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SNB Working Papers
5/2020

SCHWEIZERISCHE NATIONALBANK
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SWISS NATIONAL BANK

Legal Issues

ISSN 1660-7716 (printed version)
ISSN 1660-7724 (online version)

Negative interest rates, deposit funding and bank lending[*]

Tan Schelling[†] Pascal Towbin[‡]

January 2020

Abstract

In a negative interest rate environment, banks have generally proved reluctant to pass on negative interest rates to their retail depositors. Thus, banks that are more dependent on deposit funding face higher funding costs relative to other banks. This raises questions about the effect of negative interest rates on bank lending and monetary policy transmission. To study the transmission of negative interest rates, we use an unexpected policy decision by the Swiss National Bank in combination with a comprehensive and granular micro data set on individual Swiss corporate loans. We find that banks relying more heavily on deposit funding take more risks and offer looser lending terms than other banks. This result is consistent with the risk-taking channel, where a lower policy rate spurs bank risk-taking to maintain profits.

[*]We thank Stefanie Behncke, Itzhak Ben-David, Toni Beutler, Robert Bichsel, Jürg Blum, Martin Brown, Andreas Fuster, Christian Glocker, Tumer Kapan, Cathérine Koch, Cyril Monnet, Diane Pierret, Oleg Reichmann, Olav Syrstad, Eric Zwick and participants at seminars at the SNB and IMF, the SNB 2018 research conference, SSES 2019 conference, and the CEPR-BCBS 2019 workshop for helpful comments. The views, opinions, findings, and conclusions or recommendations expressed in this paper are strictly those of the authors. They do not necessarily reflect the views of the Swiss National Bank (SNB). The SNB takes no responsibility for any errors or omissions in, or for the correctness of, the information contained in this paper.

[†]Swiss National Bank, tan.schelling@snb.ch

[‡]Swiss National Bank, pascal.towbin@snb.ch

1 Introduction

Since 2012, several central banks have introduced negative interest rate policies for the first time in history. While nominal market rates generally adjusted quickly, banks have been reluctant to pass on negative interest rates to retail depositors. Consequently, rates have been stuck at or near zero ever since. This zero lower bound on deposit rates might be explained by the outside option of holding cash or by banks' unwillingness to lower deposit rates out of fear of losing customers to competitors (Eggertsson et al., 2019; Eisenschmidt and Smets, 2017; Heider et al., 2019). Given the observed zero lower bound on deposit rates, we ask how deposit funding impacts bank lending and monetary policy transmission in a negative interest rate environment. This question is important because deposit funding plays an essential role in retail banking. Moreover, episodes with negative interest rates may occur again in the future (Kiley and Roberts, 2017; Assenmacher and Krogstrup, 2018).

We focus on a large and unexpected monetary policy rate cut in Switzerland on 15 January 2015 and analyze changes in lending terms. We exploit a comprehensive transaction-level loan data set on Swiss corporate loans, matched with bank balance sheet data. Using a difference-in-differences methodology with the deposit ratio as an exposure-to-treatment variable (Heider et al., 2019), we find that deposit funding has an expansionary effect under negative interest rates. More specifically, after the rate cut, high-deposit banks loosen their lending terms compared to low-deposit banks and grant larger loans. These effects are more pronounced for riskier borrowers.

Our results may be explained by the risk-taking channel (Borio and Zhu, 2012; Dell'Ariccia et al., 2014, 2017). In a negative interest rate environment, funding is more costly for high-deposit banks, and their profits suffer more. To maintain profits, these banks have a stronger incentive to take risks. Our results do not confirm the notion that policy rate cuts in negative territory are no longer expansionary due to lack of transmission to deposit rates and a negative effect on bank net worth (Brunnermeier and Koby, 2018; Eggertsson et al., 2019). Although we cannot exclude that these contractionary effects due to higher marginal costs could be observed in deeper negative territory, our results indicate that higher marginal costs are not the only factor that affects the pricing of loans when banks rely on deposit funding. Rather than switching to cheaper funding sources or shrinking their balance sheet, high-deposit banks seem to take their deposit base as given and then choose how best to invest deposits in a way that covers their funding costs. This is consistent with the view of banks advanced in Hanson et al. (2015) that emphasizes the role of the deposit franchise.[1] This view is also related to the literature on the search for yield of investment and pension funds, where funds take more risks to meet the required returns on their given liabilities (Rajan, 2005).

