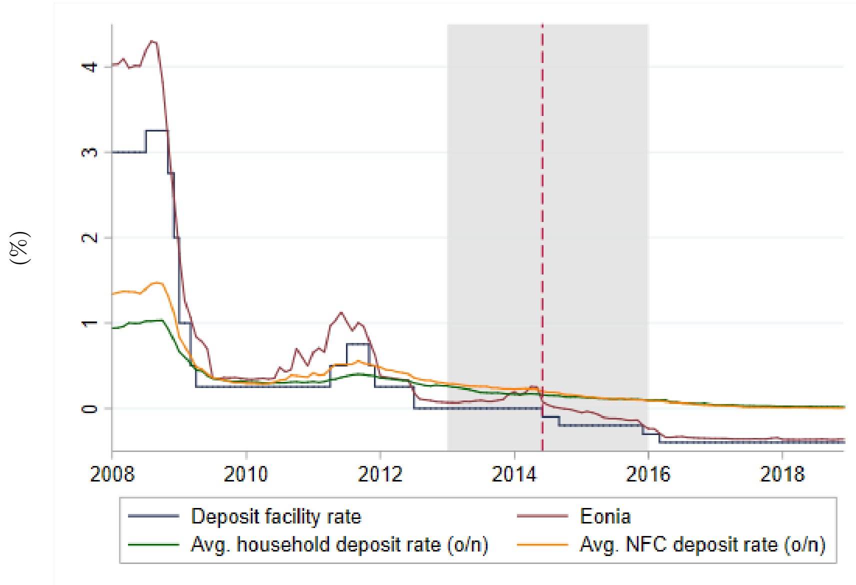
[12]Since the introduction of "fixed-rate full-allotment" refinancing by the ECB in October 2008, the DFR has been the main policy rate guiding market rates.

apparent breakdown in the pass-through has stoked debate about what the implications are for bank profitability and the bank lending channel of monetary transmission, particularly in an environment of persistently negative rates.

Figure 1 shows the evolution of average overnight household and NFC deposit rates. Prior to June 2014, retail deposit rates were mostly above the DFR. Deposit rates, market rates and policy rates moved closely together. This relationship breaks down after June 2014, when negative rates were introduced. Clear non-linearities emerge as retail deposit rates appear to asymptomatically approach zero, and the difference between deposit rates and the DFR becomes increasingly negative. This indicates an increase in the cost of funding for banks with retail deposits – whereas banks previously profited from a mark-down on retail deposit rates over the DFR, the spread reverses and widens with each subsequent rate cut in the negative rate environment. The lower bound exists because banks are reluctant to pass on negative retail deposit rates, since customers can simply withdraw their deposits and store their money as cash, which carries zero nominal return.[13]

Figure 2 shows the distribution of overnight retail deposits for households and NFCs in June 2014 and October 2018. In June 2014, deposit rates are already low, but none below zero. By October 2018, deposit rates become much more concentrated around zero. Further, a significant proportion (around 20%) of NFC deposit rates become negative, whereas household deposit rates cluster on the positive side of zero. In other words, the zero lower bound binds harder for household deposits than for NFC deposits. This is not surprising – households typically hold smaller amounts in deposit accounts and can more easily substitute to cash or arbitrage between banks. In contrast, firms presumably attach greater liquidity and service premia to their bank accounts – for example, to pay wages or settle accounts.

[13] Some papers emphasise the storage costs of cash, which would imply that the lower bound is somewhere lower than (but probably close to) zero – see, for example, Eggertsson et al. (2019). It is also plausible that the reluctance to transmit negative rates is in part due to a "first-mover's disadvantage", whereby banks do not want to be the first to charge negative rates, but will follow once the boundary has been crossed.



This figure shows the evolution of average overnight (o/n) household and NFC deposit rates in the full sample, together with the deposit facility rate and the (monthly) Eonia, from 2008 to the end of 2018. The red dotted line refers to June 2014. The shaded area refers to the sample period of the main regressions from 2013 to the end of 2015. *Source: Author's own calculations using data from IMIR and Eurostat.*

Figure 1: Policy and overnight retail deposit rates over time

The discussion above forms the basis of my econometric strategy. The clear existence of a lower bound on retail deposit rates implies that banks that are heavily reliant on deposit funding should be more affected by negative rates than banks that are not. I exploit this retail deposits channel to make "treatment" and "control" distinctions in a “difference-in-differences”-style framework around the ECB's first foray into negative rates in June 2014.

It is true that bank profitability is also affected in a more direct way by negative rates — holdings of excess liquidity constitute a direct charge by the central bank. However, these direct costs are relatively small compared to the indirect (deposit channel mediated) costs of negative rates (Jobst and Lin, 2016).

Banks can respond to the hit on their profitability in different ways. If the capital constraint is binding, banks may be forced to shrink their balance sheets and reduce lending.

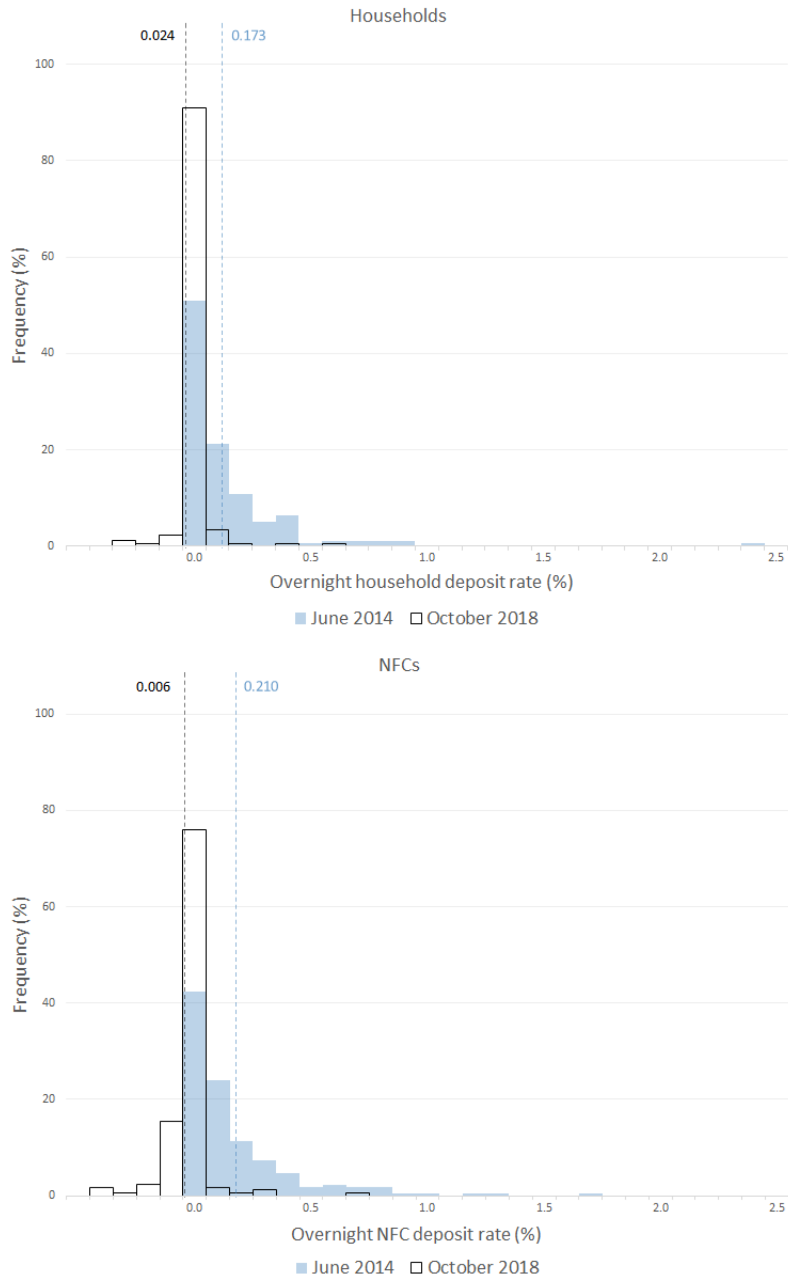


Figure 2: Household and NFC deposit rate frequencies

This figure shows the distribution of overnight deposit rates in households (top panel) and NFCs (bottom panel) over equally spaced buckets of 0.1 percentage points. The blue bars refer to rates in June 2014, and the white bars to rates in October 2018. *Source: Author's own calculations using data from IMIR.*

On the other hand, provided they are not capital constrained, banks may increase their volume of lending in order to offset the adverse effects on their profits. Alternatively, banks may not change their lending behaviour at all if the impact of negative rates is small enough, or if they can maintain profits in other ways, such as by raising fees or substituting to cheaper sources of funding. Hence the effect of negative rates on bank lending is *a priori* ambiguous.

4.2 Empirical methodology

My empirical methodology targets three outcomes of interest. The main outcome of interest is credit supply, which measures monetary policy transmission through the bank lending channel, and how it may be affected by negative rates. The other two outcomes are lending rate spreads and bank profitability. Lending rate spreads give an indication of bank risk-taking. Profitability measures show whether negative rates filter through to the net worth of banks, or whether banks instead manage to offset the impact. Bank profitability is also important from a financial stability perspective.

To test for these effects, I employ a "difference-in-differences" framework, broadly following the methodology of Heider et al. (2019). Variances on this approach have been taken by, for example, Lopez et al. (2018), Schelling and Towbin (2018), Basten and Mariathasan (2018), and Eggertsson et al. (2019). The difference-in-differences approach is appealing because it allows for causal inference, and is robust to omitted variables that equally impact the treatment and control groups. I start with the baseline panel specification:

$$y_{it} = \alpha + \beta \, Deposit\, ratio_i \times After(06/2014)_t + u_{it} \tag{1}$$

y_{it} is the dependent variable of interest related to lending behaviour. For my main results, it is the log of the volume of new loans granted by bank i in month t. I run separate regressions on lending to households for house purchases, lending to NFCs, and total lending (defined as the sum of the former two types of lending). $After(06/2014)_t$ is the treatment intervention variable which is equal to one from June 2014 when the DFR entered negative territory, and zero otherwise. $Deposit\,ratio_i$ is the treatment group indicator, and reflects the deposit ratio (% total assets) of bank i in May 2014. For the most part, $Deposit\,ratio_i$ is specified as an indicator variable which is equal to one for above median deposit ratio in May 2014, and zero for below median. This allows for more easily interpretable results and for a more intuitive distinction between "control" and "treatment" groups.[14] Alternatively, one could think of $Deposit\,ratio_i$ as a reflection of banks' business model preferences for sources of financing. I also specify $Deposit\,ratio_i$ as a continuous variable, which serves both as a robustness check and for more direct comparison with the results of Heider et al. (2019). In this case, $Deposit\,ratio_i$ can be interpreted as capturing treatment intensity. Because the variable is specified before the introduction of negative rates and is not time-varying, potential endogeneity is not a concern.[15]

Following Heider et al. (2019), I restrict the sample to a short window around when the DFR became negative – from January 2013 to December 2015 – in order to minimise the impact of confounding factors, as well as the risk that identification of the treatment group becomes invalid over the time period (Lechner, 2011). Finally, I use bank-level clustered standard errors to account for serial correlation. This is recommended by Bertrand et al. (2004), as persistence of the treatment variable in a difference-in-differences framework causes serial correlation in the error term of the regression within treated units.[16]

[14]Eggertsson et al. (2019) likewise take this identification approach.

[15]The act of loan creation necessarily involves deposit creation. Hence measuring the impact of negative rates on lending volumes by banks' deposit ratios is complicated by reverse causality. Fortunately, this issue is negated by construction of the treatment indicator variable in the difference-in-differences methodology.

[16]The number of clusters over all regressions in this paper range from 44 to 176, which is on the conservative side of a rule-of-thumb requirement of between 20 to 50 clusters in order to obtain reliable cluster-robust variance estimators (Cameron and Miller, 2015).

There are three key identifying assumptions underlying the validity of the difference-in-differences specification. First, the parallel trends assumption must be satisfied. Graphical evidence that, at least on average, the parallel trends assumption holds for the main regressions in this paper can be found in Appendix B.2. I also perform an implicit test of the parallel trends assumption (see Section 6.2). The second assumption is that the ECB's decision to enter negative rates in June 2014 was a "surprise". Otherwise, banks may already have incorporated expectations of negative rates into their lending behaviour in the months before the treatment period started. The graphs in Appendix B.2 show that although the average volume of new lending increased just before the treatment period, there was no divergence between high and low deposit banks. This implies that even if monetary policy accommodation was anticipated and had already begun to be factored in, the effect of negative rates had not (taking for granted that negative rates affect high and low deposit banks differently). This is likely because negative policy rates up until that point were unprecedented for a major central bank, and time was needed to adjust and respond to the new environment.[17] Moreover, although stakeholders had expected action by the ECB, news articles during that time variously described the move into negative rates as "bold", "extraordinary", and a "surprise", and financial markets rallied following the monetary policy announcement.[18]

The third identifying assumption is that banks with a high deposit ratio are more affected by the negative DFR than banks with a low deposit ratio (see the previous section for a theoretical and empirical discussion underlying this assumption. I also show this formally

[17]See Bech and Malkhozov (2016) for an overview of how central banks around the world have implemented negative policy rates.