Our study adds to the growing literature on the transmission of negative interest rates to bank lending in two important ways: First, our setting is well suited for clear-cut identification. The SNB's rate cut on 15 January 2015 was not anticipated by the market, and as a reaction to foreign developments, it was exogenous to domestic lend-

[1] Hanson et al. (2015) write that even in a positive rate environment " in some cases, it seems a bank's size is determined by its deposit franchise, and that taking deposits as given, its problem becomes one of how to best invest them." (p.452)

ing conditions. Moreover, the cut was large and clearly drove a wedge between the policy rate and the deposit rates. This distinguishes the Swiss case from the Euro area, Japanese and Swedish cases (Heider et al., 2019; Eggertsson et al., 2017; Bottero et al., 2019), where negative rate policies were a response to domestic conditions and were partly anticipated by market participants (Grisse et al., 2017; Wu and Xia, 2018). The policy rates were lowered in several steps, and in some countries, the zero lower bound on deposit rates was not necessarily binding.

As a second contribution, we look at a broader set of loan terms. While other studies primarily focus on loan volume or growth, we also look at the individual lending spread, interest rate, size, commission, fixed or variable rate, maturity and collateral. These are important dimensions when gauging the impact of negative interest rates.

Our strategy to identify changes in lending behavior following the introduction of negative interest rates rests on three pillars. First, we focus on a monetary policy change that was unexpected, exogenous to domestic economic conditions, and large. On 15 January 2015, the Swiss National Bank (SNB) took an unscheduled monetary policy decision and lowered the interest rate on central bank deposits by minus 50 basis points to minus 75 basis points. At the same time, it discontinued its minimum exchange rate floor vis-a-vis the euro. There was a strong and sudden reaction of market interest rates following the announcement, showing that the decision was not anticipated. Furthermore, the decision was made due to developments in the euro-dollar exchange rate that were exogenous to the Swiss economy.

Second, we conduct a difference-in-differences analysis by comparing lending conditions i) before and after the rate cut and ii) between banks with different deposit-to-asset ratios (Heider et al., 2019). Put differently, we investigate how the deposit ratio influences the response of banks to negative interest rates. This setup allows us to control for both time-invariant differences in lending supply between high- and low-deposit-ratio banks and any common changes in credit demand before and after the policy change.

Third, we use a detailed and comprehensive data set on individual loans granted to Swiss firms in the nonfinancial sector, matched with bank balance sheet data. Each loan record contains various borrower characteristics, which we combine to form a granular set of different firm types (Auer and Ongena, 2019). We use these firm types to control for heterogeneous changes in credit demand. We follow a similar approach as Khwaja and Mian (2008) and compare the lending decisions of multiple banks to the same firm type within the same time period. The identification assumption is that when multiple banks grant a loan to the same firm type within the same time period, differences in lending conditions are driven by a bank's lending supply.

Our results indicate that more deposit funding leads to looser lending terms: a one-standard-deviation increase in the deposit-to-asset ratio decreases loan spreads by 12 basis points. High-deposit banks also ease some nonprice lending terms. They grant larger individual loans, are more likely to issue fixed interest rate loans and are less likely to charge a commission in addition to interest payments. The loosening of lending terms is persistent. Deposit funding is associated with looser lending terms for more than three years after the introduction of negative interest rates.

The loosening of lending terms itself can be considered an increase in risk-taking, since banks impose less stringent conditions on any given borrower and ask for a lower compensation for the risk they take (Ioannidou et al., 2015; Paligorova and Santos, 2017). In addition, we show that the relative decline in lending spreads for high-deposit banks and the relative loosening of other lending terms is especially pronounced for firms from risky sectors. Overall, we view this pattern as consistent with a risk-taking channel of negative interest rates.

In addition to our analysis at the level of the individual loan agreement, we aggregate the individual loans to the bank/firm type level. We find that in a negative interest rate environment, reliance on deposits increases lending at both the intensive (granting larger and more loans to a firm type) and the extensive margin (entering new relationships or terminating existing relationships). At the intensive margin, a one-standard-deviation increase in the deposit ratio raises the volume of new loan agreements in a given month by 28 percent when rates are negative. At the extensive margin, a one-standard-deviation increase in the deposit ratio raises the likelihood that a bank grants a loan to a new firm type by 2.7 percentage points in a negative interest rate environment and lowers the likelihood that a bank terminates an existing firm type relationship by 0.6 percentage points. Overall, our results indicate that when market rates are negative, banks with a high amount of deposits offset their relatively higher funding costs by offering more generous lending terms and thereby capture market shares.

In addition to the deposit ratio, we discuss the role of charged reserves as a treatment-to-exposure variable (Basten and Mariathasan, 2018). Reserves held at the central bank are only charged negative interest rates if they exceed the bank-specific threshold. We find that banks with initially more charged reserves tend to loosen lending terms relative to other banks, consistent with a portfolio reallocation channel (Bottero et al., 2019). However, the effect is only short-lived. A short-lived effect is intuitive since, as we will show, differences in charged reserves were arbitraged away quickly on the interbank market.

Alongside charged reserves, we control for standard bank characteristics such as capital and size. In extensions, we control for banks' business models, foreign exchange exposure, liquidity and profitability.

The results are robust to a variety of modifications: For example, we exclude banks and firm types with a large sample weight and control for loan characteristics. We also estimate our baseline regression for interest rate cuts in positive territory. For the considered rate cuts the deposit ratio does not seem to play a role in transmission. This indicate the deposit funding only plays a role in a low interest environment where margins are compressed. Our results extend beyond the corporate loans market. Using less granular data, we analyze lending spreads on residential mortgage loans. The results point in the same direction: under negative interest rates, high-deposit banks decrease lending spreads. The effect is present for long maturities only, where yields are typically higher and provide higher margins for banks.

In the remainder of the paper, we discuss below our contribution to the literature. Section 3 provides institutional information on the rate cut and presents the empirical hypotheses. Section 4 discusses our empirical strategy and data. Section 5 presents the results. Section 6 summarizes and discusses our main findings.

2 Related literature and contribution

Our research contributes to the empirical literature on the transmission of monetary policy to bank lending. While the literature on transmission in a positive interest rate environment is well established (see, e.g., Stein and Kashyap, 2000; Jiménez et al., 2012; Jimenéz et al., 2014; Ioannidou et al., 2015; Beutler et al., 2017; Paligorova and Santos, 2017; Dell'Ariccia et al., 2017), the literature on transmission in negative territory is still at an early stage, because negative nominal interest rates are a relatively new phenomenon.

Studies on the transmission of negative interest rates typically define a variable that captures the degree of a bank's exposure to negative interest rates. Using a difference-in-differences estimation, the studies exploit variation in this exposure-to-treatment variable between banks to identify and quantify the impact on lending. The studies reach different conclusions regarding both risk-taking and lending volumes.

On the liability side of the bank balance sheet, Heider et al. (2019); Bottero et al. (2019); Eggertsson et al. (2019) use the deposit-to-asset ratio as an exposure-to-treatment variable and are thus closest to our study. In line with our findings, Heider et al. (2019) find an increase in risk-taking for European banks. However, in contrast to our study, they find a contraction in lending volumes, as do Eggertsson et al. (2019) for Swedish banks. Bottero et al. (2019) do not find a significant effect of the deposit ratio on loan growth in Italy.