[18]From *Politico*: "Surprise as ECB experiments with negative interest rates" (Hirst, 2014). From *The Guardian*: "ECB launches bold measures including negative interest rate to boost eurozone" (Monaghan and Inman, 2014). From *The Wall Street Journal*: "The European Central Bank took extraordinary steps... to stave of the threat of dangerously low inflation" (Blackstone, 2014). From *Bloomberg*: "Europe Stocks Rise Near 6-Year High as ECB Adds Stimulus"(Costa, 2014).

in the results on financing costs and lending spreads).[19] In the difference-in-differences framework, this means that low deposit banks provide for the counterfactual scenario where the policy rate was lowered but did not turn negative. Hence β measures the causal impact of the movement into negative policy rate territory on the supply of bank credit. For example, a positive β means that relative to low deposit (less affected) banks, high deposit (more affected) banks increased their lending when the policy rate went negative.

The main threats to the identifying assumptions are unspecified factors which affect the outcome variable and which cannot be differenced out. To address these concerns, I take a stepwise approach, building on the baseline regression in Equation (1) by progressively adding bank fixed effects, time fixed effects, country-time fixed effects and control variables to obtain my most refined specification:

$$y_{itk} = \alpha + \beta\, Deposit\, ratio_i \times After(06/2014)_t + \gamma\, x_{i,t-1} + \delta_i + \eta_t + c_{tk} + u_{itk} \tag{2}$$

$x_{i,t-1}$ are bank-specific control variables, including size (proxied by the log of total assets), capital ratio and securities ratio (ratios are in % of total assets). Selection of these controls is informed by the bank lending literature, which highlights the importance of bank balance sheet characteristics in the transmission of monetary policy (see for example, Kashyap and Stein, 2000; Kishan and Opiela, 2000; Jiménez et al., 2012). As is standard, I lag the balance sheet controls to avoid potential endogeneity bias. δ_i, η_t and c_{tk} are bank fixed effects, time (monthly) fixed effects and country-time fixed effects (for bank i resident in country k) respectively. Bank fixed effects control for unobservable time-invariant bank-specific factors and time fixed effects control for time-varying aggregate shocks. Country-time fixed effects are intended to control for time-varying, country-specific factors such as loan demand and fluctuations in the macroeconomic environment. Controlling for these factors is important in

[19] See Section 5.2.

order to isolate the effects of negative rates. For example, without country-time fixed effects, observed changes in the issuance of loans may be demand-driven rather than as a result of changes in credit supply owing to the negative rate environment. With this specification, the requirement that the parallel trends assumption holds is now conditional on the control variables and myriad of fixed effects.

One potential concern with the use of country-time fixed effects is the risk of contamination due to cross-border lending activities within the euro area.[20] If banks hold significant cross-border lending positions, then country-time fixed effects is not an appropriate way to control for loan demand. Unfortunately, intra-euro cross-border lending is not reported at the bank-level by the data sets. Reassuringly, cross-border loans made up only around 5% of total loans to households and NFCs between 2013 and 2015.[21]

Note that from Figure 1, it can be seen that while the DFR crossed the zero bound in June 2014, retail deposit rates were still positive. This indicates that $After(06/2014)_t$ does not *per se*, discern the "true" boundary, as there is still room for retail deposit rates to reduce. Given that retail deposit rates approach zero in an asymptotic fashion, the results, if anything, would underestimate the effect of hitting the zero lower bound on retail deposit rates.

In Figure 2 I show that the zero lower bound is more binding for household rates than for NFC rates. This implies that banks with a greater ratio of household deposits should be more affected by exposure to negative rates than banks with a greater ratio of NFC deposits. I test for this with the following modification to Equation (2):

$$\begin{aligned} y_{itk} = \alpha &+ \beta_1\, Household\, deposit\, ratio_i \times After(06/2014)_t \\ &+ \beta_2\, NFC\, deposit\, ratio_i \times After(06/2014)_t + \gamma\, x_{i,t-1} + \delta_i + \eta_t + c_{tk} + u_{itk} \end{aligned} \tag{3}$$

[20] Lending activities to residents outside of the euro area are already excluded from the data.
[21] Author's own calculations, from aggregated balance sheet data publicly available from the ECB.

$Household\,deposit\,ratio_i$ and $NFC\,deposit\,ratio_i$ are dummy variables equal to one for above median household and NFC deposit ratios (% of total assets) respectively, and zero otherwise. The discussion above implies that the estimate of β_1 should be stronger than the estimate for β_2. I also perform a similar regression to test for differences in the effect of overnight deposits versus time deposits. In this case, the expectation would be for a greater effect from the overnight deposit ratio variable, since it is overnight deposit rates which are at the zero lower bound.

4.3 Robustness checks

I perform a series of robustness checks to test the sensitivity and validity of my results.

First, negative rates did not occur in isolation. Other measures adopted by the ECB could bias the results, although this could only occur if they had heterogeneous effects on high and low deposit banks. For example, the first series of targeted longer-term refinancing operations (TLTRO-1) was announced by the ECB in tandem with the DFR rate cut in June 2014, and the PSPP began in March 2015 (within the sample time window). Although it is unclear why these measures should affect high and low deposit banks differently, I test for these possible confounding factors. For the most part, this involves varying the sample time window to exclude the influence of other ECB programmes. To account for TLTRO-1, I include in the regression a control measure of central bank financing.

Second, it could be that there is in fact, nothing extraordinary about negative rates, and results are driven by the interest rate cut rather than the negative rate environment. To discount this possibility, I perform a "placebo test" *à la* Heider et al. (2019), with the following specification:[22]

[22] This is a variant of the more general understanding of the placebo test, whereby the treatment period variable is arbitrarily reassigned to some time before the treatment period actually began. A significant result on this artificial treatment would cast aspersions on the validity of the identifying assumptions (Lechner, 2011).

$$
\begin{aligned}
y_{itk} = \alpha &+ \beta\, Deposit\, ratio_i \times After(06/2014)_t \\
&+ \theta\, Deposit\, ratio_i \times After(07/2012)_t + \gamma\, x_{i,t-1} + \delta_i + \eta_t + c_{tk} + u_{itk} \qquad (4)
\end{aligned}
$$

The sample period is extended from 2011 to 2015 in order to incorporate the most recent interest rate reduction which was still in positive territory (July 2012, when the DFR decreased from 0.25% to 0%). $After(07/2012)_t$ is a dummy variable which is equal to one from July 2012 and zero otherwise. If the estimates of β and θ are significant (and the same sign), then it is likely that it is the interest rate cut rather than the negative rate environment which is causing differences in lending behaviour between high and low deposit banks. If, however, the estimate of θ is insignificant (and the estimate of β is significant), then differences in lending behaviour can be directly attributed to negative rates.

Another potential concern is whether there are large fluctuations in bank deposit ratios over time. If true, this would jeopardise the control-treatment distinction. But deposit ratios are generally stable, particularly over a short time window – banks with relatively high (or low) deposit ratios tend to stay that way, likely because it is a function of banks' choice of business model. From the date the treatment indicator is defined in May 2014 to the end of 2015, around 8% of banks switched from being above or below the (monthly) sample median. These were banks that were generally close to the median to begin with. Nevertheless, I check the robustness of my results by using alternative definitions of the treatment indicator, such as taking an average deposit ratio over the year 2014, and replacing the dummy variable with a continuous, "treatment-intensity" indicator.

Finally, I check my results against a variety of small modifications to the main regression, such as different combinations of control variables and alternative measures of lending.

5 Results

5.1 Results on lending volumes

Column (1) of Table 2 reports the results of estimating the baseline specification in Equation (1), where the dependent variable y_{it} is the log of total lending. From Columns (2) to (6), I progressively saturate the regression with fixed effects and control variables as per the stepwise approach taking to estimating Equation (2). In Column (6), I interact the control variables with the post lower bound dummy, in case the controls have different effects on lending under negative rates.

The average treatment effect is positive, relatively stable and highly significant across all specifications. The size of the effect generally diminishes due to the progressive inclusion of controls and fixed effects. In Column (5), the interpretation is: on average, high deposit banks (above the sample median in May 2014) respond to the rate cut by increasing the (flow) volume of new loans supplied by 16.6% ($(e^{0.154} - 1) \times 100$) relative to low deposit banks.[23] In other words, the banks most affected by the negative rate environment through the retail deposits channel increase by 16.6% relative to the less affected banks. This result takes into account individual bank characteristics commonly implicated in the bank-lending literature, time-invariant bank-specific idiosyncrasies, aggregate shocks, and country-specific time-varying trends such as loan demand and cyclical effects (to the extent that they have country-level trends). Moreover, the difference-in-differences methodology ensures that any omitted variables which equally impact high and low deposit banks are differenced out.

In affirmation of the bank lending literature, the addition of relevant control variables greatly increases the explanatory power of the regression (the overall R-squared increases to 0.683 in Column (4)). The signs of the control variable are generally as expected, although

[23] As an alternative method to control for bank size, I regress against total lending expressed as a percentage of total assets. The estimated treatment effect is similarly positive and highly significant (not shown).

Table 2: Impact on total lending

Log(Total lending)

	2013-2015						2011-2015
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Deposit ratio × After(06/2014)	0.227***	0.229***	0.188***	0.178***	0.154***	0.155**	0.169**
	(0.032)	(0.032)	(0.057)	(0.056)	(0.047)	(0.059)	(0.070)
Size				0.673***	0.488**	0.401**	
				(0.207)	(0.194)	(0.200)	
Capital ratio				0.020	0.019	0.031*	
				(0.017)	(0.016)	(0.018)	
Securities ratio				-0.001	0.004	0.008	
				(0.005)	(0.006)	(0.006)	
Size × After(06/2014)						-0.006	
						(0.022)	
Capital ratio × After(06/2014)						-0.017	
						(0.011)	
Securities ratio × After(06/2014)						-0.003	
						(0.003)	
Deposit ratio × After(07/2012)							0.025
							(0.057)
Constant	6.018***	6.031***	6.238***	-1.151	0.771	1.795	4.514***
	(0.121)	(0.010)	(0.050)	(2.214)	(2.094)	(2.129)	(0.068)
R-squared (overall)	0.017	0.017	0.000	0.683	0.643	0.594	0.022
Adjusted R-squared (within)	-	0.069	0.176	0.197	0.314	0.313	0.432
Clusters	136	136	136	136	136	133	127
Obs	4781	4781	4781	4566	4566	4459	7302
Bank FE	NO	YES	YES	YES	YES	YES	YES
Time FE	NO	NO	YES	YES	YES	YES	YES
Country-Time FE	NO	NO	NO	NO	YES	YES	YES
Controls	NO	NO	NO	YES	YES	YES	NO

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

only bank size is consistently significant. All else equal, an increase in size or capitalisation is associated with increased lending. The positive and highly significant effect of size is self-explanatory – bigger banks lend more. The securities ratio switches signs from columns (4) to (5), although the magnitude is almost zero and it is insignificant across all specifications. This could be due to ambiguous effects on bank lending. On the one hand, securities held are (imperfectly) substitutable for loans, so on this basis, a high proportion of securities implies lower lending. On the other hand, the securities ratio is a proxy for liquidity, which to the extent that it signals a healthy balance sheet, could be associated with more lending. The negative coefficients on the control interaction terms in Column (6) are likewise consistent with the bank lending literature, but they are not significant. The impact of monetary policy on lending tends to be stronger for banks that are smaller, less liquid, and less well-capitalised, as these banks are less able to absorb shocks (Kashyap and Stein, 2000; Kishan and Opiela, 2000). The addition of interaction terms for the control variables reduces the overall R-squared without improving the within (adjusted) R-squared (which is more relevant for the difference-in-differences estimator). Hence, I proceed to estimate specifications in the vein of Column (5) for my other results.

In fact, the treatment effect entangles two events – the introduction of a negative rate environment, and the rate cut itself. To exclude the possibility that the rate cut is driving my results, in Column (7) I perform the placebo test specified in Equation (4). I extend the sample window from 2011 to 2015, and incorporate the prior rate cut of the DFR from 0.25% to 0% in July 2012. The estimate of β remains positive and significant, whereas the estimate of θ is insignificant and close to zero. This is strong evidence that it is the negative rate environment rather than the rate cut that is driving the heterogeneous responses in bank lending between high and low deposit banks.

The empirical literature examining the heterogeneous effects of monetary transmission in euro area banks during this time typically makes a distinction between "stressed" and "non-stressed" countries (see, for example, Altavilla et al., 2019; Holton and d'Acri, 2018). This recognises that financial market and sovereign tensions were felt very differently depending on the domestic environment, which in turn could impact bank behaviour. In Appendix A.2, I test if the effects of negative rates are different in subsamples of stressed (Spain, Ireland, Italy, Portugal) and non-stressed (Germany, France, Netherlands, Slovakia, Malta, Luxembourg, Belgium, Austria, Finland) countries. I find that negative rates have positive effects on lending volumes for the most affected banks in both subsamples of stressed and non-stressed countries.

In Table 3, I regress against more granular forms of lending. The results show that the increase in lending by the most affected banks is driven by household lending for house purchases. This can be seen graphically in Appendix B.2. In contrast, there were no significant differences in the lending to NFCs.

An important nuance is that banks appear to be more willing to charge negative retail deposit rates to NFCs than to households (see Figure 2). This implies a harder lower bound on household deposit rates. I test for this by estimating Equation (3). Column (1) of Table 4 shows the results. As expected, the results are to a large degree driven by household deposits. The estimate of β_1 (which indicates the effect on lending for banks with high household deposit ratios) is larger than the estimate of β in Column (5) of Table 2, whilst still retaining its high degree of significance. Conversely, the estimate of β_2 (which corresponds to effects on banks with high NFC deposit ratios) is small and insignificant. One important caveat to this result is that there is much more variation in the household deposit ratio variable compared with the NFC variable (in this sample, the standard deviation is 21 and 1.4 respectively). Low variation in the NFC deposit ratio variable makes it difficult to properly identify high and low NFC deposit banks.