On the asset side, Bottero et al. (2019); Basten and Mariathasan (2018) use the amount of assets of European and Swiss banks charged with negative interest rates and find both higher risk-taking and more lending through portfolio rebalancing. To unite both the asset and liability sides, Demiralp et al. (2019) interact the deposit ratio of euro area banks with charged assets and report more lending for more exposed banks. Hong and Kandrac (2018) find the same result, studying the reactions in Japanese banks' share prices at the moment of announcement of negative interest rates. Arce et al. (2018) combine survey responses on how European banks considered themselves affected by negative interest rates with bank balance sheet data and find no effect on credit supply.[2]

Our study contributes to the literature along two lines: First, we focus on a policy event that is particularly well suited for a difference-in-differences study. The interest rate cut on 15 January 2015 in Switzerland was i) exogenous to domestic economic conditions, ii) not anticipated by market participants and iii) large. This distinguishes the Swiss case from the euro area and Sweden and Japan. In these jurisdictions, central banks motivated their decisions with domestic economic conditions, namely, deflationary pressures and the intention to boost lending and were part of package of unconventional monetary measures to affect interest rates.[3] Furthermore, the decisions

[2]Further studies look at the effects on bank profitability and systemic risk (Altavilla et al., 2017; Nucera et al., 2017; Lopez et al., 2018; Molyneux et al., 2019).

[3]The ECB stated, "[t]oday we decided on a combination of measures to provide additional monetary policy accommodation and to support lending to the real economy"(European Central Bank, 2014). The Bank of Japan explained the decision as an effort "to maintain momentum toward achieving the price stability target of 2 percent" (Bank of Japan, 2016). According to the press release of the Swedish central bank, "[t]he Executive Board of the Riksbank assesses that a more expansionary monetary policy is needed to support the upturn in underlying inflation"(Riksbank, 2015).

were announced at scheduled dates and, at least in the euro area, were to some extent anticipated. [4] Both anticipation and endogeneity of the monetary policy decision pose challenges for identification. The rate cut in Switzerland (50 basis points) was large compared to rate cuts in other jurisdictions (where individual rate cuts amounted to 10-20 basis points; see Grisse et al. (2017)). A large rate cut makes it less likely that the results are materially contaminated by other shocks to interest rates over the time window studied.

Second, we use a data set that is at the loan-level, high frequency (daily), detailed with regard to individual loan terms, and covers a large part of the Swiss corporate loan market. Most of the other studies use data aggregated at the bank level at monthly frequency. Heider et al. (2019) focus on syndicated loans, which is only a subset of the market typically containing larger borrowers. Borrower information for each loan allows us to effectively control for heterogeneous demand effects. The daily frequency of our loan data allows for exact distinction between loans granted before and after the monetary shock. Information on multiple relevant loan terms such as interest rate, volume, maturity, commission, fixed or variable rate, and collateralization provides a complete picture of the dimensions along which banks changed their lending behavior. Thus, we can check whether a change in one lending term (e.g., lower loan spread) might have been compensated with a change in another (shorter loan maturity).

Basten and Mariathasan (2018) are the only study that look at bank reactions following the surprise monetary policy change in Switzerland. However, they focus on the role of variation in charged reserves using monthly loan volumes aggregated at the bank level and therefore cannot control for heterogeneous demand effects.[5] In Section 5.3, we revisit the effect of charged reserves on lending, showing that it is rather short-lived due to arbitrage on the interbank market.

3 Stylized facts and empirical hypotheses

3.1 Stylized facts

Market and deposit rates On 15 January 2015, the Swiss National Bank announced that it will lower its remuneration rate on central bank sight deposit account balances from minus 25 basis points to minus 75 basis points. Negative interest rates are charged only on the portion of a bank's sight deposits exceeding a bank-specific exemption threshold (charged reserves).[6] At the same time, the Swiss National Bank announced the discontinuance of its minimum exchange rate vis-à-vis the euro.

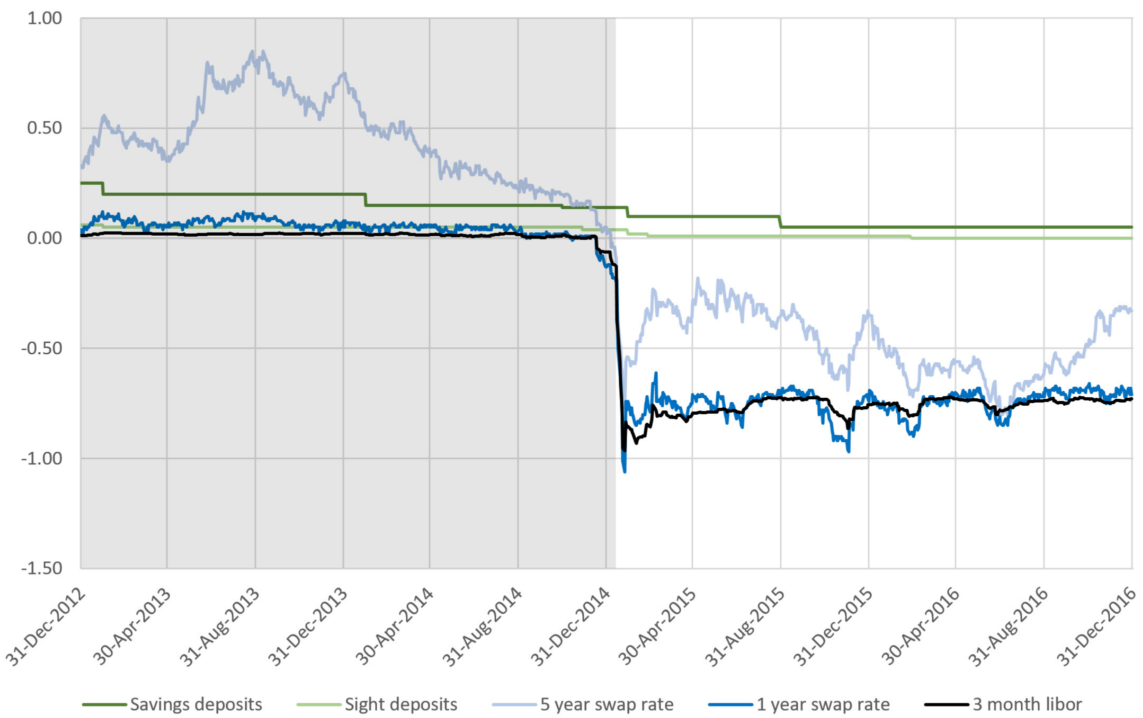
Following this decision, nominal market rates adjusted quickly and turned negative. Bank deposit rates, however, were stuck at or near zero (see Figure 1). As is evident from the 5-year swap rate, market participants expected interest rates to remain negative for an extended period of time.

[4] See Wu and Xia (2018) for evidence on the euro area and Grisse et al. (2017) for a more general overview of the extent to which negative rates were anticipated.

[5] Fuhrer et al. (2019) study the impact of reserves held at the SNB on lending spreads from 2006 to 2016.

[6] Specifically, the exemption threshold is calculated as 20 times the minimum reserve requirement for the reporting period 20 October 2014 to 19 November 2014, adjusted for changes in holding physical cash. See Swiss National Bank (2014) for details.

Figure 1: Deposit, Libor, and swap rates



Notes: Deposit rates are calculated as the median of reported private household deposit rates in the SNB interest survey. The shaded area indicates the period prior to the rate cut on 15 January 2015 from minus 0.25 pp to minus 0.75 pp. As of end-2014, 91 banks had reported deposit rates. Dispersion around the mean is low, with a standard deviation of 0.0003 and 0.0009 for sight deposits and savings deposits, respectively. No bank reported negative deposit rates at any point in time.

The two policy decisions were made because of exogenous foreign developments and came as a surprise for market participants. In its press release, the SNB (Swiss National Bank, 2015) stated that the ”euro has depreciated considerably against the US dollar and this, in turn, has caused the Swiss franc to weaken against the US dollar”. It concluded ”that enforcing and maintaining the exchange rate floor against the euro is no longer justified.” The SNB lowered its policy rate to minus 75 basis points at the same time ”to ensure that the discontinuation of the floor did not lead to an inappropriate tightening of monetary conditions.” The stated motivations in the press release clearly point to exogenous developments as triggers for the policy moves.

Moreover, the decision took market participants completely by surprise. The surprise element is inherent to a policy decision that involves discontinuing a minimum exchange rate. Any hints or guidance as to when the SNB planned to exit would have fueled speculation and thus would have made it harder for the SNB to defend the minimum exchange rate. Right after the announcement, the Swiss franc exchange rate vis-à-vis the euro jumped to a new level. More important for the purposes of this paper, market interest rates adjusted quickly, and there were no anticipation effects, as can be seen from Figure 1.