Table 3: Lending breakdown

Log(Lending):	Total lending (1)	Household lending (2)	Small NFC lending (3)	Large NFC lending (4)
Deposit ratio × After(06/2014)	0.154***	0.171**	0.059	-0.004
	(0.047)	(0.070)	(0.053)	(0.068)
Size	0.488**	0.282	0.774**	1.064***
	(0.194)	(0.172)	(0.350)	(0.218)
Capital ratio	0.019	0.008	-0.006	0.035
	(0.016)	(0.019)	(0.013)	(0.028)
Securities ratio	0.004	-0.008	0.000	0.001
	(0.006)	(0.006)	(0.006)	(0.009)
Constant	0.771	1.679	-3.726	-6.031**
	(2.094)	(1.805)	(3.758)	(2.393)
R-squared (overall)	0.643	0.484	0.429	0.534
Adjusted R-squared (within)	0.314	0.478	0.187	0.195
Clusters	136	121	129	120
Obs	4566	4044	4335	4022
Bank FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES

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

Note: Small NFC lending refers to lending to NFCs in amounts up to and including 1 million euro. Large NFC lending refers to lending to NFCs in amounts over 1 million euro.

Table 4: Deposit ratio breakdown

	Household vs NFC deposit ratio (1)	Overnight vs time deposit ratio (2)
Household deposit ratio × After(06/2014)	0.191***	
	(0.050)	
NFC deposit ratio × After(06/2014)	-0.045	
	(0.056)	
Overnight deposit ratio × After(06/2014)		0.180**
		(0.077)
Time deposit ratio × After(06/2014)		-0.099
		(0.070)
Size	0.483**	0.415**
	(0.191)	(0.202)
Capital ratio	0.019	0.014
	(0.016)	(0.016)
Securities ratio	0.005	0.008
	(0.006)	(0.006)
Constant	0.651	1.571
	(2.036)	(2.167)
R-squared (overall)	0.633	0.565
Adjusted R-squared (within)	0.319	0.311
Clusters	135	136
Obs	4531	4567
Bank FE	YES	YES
Time FE	YES	YES
Country-Time FE	YES	YES
Controls	YES	YES

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

In Column (2), I similarly decompose total deposits into overnight deposits and the remaining stock, which I loosely term "time deposits". The estimation is the same as Equation (3), except the dummy variables now denote above/below the median overnight/time deposit ratio in May 2014. As expected, the results show that the positive effect of negative rates on bank lending through the retail deposits channel is driven by overnight deposits rather than time deposits. This is because the overnight deposit rate is much closer to the zero lower bound.

Overall, the results point to a strong, positive response in the supply of credit by the banks most affected by negative rates through the retail deposits channel. This mainly takes place in the form of lending to households for house purchases, and is driven by household deposit liabilities rather than NFC deposits, and overnight deposits rather than time deposits.

5.2 Results on financing costs and lending spreads

In Table 5, I examine the impact of negative rates on financing costs and lending spreads using the same specification in Equation (2). In Column (1), I use the change in the composite borrowing rate as my dependent variable. The composite borrowing rate can be viewed as a weighted measure of banks' average funding costs. It is comprised of borrowing rates (or if not available, proxy rates) on deposits, central bank financing, and market financing, weighted by the corresponding outstanding volumes (see Appendix D for a full description of the calculation). I use outstanding volumes on interest rates due to data limitations on new business volumes. To assuage concerns over non-stationary, I regress against the first difference of the composite borrowing rate.[24] The result confirms the identifying assumption regarding high and low deposit banks – namely, high deposit banks are more affected by negative rates due to downward stickiness in funding costs. This occurs because of the breakdown in the pass-through from the policy rate to retail deposit rates.

Is increased lending by high deposit banks accompanied by lower lending spreads? Lending spreads here are defined as the difference between the lending rate at various maturities and the closest corresponding swap rate, which I take as a proxy of the risk-free rate. Hence a reduction in the lending spread can be interpreted as an indicator for looser lending terms

[24]Regressing against the level of the composite borrowing rate qualitatively leads to the same result (not shown).

Table 5: Impact on financing costs and lending rate spreads

	Cost of borrowing rates	Household lending rate spreads				
	Δ(Composite rate)	Composite spread	Up to 1 year	1 to 5 years	5 to 10 years	Over 10 years
		2013-2015				
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit ratio × After(06/2014)	0.020***	-0.087*	-0.091	-0.117	-0.119	0.046
	(0.004)	(0.046)	(0.061)	(0.141)	(0.115)	(0.081)
Size	0.018	-0.055	-0.070	-0.226	-0.105	0.095
	(0.014)	(0.189)	(0.207)	(0.274)	(0.408)	(0.224)
Capital ratio	-0.002	0.002	0.012	0.028	-0.064	0.031
	(0.001)	(0.014)	(0.015)	(0.047)	(0.077)	(0.043)
Securities ratio	0.000	0.000	-0.003	-0.006	0.004	-0.009
	(0.000)	(0.006)	(0.005)	(0.008)	(0.015)	(0.007)
Constant	-0.222	2.596	2.992	4.597	3.628	0.352
	(0.155)	(2.005)	(2.203)	(3.017)	(4.795)	(2.637)
R-squared (overall)	0.353	0.268	0.054	0.122	0.228	0.457
Adjusted R-squared (within)	0.410	0.495	0.267	0.168	0.206	0.458
Clusters	176	141	141	116	114	106
Obs	6025	4848	4823	3938	3867	3622
Bank FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES

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

and increased risk-appetite. Admittedly, this interpretation requires two strong assumptions – that banks completely hedge their interest-rate risk (such that the swap rate is an appropriate proxy), and that the quality of loans does not change (Paligorova and Santos, 2017). *Ceteris paribus*, a rate cut would be expected improve the quality of loans since borrowers are more likely to repay under the more supportive macroeconomic conditions generated by the rate cut – however if the change in loan quality affects high and low deposit banks equally, then the effect is differenced out.

In Columns (3) to (6), I regress against lending spreads at various maturities. Here I focus on household lending rates for house purchases in light of evidence from Table 3 that the increase in lending is mostly in house purchases. In Column (2), the dependent variable is the composite lending spread, which is a weighted average (by new business volumes) of the lending spreads at different maturities. Whilst the coefficient estimates for β are uniformly negative from Columns (2) to (5), it is only significant (at a 10% level) for the composite lending spread.[25] These results gain in statistical power when I remove country-time fixed effects and instead specifically control for country-level loan demand and cyclical effects (this alternative specification was performed as a robustness check – see Appendix A.4). In this case, the estimate of β for the composite lending spread becomes significant at a 5% significance level and the equivalent estimate for the lending spread for up to one-year maturity becomes significant at a 10% level.

These results offer limited evidence that high deposit banks reduced lending spreads relative to low deposit banks. The effect may be more prominent for short-term lending rates, as the p-values become progressively larger at higher maturities.

Overall, the results in this subsection confirm that negative rates have highly significant effects on the overall cost of funding for high deposit banks relative to low deposit banks.

[25] Moreover, on visual inspection, the parallel trends relationship is only clear for the composite lending spread (see B.2 for the graphs and relevant discussion).

There is limited evidence of a price effect from the negative rate environment, which may be interpreted as an increase in risk-taking for some of the most affected banks.

5.3 Results on profitability

If by raising lending volumes, banks are compensating enough for the hit on profitability due to negative rates, then net interest margins should not be affected. In Table 6, I test for this using merged data from SNL Financial on net interest margins. Because the data is only available quarterly, for this subsection I truncate the entire data set to quarterly frequency. Variables are calculated as simple averages over the quarter. Time and country-time fixed effects are now quarterly.

In Column (1), I confirm the highly significant positive effects on lending for high deposit banks relative to low deposit banks in the quarterly data set. In Column (2), I regress against banks' net interest margins, which are generally the most important component of bank profitability. The net interest margin is the difference between net interest income and net interest expenses, expressed as a percentage of the average volume of interest-earning assets. The estimate of β is close to zero and insignificant. Hence I conclude that there is no evidence that negative rates affect net interest margins for the banks most affected through the retail deposits channel. In Column (3), I test for effects on net fee income (% of average assets). The insignificant estimate of β indicates that there is also no evidence that high deposit banks compensate for negative rates by raising by net fees (relative to low deposit banks).

5.4 Robustness results

In Table 2, I showed that my results on lending are robust to different combinations of control variables and fixed effects. They are also not driven by the rate cut, as demonstrated by the

Table 6: Impact on profitability

Dependent variable:	Log(Total lending)	NIM (%)	NFI (%)
	2013-2015		
	(1)	(2)	(3)
Deposit ratio × After(06/2014)	0.143***	-0.049	0.006
	(0.049)	(0.036)	(0.016)
Size	0.141	-0.286*	-0.123*
	(0.291)	(0.152)	(0.068)
Capital ratio	0.002	0.015	0.001
	(0.019)	(0.020)	(0.008)
Securities ratio	0.017***	-0.005	-0.003**
	(0.006)	(0.004)	(0.002)
Constant	5.642*	4.001**	1.718**
	(3.168)	(1.742)	(0.708)
R-squared (overall)	0.138	0.036	0.031
Adjusted R-squared (within)	0.265	0.151	0.059
Clusters	116	128	127
Obs	1202	1401	1390
Bank FE	YES	YES	YES
Time FE	YES	YES	YES
Country-Time FE	YES	YES	YES
Controls	YES	YES	YES

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

Note: NIM and NFI refer to net interest margin (% average interest-earning assets) and net fee income (% average assets) respectively.

placebo test. In Appendix A.3, I perform the familiar placebo test for my other significant findings. Overall, I conclude that they rule out the possibility that the interest rate cut rather than the negative rate environment is driving my results. For the remainder of this section, I provide further robustness checks, with particular focus on my main findings on bank lending volumes.

Table 7 shows the results from estimating Equation (2) on volumes of bank lending with various isolated modifications. For most of the results in this table, the relevant comparison

Table 7: Alternative specifications

Log(Lending):	Total lending						Household lending
Perturbation:	2014 deposit ratio	Continuous deposit ratio	Varying the time period			Alternative control variables	
	2013-2015		01/13-12/14	10/13-02/15	06/13-06/15	2013-2015	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Deposit ratio × After(06/2014)	0.147***	0.003***	0.063*	0.091***	0.115***	0.182***	0.201***
	(0.046)	(0.001)	(0.037)	(0.033)	(0.041)	(0.064)	(0.076)
Size	0.492**	0.474**	0.150	-0.046	0.170	0.391*	0.175
	(0.192)	(0.193)	(0.254)	(0.279)	(0.242)	(0.224)	(0.206)
Capital ratio	0.016	0.018	0.003	0.011	0.017	0.035	0.017
	(0.016)	(0.016)	(0.016)	(0.018)	(0.017)	(0.023)	(0.018)
Securities ratio	0.004	0.005	0.006	0.010	0.008	0.011	-0.013**
	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)	(0.006)
Central bank financing ratio						-0.003	
						(0.007)	
Excess liquidity ratio						-0.008	
						(0.006)	
Unemployment rate							-0.019
							(0.035)
BLS demand							0.004***
							(0.001)
R-squared (overall)	0.634	0.629	0.328	0.083	0.231	0.643	0.358
Adjusted R-squared (within)	0.316	0.313	0.243	0.255	0.317	0.314	0.336
Clusters	136	137	136	136	136	136	116
Obs	4568	4601	2995	2208	3260	4566	3881
Bank FE	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES	YES	YES	NO
Controls	YES	YES	YES	YES	YES	YES	YES

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

is with Column (5) of Table 2. For convenience, I omit reporting of the constant term.

In Column (1) I redefine the treatment indicator as a dummy variable equal to one if the average deposit ratio in 2014 is above the median, and zero otherwise. The significance and magnitude of the estimate of β is similar to that in Column (5) of Table 2. This provides further evidence of the soundness of the identification of the treatment group. Following the identification strategy of Heider et al. (2019), Column (2) replaces the treatment indicator with a continuous deposit ratio variable (deposit ratio in May 2014), which can be interpreted as a measure of "treatment intensity". The β estimate retains its significance at a 1% level. With the treatment intensity definition the economic interpretation is: a 1-standard-deviation (22.13 in this sample) increase in deposit ratio translates to an increase in lending by approximately 6.6%. [26]

Columns (3) to (5) test the robustness of my results by varying the sample time window. Column (3) shortens the post-treatment period to December 2014 in order to exclude possible contaminating influence from the ECB's PSPP, which was announced in January 2015; and the LCR in Basel III, which was introduced in January 2015 but not fully implemented until January 2019.[27] While it is unclear how the PSPP would affect high and low deposit banks differently, it is plausible that the LCR could have heterogeneous effects.

The LCR requires that banks hold sufficient reserves of high-quality liquid assets such that they are able to continue operating under 30 days of significant liquidity stress. In general, non-deposit funding requires a higher liquidity buffer (particularly relative to deposits backed by deposit guarantees). Hence one might expect the LCR to be relatively more constraining for low deposit banks, thereby limiting their lending *vis-à-vis* high deposit banks and driving

[26]The calculation is: $22.13 \times 0.003 \times 100 = 6.6\%$

[27]Arguably, the asset purchase programme was anticipated as early as August 2014 following a turning-point speech by ECB President Mario Draghi at Jackson Hole (Draghi, 2014b). Given how close this was to the introduction of negative rates in June 2014, in this case I cannot completely exclude possible anticipation effects.

the results in Table 2. On the other hand, the LCR was only implemented gradually over four years, so this effect might not be particularly large.