The exogeneity and surprise element of the two policy decisions play an important role in our identification strategy in analyzing banks’ reactions to a rate cut in negative territory.

Prior to the interest rate cut on 15 January 2015, the SNB had announced the introduction of negative interest rate policies and the definition of bank-specific exemption thresholds on 18 December 2014. The remuneration of central bank deposits was lowered from 0 to minus 25 basis points but was effective only from 22 January onwards, making identification less clean due to timing issues. This earlier announcement also had much smaller effects on market rates (12-month swap rates remained close to zero). In our robustness checks, we will exclude the period between 18 December 2014 and 15 January 2015.

Lending rates Moving from market and deposit rates to corporate lending rates, Figure 2 shows the average lending rates (upper panel) and lending spreads with respect to Swiss government bonds (lower panel). In this figure, the sample of banks is split into two groups: those with a deposit ratio above and below the median. Two observations stand out: First, lending rates moved relatively little following the monetary policy rate cut, indicating incomplete interest rate pass-through. Since pass-through to Swiss government bond yields was stronger and quicker, lending spreads with respect to government bonds increased after the rate cut. Pass-through may have been incomplete for a number of reasons, including heightened credit risk or market structure.

Our focus in this study will be on how a bank's funding profile affects its response to negative interest rates, controlling for other supply and demand factors. This brings us to the second observation. There are notable differences between the two bank groups in their responses to negative interest rates. High-deposit banks lowered spreads relative to low-deposit banks, i.e., interest pass-through was stronger.[7] In the rest of the paper, we will explore this stylized fact about the role of funding in more detail.

3.2 Empirical hypotheses

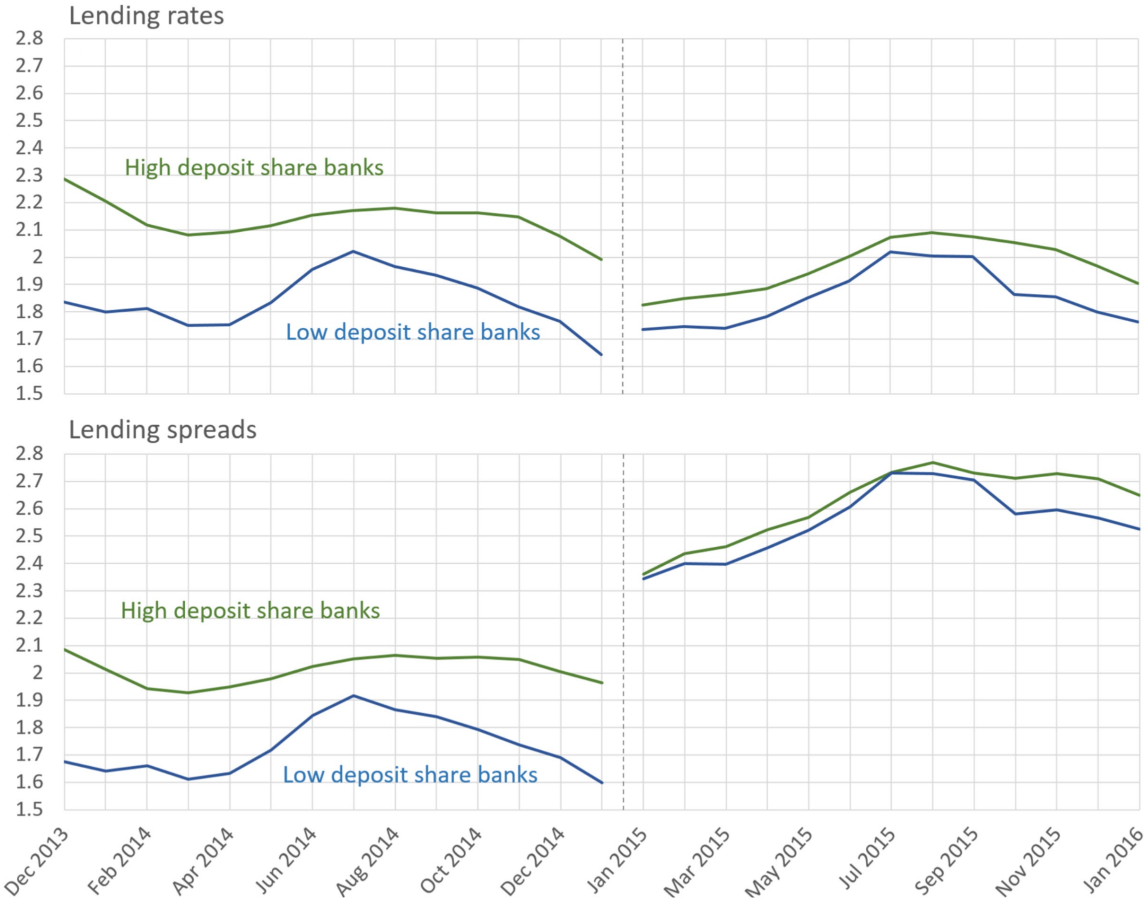
From a theoretical perspective, the combination of negative market rates and a lower bound on deposit rates may affect transmission through three channels: the bank lending channel, the bank balance-sheet channel, and the risk-taking channel. Whereas the bank lending and the bank balance-sheet channel could be weakened or reversed, the risk-taking channel may be strengthened.