Nevertheless, omitting potential effects of the LCR and the PSPP in Column (3) leads to an estimate of β that remains significant and positive – although the significance is reduced to a 10% level and the point estimate is much smaller. Whilst I cannot exclude the possibility that either the LCR or PSPP is responsible for the difference in the magnitude of the estimate, I conjecture that it is more likely that by shortening the time window to only six months after the introduction of negative rates, the regression no longer captures the full, delayed response of banks. Given that negative rates were unprecedented for a major central bank up until June 2014, it is plausible that banks took some time to adjust to the new negative rate environment. Some legal, institutional and IT frameworks also required clarity and in certain cases, modification, which could also have delayed the response of banks. Overall, the point estimate of 0.063 could be considered a lower bound of the estimate of β.

In Columns (4) and (5) I test other arbitrary variations to the time period, keeping a symmetric window around June 2014. The β estimate retains its high degree of significance (p-value less than 0.01).

Column (6) includes two additional control variables, which measure central bank financing and excess liquidity (% of total assets). Central bank financing consists of total funding through LTROs, TLTROs and marginal refinancing operations. Excess liquidity is the sum of deposit facility and current account holdings, minus the minimum reserve requirement. With these additional controls, the estimate of β remains highly significant.[28] Hence the results are not driven by ECB funding programmes which were operating concurrently (TLTRO-1, for example, was announced simultaneously with the introduction of negative rates in June 2014), or by variations in excess liquidity.

[28] The results are also robust in regressions where each of the controls is added individually (not shown).

Finally, in Column (7) I replace country-time fixed effects with more specific country-level controls of business cycle fluctuations and loan demand. They are the (lagged) monthly unemployment rate, and an indicator for housing demand as measured by the BLS.[29] Since the BLS indicator is quarterly, I use a simple linear interpolation method to retrieve monthly values. I also change the dependent variable to the log of new household lending to reflect that the BLS indicator only measures housing demand. The significance and magnitude of the result is comparable to Table 3. I also include these control variables for my regressions on borrowing and lending rates, and profitability measures (see Appendix A.4). The results show an overall improvement in the significance of negative rates on lowering lending spreads. For the profitability variables, the results remain insignificant.

My preferred measurement of lending is the (flow) volume of new loans granted which the ECB defines as "new business". This comprises new financial contracts between households or NFCs and banks, but also re-negotiations of existing loans. It is possible that re-financing of loans rather than the issuance of new lending could be driving the observed increase in the new business lending variable. As an alternative dependent variable, I use the log of outstanding loans on banks' portfolios at the end of each month. This is a stock variable which is less affected by re-negotiations. The disadvantage is that it is affected by write-downs and changes in the timing of loan repayments. If banks target the volume of loans they keep on their portfolio, however, then outstanding loans is a more appropriate measure, and would reflect whether banks change their targeted volumes in response to the negative rate environment. The results from estimating Equation (2) using outstanding total loans are reported in Table 8. As before, a stepwise approach is taken.

The estimate of β is positive across all specifications, but only gains significance once

[29] The relevant survey question is, "Over the past three months (apart from normal seasonal fluctuations), how has the demand for loans to households changed at your bank?". Banks can choose between five responses ranging from "decreased considerably" to "increased considerably", as well as an "N/A" option.

Table 8: Impact on outstanding total loans

Log(Outstanding total loans)

	2013-2015					
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit ratio × After(06/2014)	0.013	0.014	0.052***	0.031***	0.023**	0.029**
	(0.011)	(0.011)	(0.018)	(0.010)	(0.010)	(0.012)
Size				0.673***	0.693***	0.697***
				(0.207)	(0.067)	(0.066)
Capital ratio				0.020	0.001	0.001
				(0.017)	(0.002)	(0.003)
Securities ratio				-0.001	-0.012***	-0.012***
				(0.005)	(0.002)	(0.002)
Size × After(06/2014)						0.002
						(0.005)
Capital ratio × After(06/2014)						-0.000
						(0.002)
Securities ratio × After(06/2014)						0.001*
						(0.000)
Constant	9.754***	9.756***	9.745***	2.603***	2.623***	2.558***
	(0.103)	(0.003)	(0.012)	(0.625)	(0.690)	(0.704)
R-squared (overall)	0.022	0.022	0.031	0.891	0.895	0.895
Adjusted R-squared (within)	-	0.004	0.031	0.636	0.706	0.709
Clusters	142	142	142	142	142	141
Obs	4902	4902	4902	4686	4686	4639
Bank FE	NO	YES	YES	YES	YES	YES
Time FE	NO	NO	YES	YES	YES	YES
Country-Time FE	NO	NO	NO	NO	YES	YES
Controls	NO	NO	NO	YES	YES	YES

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

bank and time fixed effects are included. Taking Column (5) as an example, the economic interpretation is: on average, high deposit banks (above the sample median) respond to negative rates by increasing their loan portfolios by (approximately) 2.3% relative to low deposit banks.

Finally, I check to see if there is something special about the stock of syndicated loans which could be driving the opposing results on bank lending reported by Heider et al. (2019). The results can be found in Appendix A.5. I find overwhelmingly insignificant effects, which indicates that syndicated loans are not responsible for my significant findings – however I cannot replicate the negative effects on lending found by Heider et al. (2019) either.

6 Extensions

In this section, I perform two small extensions motivated by the main results.

6.1 The role of bank capitalisation

In this subsection, I examine the role of ex-ante bank capitalisation in the response of banks to negative rates. I split the overall sample into banks above and below the median Tier 1 capital ratio. The Tier 1 capital ratio is calculated as an average over the six months before negative rates were introduced in June 2014. In Table 9, I test for effects on bank lending and profitability measures within these subsamples.

Columns (1) and (2) show the results on total lending. In both subsamples, there are positive effects for high deposit banks relative to low deposit banks. The β estimate is marginally insignificant for the above median subsample (p-value 0.112) but significant for the below median subsample (p-value 0.052). There is a noticeable difference in point estimates but a direct comparison cannot be made since the regressions are over different subsamples.

Table 9: Bank capitalisation and negative rates

Dependent variable:	Log(Total lending)		NIM (%)		NFI (%)	
	2013-2015					
Tier 1 capital ratio: *(median ≈ 12.3%)*	Below median (1)	Above median (2)	Below median (3)	Above median (4)	Below median (5)	Above median (6)
Deposit ratio*After(06/2014)	0.186*	0.119	0.008	-0.154***	0.044	-0.042
	(0.094)	(0.073)	(0.053)	(0.061)	(0.029)	(0.033)
Size	0.478**	0.404	-0.268	-0.578*	-0.295**	-0.054
	(0.192)	(0.498)	(0.285)	(0.320)	(0.139)	(0.101)
Capital ratio	0.009	0.013	0.056**	-0.026	-0.002	-0.002
	(0.007)	(0.012)	(0.026)	(0.034)	(0.003)	(0.002)
Securities ratio	-0.006	0.048	0.006	-0.010	-0.003	0.008
	(0.018)	(0.053)	(0.008)	(0.009)	(0.015)	(0.010)
Constant	1.338	1.488	3.267	7.707**	3.692**	0.906
	(2.124)	(5.592)	(3.166)	(3.680)	(1.562)	(1.138)
R-squared	0.644	0.450	0.178	0.007	0.003	0.090
Adjusted R-squared (within)	0.242	0.335	0.359	0.150	0.112	0.175
Clusters	49	50	58	55	55	58
Obs	1632	1697	637	600	600	637
Bank FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES

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

Note: NIM and NFI refer to net interest margin (% average interest-earning assets) and net fee income (% average assets) respectively.

Columns (3) and (4) reveal heterogeneous effects on net interest margins. High deposit banks in the below median subsample are not significantly affected. In contrast, a highly significant negative effect on net interest margins is detected for high deposit banks in the above median bank capitalisation subsample. The average treatment effect of the negative rate environment on high deposit banks is a 0.15 percentage point reduction in net interest margins relative to low deposit banks.

In Columns (5) and (6) I show that, just as with the overall sample, net fee income is not significantly affected by negative rates in either of the above or below median subsamples.

6.2 Impact of persistently negative rates

In Table 10, I take the sample of banks used in the main results on total lending, truncate the data set to quarterly frequency, and extend the time window from 2013 to 2018. Extending the time window comes at the expense of increased risk of confounding factors potentially affecting the regression, which could invalidate the parallel trends assumption. Identification of high and low deposit banks also becomes more suspect. On the other hand, the exercise allows for broader economic analysis of the effects of persistently negative rate environments.

The results in Column (1) test for whether the positive effect on lending remains in the extended window from 2013 to 2018, using the familiar specification in Equation (2). Further attrition in the sample size occurs due to missing observations in banks. For simplicity, I have omitted the coefficient estimates of the control variables and constant in the output. The estimate of β retains its positive sign and significance.

In Column (2), I interact $Deposit\, ratio_i$ with quarterly dummies, using the first quarter of 2013 as the reference period. The regression is:

$$y_{itk} = \alpha + \sum_{j=2013q2}^{2018q4} \beta_j \left(Deposit\, ratio_i \times Quarter_j \right) + \gamma\, x_{i,t-1} + \delta_i + \eta_t + c_{tk} + u_{itk} \qquad (5)$$

where $Quarter_j$ denote the quarterly dummies in the interaction terms and $2013q2$, for example, refers to the second quarter of 2013. Equation (5) allows for analysis of the effects of negative rates in each of the quarters after negative rates were introduced. Moreover, the quarterly terms in the pre-treatment period serve as an additional implicit check of the parallel trends assumption. Insignificant coefficient estimates indicate that the trend between high and low deposit banks are not significantly different in the pre-treatment period.

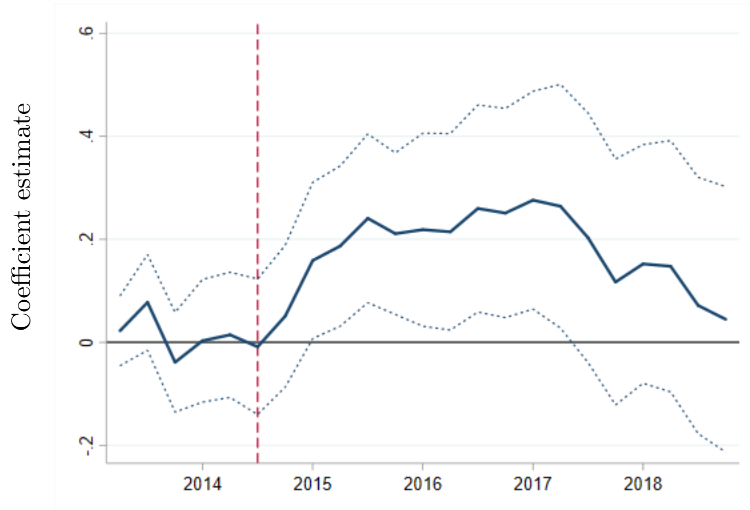
Table 10: Impact on lending over time

Log(Total lending)

	(1)	(2)			
	2013-2018				
Deposit ratio × After(06/2014)	0.158**				
	(0.069)				
Deposit ratio					
interacted with:					
		2013q2	0.022	*2016q2*	0.215**
			(0.034)		(0.096)
		2013q3	0.078	*2016q3*	0.260**
			(0.047)		(0.102)
		2013q4	-0.039	*2016q4*	0.251**
			(0.049)		(0.103)
		2014q1	0.003	*2017q1*	0.276**
			(0.060)		(0.107)
		2014q2	0.015	*2017q2*	0.264**
			(0.061)		(0.120)
		2014q3	-0.009	*2017q3*	0.203*
			(0.066)		(0.122)
		2014q4	0.051	*2017q4*	0.117
			(0.070)		(0.121)
		2015q1	0.159**	*2018q1*	0.152
			(0.077)		(0.117)
		2015q2	0.187**	*2018q2*	0.148
			(0.079)		(0.123)
		2015q3	0.241***	*2018q3*	0.072
			(0.083)		(0.126)
		2015q4	0.211***	*2018q4*	0.045
			(0.079)		(0.130)
		2016q1	0.219**		
			(0.095)		
R-squared (overall)	0.739	0.740			
Adjusted R-squared (within)	0.298	0.304			
Clusters	125	125			
Obs	2727	2727			
Bank FE	YES	YES			
Time FE	YES	YES			
Country-Time FE	YES	YES			
Controls	YES	YES			

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

Figure 3 graphs the results of the quarterly coefficient estimates.



This figure shows the evolution of total lending of high deposit banks relative to low deposit banks, as measured by the quarterly estimates of β_j. The dotted blue lines represent the 95% confidence intervals (standard errors clustered by bank). The dotted red line refers to June 2014, when negative policy rates were first introduced by the ECB. *Source: Author's own calculations using data from IBSI/IMIR and SNL Financial.*

Figure 3: Evolution of $\hat{\beta}_j$

The coefficient estimates of the quarterly dummies for the pre-treatment period are uniformly insignificant, which validates the parallel trends assumption. In the post-treatment period, the results show that the increase in lending by high deposit banks relative to low deposit banks disappears as the negative rate environment persists. The increase in lending occurs with a lag, with significant positive effects only starting to appear six months after the introduction of negative rates. This continues until the third quarter of 2017, after which the quarterly coefficient estimates rapidly decrease in both magnitude and significance. This suggests that the positive effects on lending for high deposit banks dissipate as the negative rate environment persists. Note also the wide 95% confidence intervals, which shows that although the average treatment effect of negative rates was positive between from 2015 to

2017, there was still a large amount of heterogeneity in the response.

In Appendix A.6, I test for the effects of persistently negative rates on profitability by estimating Equation (5) with net interest margin and net fee income as dependent variables. In both cases, no significant differences between high and low deposit banks are detected in the quarterly interaction terms. This is not to suggest that bank fees and net interest margins are unaffected by persistently negative rates in general – only that any effects are not mediated through the retail deposits channel.

7 Discussion

7.1 Interpretation of results

The main results point to an amplification of the bank lending channel for the banks most affected by negative rates through the retail deposits channel. High deposit banks increased their lending relative to low deposit banks, controlling for bank-specific characteristics and the country-level macroeconomic environment. While the funding costs for high deposit banks rose relative to low deposit banks, overall, net interest margins were not significantly affected, which suggests that increased lending volumes were sufficient to offset the adverse effects of negative rates on funding costs and bank profitability. There is no evidence that high deposit banks increased net fees (relative to low deposit banks) as an alternative way to compensate.

There is limited evidence of a price effect – that is, high deposit banks may also have lowered their lending spreads relative to low deposit banks, which could be interpreted as an increase in risk-taking. However, the volume effect appears to be more significant. That lending volumes increased on average for the most affected banks indicates that capital constraints were not binding. This implies that the reversal rate was not breached.

These findings are generally in line with survey evidence from the BLS. Since questions about the negative DFR were included in the BLS in the first quarter of 2016, a positive net percentage of euro area banks have indicated that they responded with higher loan volumes, lower lending rates and lower lending margins.[30] Positive effects on lending due to the negative rate environment have also been found by other recent papers (Demiralp et al., 2019; Lopez et al., 2018; Schelling and Towbin, 2018; Basten and Mariathasan, 2018).

The results on lending contrast with Heider et al. (2019), who find that negative rates lead to *less* lending by euro area banks that have a greater reliance on deposit funding. However, their sample is limited to syndicated loans. This allows them to link borrowers and lenders and analyse individual loan terms. The disadvantage is that outstanding syndicated loans only make up less than 5% of a bank's total loan portfolio on average, which may not be representative of total lending. Further, the use of outstanding amounts is not solely determined by new lending – faster repayments, for example, could be driving the reduction in syndicated loans rather than a reduction in lending. Nevertheless, by using outstanding syndicated loans as my dependent variable (see Appendix A.5), I cannot replicate the results of Heider et al. (2019). Another difference is in the data set. Heider et al. (2019) use data from DealScan with a baseline sample size of 23 banks. This paper uses data from the ECB, with a larger baseline sample of 189 banks.

Why do banks that are most affected by the negative rate environment increase their lending volumes? I consider two potential explanations.

As pointed out by Brunnermeier and Koby (2018), the capital gains effect on long-term fixed income securities offsets the adverse impact on deposit funding costs. If high deposit banks have relatively large portfolios of long-term fixed income assets, then capital gains

[30] The relevant survey questions are: "Given the ECB's negative deposit facility rate, did or will this measure, either directly or indirectly contribute to: impact on your bank's lending rates/loan margins/lending volumes?" Loan margin refers to the spread of the bank's lending rate and a relevant market reference rate.

may induce them to increase their lending – in particular if they were capital constrained before the rate cut. This does not bear out in the summary statistics. In May 2014, the month before the rate cut, low deposit banks had *higher* average holdings of securities with maturity of more than 2 years than high deposit banks (5.3% of total assets as compared to 3.4%).[31] Moreover, the capital gains effect is a product of the interest rate cut rather than the negative environment. Given that the placebo test does not detect any significant differences in lending as a result of the rate cut, it is unlikely that capital gains are driving the results.

The second explanation is that if banks are not capital constrained, reducing lending volumes in response to the adverse effects of negative rates on net worth is not a given. In fact, banks may opt to *increase* lending volumes as a way to maintain profit levels. As argued by Schelling and Towbin (2018), the volume effect could be bolstered by a reduction in lending terms as a way to capture market share (lower lending rates might also be expected to increase the "size of the pie" due to a shift along the demand curve). However, it is plausible that banks are able to increase their lending volumes without changing their lending terms. One example is an environment in which there is excess demand and credit supply is a constraining factor. This could occur in a period heightened risk aversion. In this environment, banks can increase loan volumes without necessarily compromising on lower lending spreads or lower loan quality.

Although the effect of initial capital revaluation on fixed income assets is unlikely to be driving the results on bank lending, the fading out of the capital gains effect could still be important, particularly in a persistent negative rate environment. As long-term assets mature, the positive effects of the one-off revaluation due to the rate cut diminish.

[31] Specifically controlling for the capital gains effect by including securities held with maturity greater than two years as a control variable in the regression in Equation (2) did not significantly change the results either (not shown).

Meanwhile, deterioration of bank profitability in the negative rate environment becomes more pronounced. This creeping up effect gradually increases the likelihood that banks will become capital constrained, which could eventually lead to contractionary effects on lending. My findings do not preclude this possibility. Indeed, the results in Table 10 show that the positive effects on lending for high deposit banks diminish the longer that banks are operating in the negative rate environment. This could reflect lower demand for loans such that banks are unable to increase their lending volumes without lowering prices, or the increasingly detrimental effects of negative rates on bank profitability making it more difficult for banks to sustain increased lending volumes as they approach their capital constraints – or both. An alternative explanation is that while the shock of negative rates initially leads to a divergence in lending behaviour between high and low deposit banks, as banks began to adapt to the new environment, these differences gradually return to pre-treatment trends.

If banks cannot compensate by increasing their lending volumes, then they may find other ways to maintain their profitability – for example, by increasing fees. But the results in Appendix A.6 do not detect any significant effects of negative rates on net fee income between high and low deposit banks. Nevertheless, since mid-2017 net fee income has been rising for both high and low deposit banks (see Appendix B.3). Given that my empirical strategy relies on identification through cross-sectional differences in deposit ratios, it is perhaps not surprising that the regression results do not return significant effects. This points to an important corollary – that the retail deposits channel is not the only mechanism by which negative rates affect bank profitability. For example, banks are also affected through the direct charge on holdings of excess reserves, and the low-for-long interest rate environment in general affects maturity transformation activities due to a flatter yield curve. In a generally low profitability environment, banks may be raising fees regardless of their deposit ratio. Hence, my findings of insignificant effects on net fee income *through the retail deposits channel* are not necessarily inconsistent with other papers which have found more generally that banks in negative rate environments increase fees. Similar nuance should be applied to the interpretation of my results on net interest margins.[32]

A secondary finding of this paper is that the increase in lending is driven by lending to households for house purchases rather than NFC lending. This can be attributed to different loan demand conditions at the time as well as the cyclicality of house prices. With regards to the latter, in an environment of rising house prices, banks may be more willing to increase housing loan supply due to better collateralisation, lower loan loss provisions and higher flow of repayments. Indeed, on aggregate, house prices in the euro area were rising between 2013 and 2015.[33] On the demand side, households (as opposed to large firms) are more likely to face credit market frictions and are hence more elastic to monetary policy (Gertler and Gilchrist, 1993). An alternative explanation is that the lower bound hits harder for household deposit rates, and to the extent that banks make lending decisions based on margins between household lending rates and corresponding household deposit rates, this would lead to a much stronger effect on household lending. Survey evidence from the BLS indicates that banks responded to the negative DFR with larger increases in household lending relative to NFC lending.[34]

One might expect that low capitalised banks have a higher probability of facing binding capital constraints. If true, then these banks are more limited in their ability to increase lending volumes, which in turn, could lead to significant negative effects on net interest

[32] Lopez et al. (2018) find that negative rates lead to declines in net interest income which are offset by increases in non-interest income, resulting in little overall impact on bank profitability. Borio et al. (2015) and Claessens et al. (2018) find that unusually low interest rates erode net interest income. Altavilla et al. (2018) find that accommodative monetary policy is not associated with lower bank profitability once the endogeneity of current and expected macroeconomic and financial conditions is controlled for.

[33] Source: House price index from Eurostat.

[34] The results of the first quarter of 2016 BLS (the first time the survey included questions about the ECB's negative DFR) indicate that a net percentage of 16% of euro area banks reported a positive impact of the negative DFR on housing lending volumes, as opposed to 2% for loans to enterprises (Scopel et al., 2016). Between 2016 and 2018, the average was 15% for housing loans and 8% for loans to enterprises.

margins. In support of this line of reasoning, Arce et al. (2018) find that banks that report a higher impact of negative rates on their net interest income in the BLS are on average, less capitalised and tend to grant loans with shorter maturity and lower average loan size (although they only test for correlation).

In fact, I find the opposite. The positive effects of negative rates on total lending are more significant for less capitalised banks, leading to insignificant effects on net interest margins. In contrast, high deposit banks in the subsample with better Tier 1 capitalisation did suffer significant negative effects on their net interest margins.

My explanation of these results is that banks that are better capitalised are less responsive to negative rates precisely because they have the capacity (or excess capacity) to absorb the shock to their profitability. In contrast, less well-capitalised banks are more concerned with deteriorating capital cushions, and are spurred into action to offset the adverse impact on profitability – for example, by increasing lending volumes. In the extreme, the latter effect can be attributed to a "gambling for resurrection" motive (Jensen and Meckling, 1976). A closely related explanation has to do with the extent to which choice of bank capitalisation reflects risk preferences (McShane and Sharpe, 1985). If better capitalised banks are indeed more risk-averse, then the results could reflect the reticence of these banks to take on more risk by raising lending volumes, instead opting to wear the hit on profitability. In other words, banks with less "skin in the game" may be more willing to take on risk (Holmstrom and Tirole, 1997).

These results on bank capitalisation are consistent with the bank lending literature on the effects of conventional monetary policy (usually described in terms of a monetary policy contraction). Typically, studies in this area find that healthier and better capitalised banks are less responsive to monetary policy interventions (Jiménez et al., 2012; Kishan and Opiela, 2000). However the reason is different – they attribute the insensitivity to the relative ease of better capitalised banks to substitute to non-deposit financing. In support of my results, Bottero et al. (2019) also find stronger expansionary effects on lending for well-capitalised banks in a sample of Italian banks. Altavilla et al. (2019) find that less profitable banks are more likely to pass on negative retail deposit rates to NFCs, which in a similar manner, they motivate as banks with less ability to absorb the monetary policy shock passing the rate cut on to their clients in an attempt to preserve profitability. Finally, Jiménez et al. (2014) find in a sample of Spanish banks that a lower overnight interest rate induces less capitalised banks to grant more loan applications to ex-ante risky firms than better capitalised banks, and these loans are more likely to be larger in volume and uncollateralised.

The results also provide further evidence that the reversal rate was not breached, as even the less capitalised banks were able to increase their lending. Further, the median Tier 1 capital ratio was around 12.3% – well in excess of the baseline 6% requirement imposed by Basel III (although individual banks may have additional capital requirements)[35]. According to Brunnermeier and Koby (2018), banks would have to be approaching their capital constraints in order for downward pressures on lending to start to appear.

In sum, although my results are not inconsistent with the existence of a reversal rate, at a minimum they point to a missing factor in the framework by Brunnermeier and Koby (2018) – namely that banks seek other avenues in order to maintain their profit margins. From a theoretical perspective, this has thorny and uncomfortable connotations – for example, that banks were not behaving optimally to begin with. On the other hand, given the heightened level of uncertainity and risk aversion at the time, this is perhaps not an implausible assertion. Importantly, the adverse effects of negative rates may become more evident when there is less "slack" in banks' ability to manoeuvre.

[35] Globally systemically important banks are required to hold additional capital of between 1% and 3.5% of risk-weighted assets (although in practice the highest capital surcharge has not exceeded 2.5%). Additional capital constraints may also be imposed by individual countries, such as countercyclical buffers or stricter requirements on banks that have systemic importance domestically.

7.2 Policy implications and future research

Overall, the positive effect on bank lending by negative rates is consistent with the ECB's intention to provide ample monetary policy accommodation (Draghi, 2014a). Up until 2015, the evidence strongly indicates that the reversal rate was not breached – although it is certainly plausible that in the years since, banks have moved closer to the reversal rate. On the other hand, a key finding of this paper is that banks seek other avenues to maintain their profitability. While the strategy of increasing lending volumes may not have been sustainable (as suggested by Table 10), bank fees for both high and low deposit banks have been rising recently, which is at least suggestive that banks are not yet completely stymied in how they respond to negative rates.[36] This suggests that the ECB has the policy space to manoeuvre rates further into negative territory without provoking contractionary behaviour.[37]

Moreover, the zero lower bound on retail deposit rates is not necessarily immutable. For example, customers could become less resistant to the prospect of being charged for their deposits as negative rates become the "norm", and other banks may be inclined to follow once the first bank makes the move to transmit negative rates to depositors. Both scenarios would mitigate the adverse impact of negative rates through the retail deposits channel, leaving space for further rate cuts.

The heterogeneous impact of negative rates should be considered. Most prominently, high deposit banks are more sensitive to the negative rate environment than low deposit banks. This implies additional heterogeneity in monetary transmission through the bank lending channel and potentially, in risk-taking too. Heterogeneous effects could become increasingly

[36] Raising fees may be the more attractive outlet to transmit negative rates because 1) customers are already used to being charged account-keeping and administration fees for their accounts and 2) it avoids the psychological barrier for customers of being charged negative rates on their savings.

[37] A relevant consideration is that additional changes to Basel III (dubbed "Basel IV" by the industry) take effect from January 2022, and could constitute significantly stricter capital requirements for banks that use internal risk models (see Bank for International Settlements, 2013 for more). All else equal, this would have the effect of increasing the reversal rate.

evident between bank business models and between countries. This should be considered when making monetary policy decisions in negative rate environments.

Expansionary monetary policy naturally stimulates risk-taking – but whether negative rates promote *excessive* risk-taking behaviour is an avenue for future research. As a motivating factor, this paper finds some evidence that banks may respond to negative rates by lowering lending standards.

Banks with different levels of capitalisation are also affected differently. Only the net interest margins of high deposit, well-capitalised banks appear to be negatively affected. This is reassuring from a (micro) financial stability perspective in that the probability of default of these banks is likely to be low. In contrast, the effect on net interest margins for less capitalised banks is insignificant, which suggests that the positive effect on lending volumes sufficiently compensates for the hit on profitability due to negative rates. This in itself implies increased risk-taking, but what it means for financial stability depends crucially on the compositional risk content of the loans. Given that further rate cuts in negative territory are possible, a more comprehensive analysis of the implications of negative rates for financial stability risk is warranted.

How negative rates affect macro risks is not a focus of this paper, however the results on lending breakdown provide a useful springboard for discussion. The positive effects on lending are almost completely driven by mortgage lending, which may point to a lack of productive investment opportunities in the NFC sector. Greater mortgage lending could be seen as a positive from a welfare perspective, and the indirect effects of gaining greater access to the credit market would in the short term boost the consumption of credit-constrained households. However recent studies on finance and growth find no correlation between household credit and economic growth – as opposed to corporate credit, which is positively associated with growth (see for example, Thorsten et al., 2012). Rapid growth in mortgage lending could also fuel asset price inflation and the procyclicality of the financial cycle, which would have adverse implications for financial stability.

Finally, this paper abstracts from other channels by which negative (or low) interest rates in general affect banks. An obvious extension would be to incorporate the joint effect of excess reserve holdings, which has become increasingly important in recent years. While the direct charge due to negative rates is still expected to be smaller than the indirect effect through retail deposits, excess reserve holdings are unevenly distributed throughout the euro area. This could be driving additional heterogeneous effects. An examination of the excess reserves channel would also be useful to inform discussion about the merits of deposit tiering. Taking a further step back, whilst the link between negative rates and credit supply has been established, the end-transmission of rate cuts in negative territory to the real economy necessarily depends on the response of borrowers.

8 Conclusion

This paper examines the transmission of negative rates through the retail deposits channel. I find strong evidence that the most affected banks increase their credit supply relative to those less affected. However, these effects diminish as the negative rate environment persists. Importantly, no contractionary effects are detected, which suggests that the reversal rate has not yet been breached. In fact, the results point to an amplification of the bank lending channel – although with heterogeneous transmission and likely implications for risk-taking behaviour. The policy implications of this paper should be considered as part of a broader assessment of the short and longer-term trade-offs that pertain to accommodative monetary policy under negative (or low) rates in general.

References

Altavilla, C., Boucinha, M., Peydró, J.-L., & Beck, T. (2018). Monetary policy and bank profitability in a low interest rate environment. *Economic Policy*, *33*(96), 531–586.

Altavilla, C., Burlon, L., Giannetti, M., & Holton, S. (2019). *Is there a zero lower bound? The effects of negative policy rates on banks and firms* (Working Paper Series No. 2289). European Central Bank.

Arce, Ó., García-Posada, M., Mayordomo, S., & Ongena, S. (2018). *Adapting lending policies when negative interest rates hit banks' profits* (Working Papers No. 1832). Banco de España.

Bank for International Settlements. (2013). *High-level summary of Basel III reforms*. Basel Committee on Banking Supervision.

Basten, C. & Mariathasan, M. (2018). *How banks respond to negative interest rates: Evidence from the swiss exemption threshold* (CESifo Working Paper Series No. 6901). CESifo Group Munich.

Bech, M. L. & Malkhozov, A. (2016). How have central banks implemented negative policy rates? *BIS Quarterly Review*.

Bernanke, B. S. (2007). *The financial accelerator and the credit channel* (Speech No. 296). Board of Governors of the Federal Reserve System (U.S.)

Bernanke, B. S. & Blinder, A. S. (1988). Credit, money, and aggregate demand. *American Economic Review*, *78*(2), 435–439.

Bernanke, B. S. & Blinder, A. S. (1992). The federal funds rate and the channels of monetary transmission. *American Economic Review*, *82*(4), 901–921.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? *The Quarterly Journal of Economics*, *119*(1), 249–275.

Blackstone, B. (2014, June 5). *ECB unveils rate cuts, lending package. The Wall Street Journal*. Retrieved from https://www.wsj.com/articles/ecb-enters-uncharted-territory-with-rate-cuts-1401969463

Blinder, A., Ehrmann, M., de Haan, J., & Jansen, D.-J. (2017). Necessity as the mother of invention: Monetary policy after the crisis. *Economic Policy*, *32*(92), 707–755.

Borio, C., Gambacorta, L., & Hofmann, B. (2015). *The influence of monetary policy on bank profitability* (BIS Working Papers No. 514). Bank for International Settlements.

Bottero, M., Minoiu, C., Peydró, J.-L., Polo, A., Presbitero, A. F., & Sette, E. (2019). *Negative monetary policy rates and portfolio rebalancing: Evidence from credit register data* (Economics Working Papers No. 1649). Department of Economics and Business, Universitat Pompeu Fabra.

Brunnermeier, M. K. & Koby, Y. (2018). *The reversal interest rate* (NBER Working Papers No. 25406). National Bureau of Economic Research, Inc.

Cameron, A. C. & Miller, D. L. (2015). A practitioner's guide to cluster-robust inference. *Journal of Human Resources*, *50*(2), 317–372.

Claessens, S., Coleman, N., & Donnelly, M. (2018). "Low-for-long" interest rates and banks' interest margins and profitability: Cross-country evidence. *Journal of Financial Intermediation*, *35*(PA), 1–16.

Costa, S. H. (2014, June 5). *Europe stocks rise near 6-year high as ecb adds stimulus. Bloomberg*. Retrieved from https://www.bloomberg.com/news/articles/2014-06-05/europe-stock-index-futures-are-little-changed-before-ecb

Demiralp, S., Eisenschmidt, J., & Vlassopoulos, T. (2019). *Negative interest rates, excess liquidity and retail deposits: banks' reaction to unconventional monetary policy in the euro area* (Working Paper Series No. 2283). European Central Bank.

Disyatat, P. (2011). The bank lending channel revisited. *Journal of Money, Credit and Banking*, *43*(4), 711–734.

Draghi, M. (2014a, June 5). *Introductory Statement to the Press Conference (with Q&A). Frankfurt, Germany.* Retrieved from https://www.ecb.europa.eu/press/pressconf/2014/html/is140605.en.html

Draghi, M. (2014b, August 22). *Unemployment in the euro area. Jackson Hole, United States.* Retrieved from https://www.ecb.europa.eu/press/key/date/2014/html/sp140822.en.html

Drechsler, I., Savov, A., & Schnabl, P. (2017). The deposits channel of monetary policy. *The Quarterly Journal of Economics*, *132*(4), 1819–1876.

Eggertsson, G. B., Juelsrud, R. E., Summers, L. H., & Wold, E. G. (2019). *Negative nominal interest rates and the bank lending channel* (Working Paper No. 25416). National Bureau of Economic Research.

Gambacorta, L. (2005). Inside the bank lending channel. *European Economic Review*, *49*(7), 1737–1759.

Gertler, M. & Gilchrist, S. (1993). The role of credit market imperfections in the monetary transmission mechanism: Arguments and evidence. *Scandinavian Journal of Economics*, *95*(1), 43–64.

Heider, F., Saidi, F., & Schepens, G. (2019). Life below zero: Bank lending under negative policy rates. *The Review of Financial Studies.*

Hirst, N. (2014, June 12). *Surprise as ECB experiments with negative interest rates. Politico.* Retrieved from https://www.politico.eu/article/surprise-as-ecb-experiments-with-negative-interest-rates/

Holmstrom, B. & Tirole, J. (1997). Financial intermediation, loanable funds, and the real sector. *The Quarterly Journal of Economics*, *112*(3), 663–691.

Holton, S. & d'Acri, C. R. (2018). Interest rate pass-through since the euro area crisis. *Journal of Banking & Finance*, *96*(100), 277–291.

Jensen, M. C. & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics*, *3*(4), 305–360.

Jiménez, G., Ongena, S., Peydro, J.-L., & Saurina, J. (2012). Credit supply and monetary policy: Identifying the bank balance-sheet channel with loan applications. *American Economic Review*, *102*(5), 2301–26.

Jiménez, G., Ongena, S., Peydró, J.-L., & Saurina, J. (2014). Hazardous times for monetary policy: What do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking? *Econometrica*, *82*(2), 463–505.

Jobst, A. & Lin, H. H. (2016). *Negative interest rate policy (NIRP); Implications for monetary transmission and bank profitability in the euro area* (IMF Working Papers No. 16/172). International Monetary Fund.

Kashyap, A. K. & Stein, J. C. (1994). Monetary policy and bank lending. In *Monetary policy* (pp. 221–261). The University of Chicago Press.

Kashyap, A. K. & Stein, J. C. (2000). What do a million observations on banks say about the transmission of monetary policy? *American Economic Review*, *90*(3), 407–428.

King, M. (2000, January 7). *Monetary policy: Theory in practice*. Bank of England. Retrieved from https://www.bankofengland.co.uk/speech/2000/monetary-policy-theory-in-practice

Kishan, R. P. & Opiela, T. (2000). Bank size, bank capital, and the bank lending channel. *Journal of Money, Credit and Banking*, *32*(1), 121–41.

Lechner, M. (2011). The estimation of causal effects by difference-in-difference methods. *Foundations and Trends(R) in Econometrics*, *4*(3), 165–224.

Lopez, J. A., Rose, A. K., & Spiegel, M. M. (2018). *Why have negative nominal interest rates had such a small effect on bank performance? Cross country evidence* (Working Paper No. 25004). National Bureau of Economic Research.

McShane, R. W. & Sharpe, I. G. (1985). A time series/cross section analysis of the determinants of Australian trading bank loan/deposit interest margins: 1962-1981. *Journal of Banking & Finance*, *9*(1), 115–136.

Monaghan, A. & Inman, P. (2014, June 5). *ECB launches bold measures including negative interest rate to boost eurozone. The Guardian.* Retrieved from https://www.theguardian.com/business/2014/jun/05/european-central-bank-cuts-deposit-rates

Paligorova, T. & Santos, J. A. (2017). Monetary policy and bank risk-taking: Evidence from the corporate loan market. *Journal of Financial Intermediation*, *30*(100), 35–49.

Rognlie, M. (2016). What lower bound? Monetary policy with negative interest rates. *Unpublished manuscript.*

Romer, C. & Romer, D. (1990). New evidence on the monetary transmission mechanism. *Brookings Papers on Economic Activity*, *21*(1), 149–214.

Schelling, T. & Towbin, P. (2018). *Negative interest rates, deposit funding and bank lending.* mimeo.

Scopel, S., Hempell, H. S., & Köhler-Ulbrich, P. (2016). *The euro area bank lending survey* (Occasional Paper Series No. 179). European Central Bank.

Thorsten, B., Berrak, B., Rioja, F., & Valev, N. (2012). Who gets the credit? And does it matter? Household vs. firm lending across countries. *The B.E. Journal of Macroeconomics*, *12*(1), 1–46.

Glossary of terms

Acronyms

BoJ	Bank of Japan
BLS	Bank lending survey
DFR	Deposit facility rate
DN	Danmarks Nationalbank
ECB	European Central Bank
Eonia	Euro overnight index average
IBSI	Individual balance sheet indicators
IMIR	Individual MFI interest rates
LCR	Liquidity coverage ratio
LTRO	Long-term refinancing operation
MFI	Monetary financial institution
MRO	Marginal refinancing operation
NFC	Non-financial corporation
PSPP	Public sector purchase programme
SNB	Swiss National Bank
TLTRO	Targeted long-term refinancing operation

Glossary

BLS demand	Country-level demand for euro area loans for house purchases, measured in net percentages from bank survey responses. Net percentage is the difference between the share of banks that report an increase in loan demand over the past three months and the share of banks that report a decrease in loan demand. *Source: ECB BLS.*
Capital ratio	Outstanding capital and reserves, as a percentage of total assets. *Source: IBSI.*

Central bank financing ratio	Share of financing from LTROs, TLTROs and MROs, as a percentage of total assets. *Sources: ECB, IBSI.*
Composite borrowing rate	Weighted average (by outstanding volumes) of bank borrowing rates and proxy borrowing rates. See Appendix D for a detailed description of the calculation. *Sources: Volumes from IBSI. Deposit rates from IMIR. Eonia from Eurostat. Yield rates from Deutsche Bundesbank.*
Composite household lending rate	Weighted average (by new business) of bank lending rates at various maturities. *Source: IMIR.*
Deposit ratio	Share of household and NFC deposits as a percentage of total assets *Source: IBSI.*
Excess liquidity ratio	Deposit facility plus current account holdings minus the minimum reserve requirement, expressed as a percentage of total assets. *Source: ECB.*
External assets	Loans and securities held where the counterparty is a non-euro area resident *Source: IBSI.*
Household lending	Volume of euro area loans granted as new business to households for house purchases *Source: IMIR.*
Household lending spread	Difference between lending rates to households for house purchases at various maturities and the closest corresponding swap rate. *Lending rates from IMIR. Swap rates from Bloomberg.*
Large NFC lending	Volume of loans granted to NFCs as new business, in amounts of over 1 million euro. *Source: IMIR.*
Net fee income	The difference between fee income and fee expenses, as a percentage of average assets. *Source: SNL Financial.*
Net interest margin	The difference between interest income and interest expenses, as a percentage of average interest generating assets. *Source: SNL Financial.*
New business	Any new agreement between a household or NFC and the bank, including new negotiations over existing contracts.
Outstanding loans	Outstanding loan volumes as at the end of each month. *Source: IBSI.*

Securities ratio	Total debt securities held as a percentage of total assets. *Source: IBSI.*
Size	Log of total assets. *Source: IBSI.*
Small NFC lending	Volume of loans granted to NFCs as new business, in amounts up to and including 1 million euro. *Source: IMIR.*
Tier 1 capital ratio	Tier 1'capital as a percentage of risk-weighted assets *Source: SNL Financial.*
Total lending	Sum of the volume of new loans granted as new business to households for house purchases and NFCs. *Source: IMIR.*

A Supplemental tables

A.1 Descriptive statistics of regression variables

Variable	Units	N	Mean	Median	St. Dev.	p5	p95
Dependent variables							
Lending volumes							
Log(Total lending)	Lending in mill. euro	6572	5.67	5.76	1.70	2.92	8.42
Log(Household lending)		5918	3.94	4.02	1.87	0.61	6.83
Log(Small NFC lending)		6307	3.64	3.64	2.06	0.15	7.09
Log(Large NFC lending)		6030	4.92	5.03	1.91	1.47	8.15
Log(Outstanding total loans)		6804	9.57	9.62	1.33	7.44	11.82
Log(Outstanding syndicated loans)		5769	6.37	6.49	1.90	3.01	9.19
Borrowing and lending rates							
Composite borrowing rate	%	6804	0.96	0.83	0.66	0.11	2.24
Composite household lending spread		5918	2.26	2.15	0.85	1.24	3.45
Household lending spread - up to 1 year		5596	2.49	2.37	0.98	1.30	4.05
Household lending spread - 1 to 5 years		4967	2.61	2.33	1.32	1.34	4.86
Household lending spread - 5 to 10 years		4983	2.55	1.80	1.98	0.90	7.50
Household lending spread - over 10 years		4742	1.95	1.65	1.17	0.63	4.10
Profitability							
Net interest margin	%	1551	0.84	0.64	0.71	0.09	2.21
Net fee income		1599	0.34	0.23	0.34	-0.01	1.08
Deposit ratio variables							
Deposit ratio	%	6804	37.74	39.80	24.65	0.19	77.10
Deposit ratio in May 2014		6804	37.83	39.16	24.53	0.19	77.10
Average deposit ratio in 2014		6804	37.89	40.72	24.52	0.19	75.64
Overnight deposit ratio in May 2014		6804	19.62	17.01	16.17	0.05	47.61

Variable	Units	N	Mean	Median	St. Dev.	p5	p95
Control and other variables							
Size	Assets in mill. euro	6804	10.64	10.61	1.39	8.39	13.09
Capital ratio		6804	8.58	7.56	4.63	2.81	16.35
Securities ratio		6670	19.94	18.53	12.49	2.33	39.98
Unemployment rate		6804	10.14	9.16	5.93	4.66	24.83
BLS demand	%	2196	15.06	13.79	35.27	-55.56	75.00
Central bank financing ratio		6804	2.49	0.00	6.49	0.00	11.71
Excess liquidity ratio		5180	0.72	0.04	1.92	-0.44	4.41
Average Tier 1 capital ratio in 2014		756	13.39	12.42	3.96	8.64	19.93

Note: N; St. Dev.; p5; and p95 refer to number of observations, standard deviation, 5th percentile and 95th percentile respectively. See the Glossary for definitions and data sources of variables.

A.2 Lending in stressed/non-stressed countries

Log(Total lending)

	2013-2015	
	Stressed countries	Non-stressed countries
	(1)	(2)
Deposit Ratio × After(06/2014)	0.220**	0.102*
	(0.089)	(0.055)
Size	0.499*	0.639**
	(0.263)	(0.247)
Capital ratio	0.003	0.059**
	(0.018)	(0.029)
Securities ratio	-0.005	0.010
	(0.009)	(0.007)
Constant	1.080	-1.223
	(2.860)	(2.694)
R-squared (overall)	0.659	0.646
Adjusted R-squared (within)	0.265	0.345
Clusters	44	92
Obs	1450	3116
Bank FE	YES	YES
Time FE	YES	YES
Country-Time FE	YES	YES
Controls	YES	YES

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

A.3 Placebo tests

Dependent variable:	Log(Household lending)	Δ Composite borrowing rate	Composite lending spread
Table reference:	Table 3	Table 5	Table 5
		2011-2015	
	(1)	(2)	(3)
Deposit ratio ×After(06/2014)	0.164**	0.018***	-0.056
	(0.066)	(0.003)	(0.046)
Deposit ratio × After(07/2012)	0.065	-0.039***	0.134***
	(0.056)	(0.005)	(0.041)
Clusters	127	174	148
Obs	7302	10193	8845
Bank FE	YES	YES	YES
Time FE	YES	YES	YES
Country-Time FE	YES	YES	YES
Controls	NO	NO	NO

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

For reference, the relevant specification for the placebo test is Equation (4). In Column (1), the estimate of the coefficient of $Deposit\, ratio \times After(07/2012)$ (i.e. θ) is insignificant and close to zero. In Column (2), the coefficient estimate is highly significant, but the opposite sign of the estimate of β. This indicates that whereas rate cuts in positive territory are more favourable to lowering the cost of funding for high deposit banks relative to low deposit banks, rate cuts in negative territory have the opposite effect (a higher cost of funding for high deposit banks). In Column (3), the coefficient estimate of θ is also highly significant, but is likewise the opposite sign of the estimate of β. However, the estimate of β loses significance as a result of extending the sample time window backwards. Overall, these results exclude the possibility that rate cuts are driving the significance of the main findings.

A.4 Robustness check – country-specific variables

Table A.4.1: Robustness on lending and profitability

	Lending:	Profitability:	
Dependent variable:	Log(Household lending)	NIM (%)	NFI (%)
	2013-2015		
	(1)	(2)	(3)
Deposit ratio × After(06/2014)	0.201***	-0.028	0.005
	(0.076)	(0.036)	(0.015)
Size	0.175	-0.380**	-0.124*
	(0.206)	(0.171)	(0.064)
Capital ratio	0.017	0.021	0.004
	(0.018)	(0.018)	(0.008)
Securities ratio	-0.013**	-0.001	-0.003*
	(0.006)	(0.005)	(0.002)
Unemployment rate	-0.019	-0.033*	0.002
	(0.035)	(0.019)	(0.007)
BLS demand	0.004***	-0.001*	0.000
	(0.001)	(0.000)	(0.000)
Constant	2.829	5.253***	1.718**
	(2.204)	(1.866)	(0.708)
R-squared (overall)	0.358	0.000	0.031
Adjusted R-squared (within)	0.336	0.072	0.059
Clusters	116	127	127
Obs	3881	1390	1390
Bank FE	YES	YES	YES
Time FE	YES	YES	YES
Country-Time FE	NO	NO	NO
Controls	YES	YES	YES

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

Table A.4.2: Robustness on borrowing rates and lending spreads

	Cost of borrowing rates:	Household lending rate spreads:				
Dependent variable:	Δ Composite rate	Composite spread	Up to 1 year	1 to 5 years	5 to 10 years	Over 10 years
		2013-2015				
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit ratio × After(06/2014)	0.016***	-0.122**	-0.120*	-0.131	-0.136	-0.043
	(0.004)	(0.048)	(0.065)	(0.134)	(0.099)	(0.085)
Size	0.031**	-0.042	-0.043	-0.108	-0.013	0.108
	(0.015)	(0.172)	(0.205)	(0.216)	(0.322)	(0.192)
Capital ratio	-0.000	-0.011	-0.011	0.007	-0.056	0.013
	(0.001)	(0.011)	(0.013)	(0.033)	(0.034)	(0.032)
Securities ratio	-0.000	0.005	0.003	0.000	0.007	-0.001
	(0.000)	(0.004)	(0.005)	(0.007)	(0.011)	(0.008)
Unemployment rate	-0.001	0.049	0.043	0.031	0.141	0.157
	(0.002)	(0.031)	(0.030)	(0.085)	(0.130)	(0.095)
BLS demand	-0.000	-0.003***	-0.003***	-0.002***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Constant	-0.345**	2.182	2562	3206	1397	-0.877
	(0.157)	(1.819)	-2177	-2601	-3287	-2508
R-squared (overall)	0.050	0.250	0.012	0.175	0.581	0.378
Adjusted R-squared (within)	0.123	0.361	0.176	0.168	0.191	0.318
Clusters	170	146	136	113	112	103
Obs	5821	5016	4654	3839	3804	3524
Bank FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Country-Time FE	NO	NO	NO	NO	NO	NO
Controls	YES	YES	YES	YES	YES	YES

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

A.5 Robustness: outstanding syndicated loans

Log(Outstanding syndicated loans)

			2013-2015		
	(1)	(2)	(3)	(4)	(5)
Deposit ratio × After(06/2014)	-0.001	-0.001	0.001	0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Size				0.831***	0.907***
				(0.114)	(0.131)
Capital ratio				-0.008	0.004
				(0.008)	(0.008)
Securities ratio				0.002	0.000
				(0.003)	(0.004)
Constant	7.053***	7.075***	7.015***	-2.210*	-3.119**
	(0.157)	(0.010)	(0.036)	(1.283)	(1.471)
R-squared (overall)	0.077	0.077	0.020	0.526	0.518
Adjusted R-squared (within)	-	0.008	0.028	0.281	0.362
Clusters	108	108	108	108	108
Obs	3688	3688	3688	3529	3529
Bank FE	NO	YES	YES	YES	YES
Time FE	NO	NO	YES	YES	YES
Country-Time FE	NO	NO	NO	NO	YES
Controls	NO	NO	NO	YES	YES

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

Note: In order to be as close to Heider et al. (2019) as possible, I use the continuous treatment intensity variation of the deposit ratio in May 2014.

A.6 Impact of persistently negative rates on profitability

Table A.6.1: Impact on net interest margins over time

Net interest margin (%)

		2013-2018 (1)		
Deposit ratio				
interacted with:				
	2013q2	0.069	*2016q1*	0.001
		(0.045)		(0.080)
	2013q3	0.176**	*2016q2*	0.061
		(0.071)		(0.084)
	2013q4	0.082	*2016q3*	0.054
		(0.051)		(0.087)
	2014q1	0.023	*2016q4*	0.036
		(0.058)		(0.085)
	2014q2	0.018	*2017q1*	0.033
		(0.069)		(0.082)
	2014q3	0.089	*2017q2*	0.029
		(0.088)		(0.112)
	2014q4	0.057	*2017q3*	0.024
		(0.074)		(0.131)
	2015q1	-0.012	*2017q4*	0.020
		(0.061)		(0.112)
	2015q2	0.022	*2018q1*	0.011
		(0.072)		(0.109)
	2015q3	0.032	*2018q2*	-0.027
		(0.086)		(0.143)
	2015q4	-0.027	*2018q3*	-0.053
		(0.087)		(0.147)
R-squared (overall)		0.066		
Adjusted R-squared (within)		0.128		
Clusters		92		
Obs		1888		
Bank FE		YES		
Time FE		YES		
Country-Time FE		YES		
Controls		YES		

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

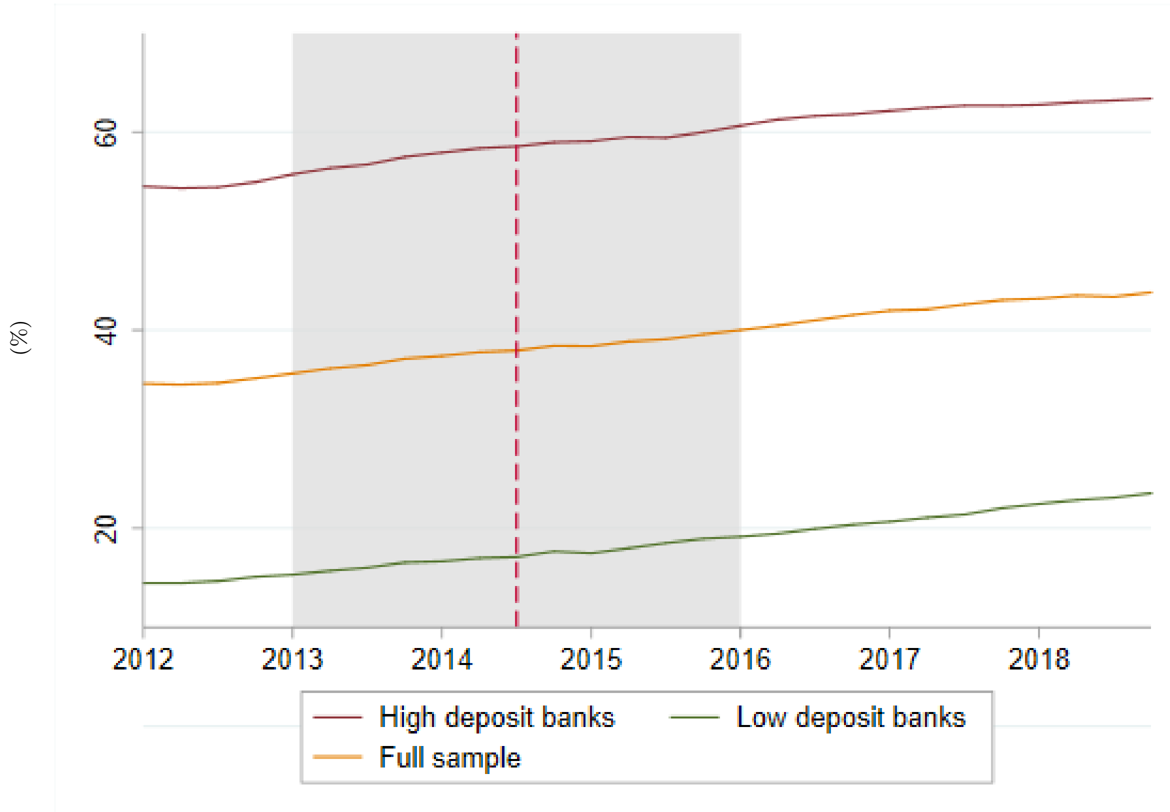
Table A.6.2: Impact on net fee income over time

Net fee income (%)				
		2013-2018		
		(1)		
Deposit ratio				
interacted with:				
	2013q2	0.015	*2016q1*	0.004
		(0.020)		(0.031)
	2013q3	0.043	*2016q2*	0.046
		(0.035)		(0.034)
	2013q4	0.030	*2016q3*	0.041
		(0.029)		(0.037)
	2014q1	0.011	*2016q4*	0.028
		(0.027)		(0.037)
	2014q2	0.012	*2017q1*	0.019
		(0.032)		(0.034)
	2014q3	0.019	*2017q2*	0.026
		(0.042)		(0.047)
	2014q4	0.017	*2017q3*	0.024
		(0.037)		(0.051)
	2015q1	-0.006	*2017q4*	0.056
		(0.027)		(0.038)
	2015q2	0.046	*2018q1*	0.009
		(0.033)		(0.039)
	2015q3	0.028	*2018q2*	-0.030
		(0.030)		(0.048)
	2015q4	0.009	*2018q3*	-0.032
		(0.033)		(0.048)
R-squared (overall)		0.001		
Adjusted R-squared (within)		0.079		
Clusters		94		
Obs		1953		
Bank FE		YES		
Time FE		YES		
Country-Time FE		YES		
Controls		YES		

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

B Supplemental figures

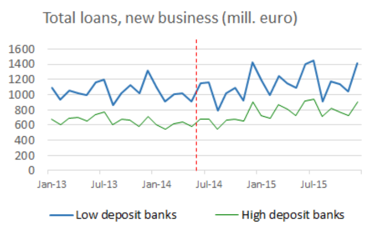
B.1 Average deposit ratio over time

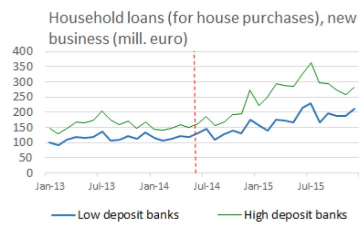


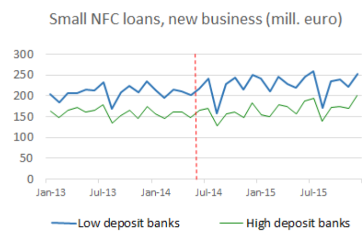
This figure plots the average deposit ratio (% total assets) over time in the baseline sample. High (low) deposit banks refer to banks with deposit ratios above (below) the sample median in May 2014. The dotted red line refers to June 2014. The shaded area refers to the sample period of the main regressions from 2013 to the end of 2015. *Source: IBSI.*

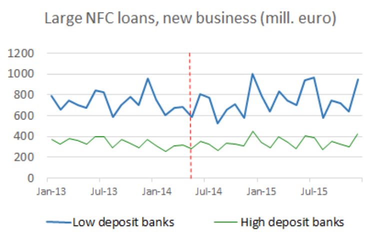
B.2 Parallel trends graphs

Lending volumes:

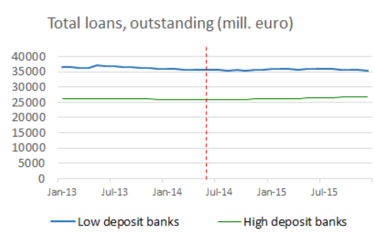


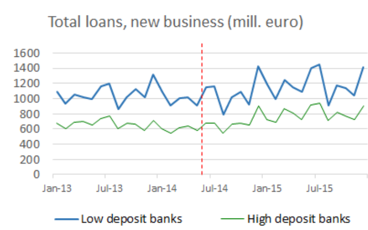


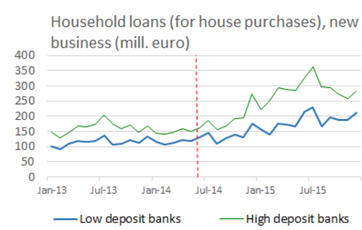




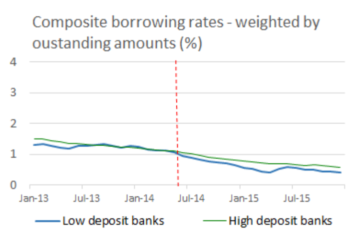
Outstanding loans:

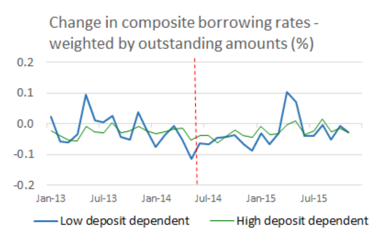


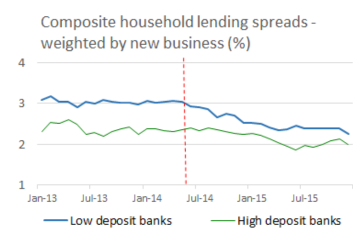


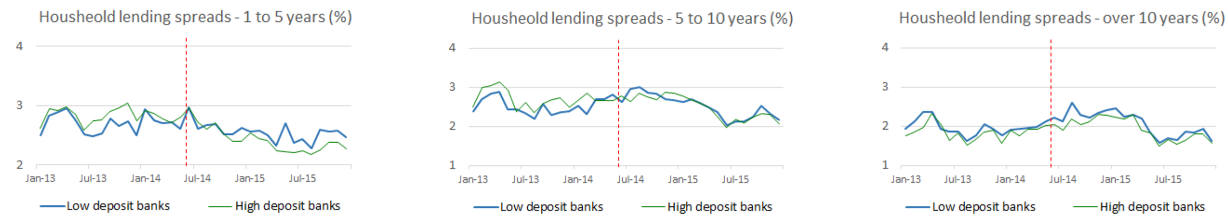


Borrowing rates and lending spreads:

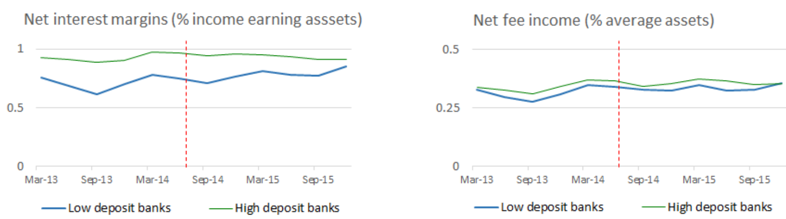








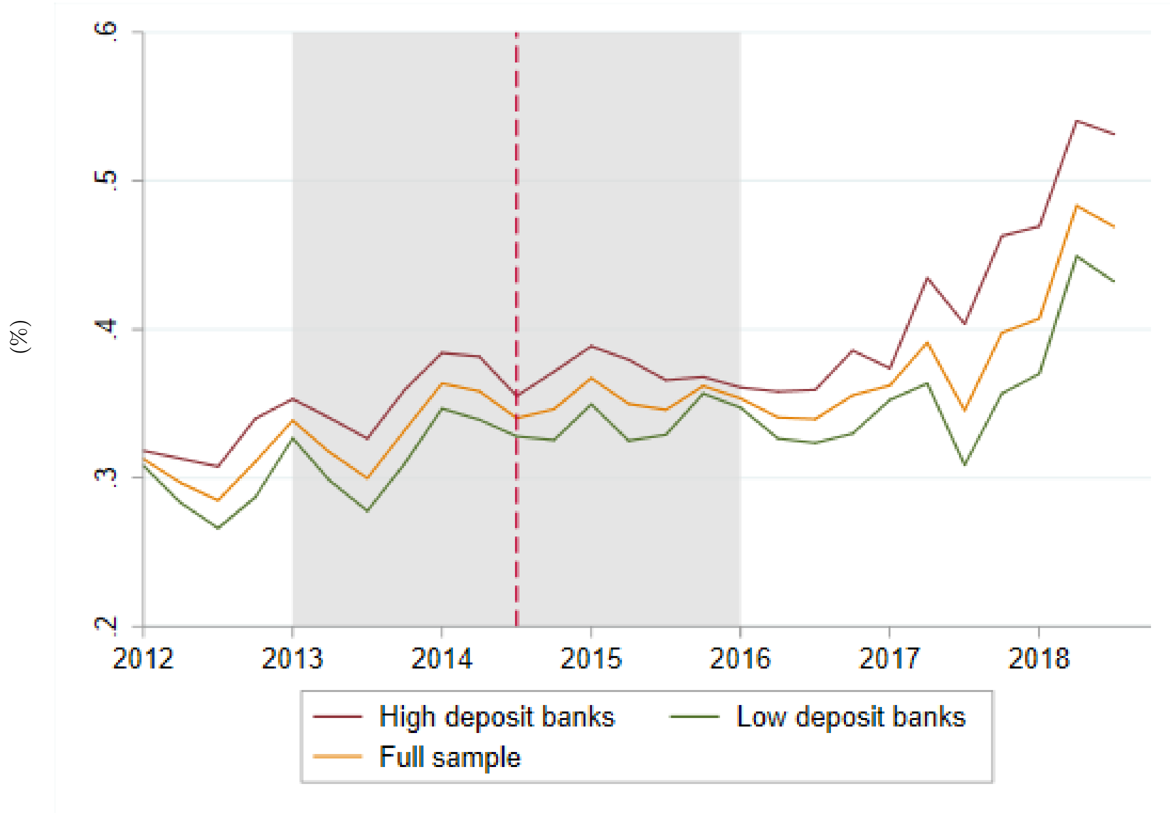
Profitability:



These graphs plot the average of the dependent variables over time in high and low deposit banks drawn from the baseline sample. High (low) deposit banks refer to banks with deposit ratios above (below) the median in May 2014. The dotted red lines refer to June 2014. *Source: Author's own calculations using data from IBSI/IMIR and SNL Financial.*

Note that the parallel trends assumption applies conditional on the control variables and fixed effects used in the regressions, whereas the above graphs show the "unconditional" relationship for the sample average. Nevertheless, a clear parallel trends relationship in the graphs adds confidence to the validity of the difference-in-differences methodology.

B.3 Average net fee income over time



This figure plots the average net fee income (% average assets) over time in the baseline sample. High (low) deposit banks refer to banks with deposit ratios above (below) the sample median in May 2014. The dotted red line refers to June 2014. The shaded area refers to the sample period of the main regressions from 2013 to the end of 2015. *Sources: SNL Financial and IBSI*

C Cleaning strategy for regression

Lending (flow) variables

Includes: All lending variables including total, household, small NFC, and large NFC lending

1. Drop all observations with a monthly growth rate below the 5th and above the 95th percentiles
2. Drop all banks with 5 or more missing observations
3. Winsorise at the 1st and 99th percentiles

Outstanding loans (stock) variables

Includes: All outstanding loan variables including total and syndicated loans

1. Drop all observations with a monthly growth rate below the 5th and above the 95th percentiles
2. Drop all banks with 5 or more missing observations

Interest rate variables

Includes: All borrowing rates and household lending rate spreads

1. Drop all observations below the 1st or above the 99th percentile
2. Drop all banks with 5 or more missing observations

Profitability variables

Includes: Net interest margins and net fee income

1. Winsorise at the 1st and 99th percentiles

Bank-specific control variables

Includes: Size, capital ratio, securities ratio

1. Winsorise at the 1st and 99th percentiles

D Calculation of composite borrowing rate

Bank funding sources are decomposed into five categories: deposit financing; central bank financing; interbank financing; financing by insurance corporations and pension funds; and debt securities. The composite borrowing rate is composed of borrowing rates (or proxy rates if the corresponding rate is not available) over these funding categories, weighted by outstanding amounts. The rates used can be found in the table below.

Funding Category	**Borrowing rate(s) (or proxy rate)**
Deposits (household and NFC deposits)	For deposits in M3, household/NFC deposit rates for deposits up to 2 years. For deposits not in M3, household/NFC deposit rates for deposits over 2 years.
Central bank financing (includes LTRO, TLTRO, MRO financing)	MRO rate.
Financing by insurance corporations and pension funds	Eonia.
Debt securities	Monthly yield on listed Federal securities with annual coupon payments and residual maturity of 10 years, derived from the term structure of interest rates.

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