In particular, the bank lending channel (Bernanke and Blinder, 1988; Kashyap and Stein, 1994) and its modern variant the deposit channel (Drechsler et al., 2017) suggest that a policy rate cut leads to an increase in the volume of deposits. Since deposits are a cheap source of funding, banks can expand their lending. However, Eggertsson et al. (2019) argue that in a negative interest rate environment, the bank lending channel collapses because deposit rates no longer respond to policy rate cuts.

According to the bank balance-sheet channel (Bernanke and Gertler, 1995; Gertler and Kiyotaki, 2010), a monetary expansion increases bank net worth. Higher net worth allows the bank to obtain better funding terms or relieves capital constraints. The positive effect on net worth occurs because of maturity mismatches, with the value of

[7] Note that the difference in *levels* prior to the rate cut (higher average rates for high-deposit banks) is not a robust feature of the data and sensitive to the exact specification. In our preferred specification, differences in levels will be absorbed by fixed effects.

Figure 2: Monthly rolling average lending rates and spreads of high and low deposit share banks



Notes: The lending rate is the interest rate charged on a loan at inception. The lending spread is defined as the difference between the lending rate and the yield on a Swiss government bond with the same maturity. Banks are split into two groups according to their deposit ratios. The deposit ratio is defined as the sum of Swiss franc sight and savings deposits over total assets as of December 2014. Within the two groups, 3-month rolling averages were calculated from our loan-level data set for a window of +/-360 days around the 15 January 2015 rate cut. Data sources are described in Section 4.1.

bank assets being less sensitive to interest rate changes than liabilities. In a negative interest rate environment, the positive effect on net worth may be weakened or even reversed, as deposit rates no longer respond to rate cuts and the value of liabilities becomes less interest rate sensitive. Interest rate margins and profitability decrease (Brunnermeier and Koby, 2018; Eggertsson et al., 2019), eventually lowering net worth and constraining lending capacity. Hence, as a result of relatively higher funding costs, we would expect high-deposit banks to lend less at higher interest rates.

According to the risk-taking channel (Borio and Zhu, 2012; Dell'Ariccia et al., 2014), banks increase risk in response to rate cuts. Pennacchi and Santos (2018) and Alessandri and Haldane (2009) provide evidence that banks target a specific level of return on equity and that if their profitability falls, they increase risk-taking to maintain profits. The risk-taking channel may be strengthened in a negative rate environment, either because of informational frictions or behavioral biases.

Dell'Ariccia et al. (2014, 2017) provide a theoretical foundation for the risk-taking channel that relies on informational frictions and limited liability. In a positive rate environment, there are two opposing effects of a rate cut. On the asset side, a reduction in the policy rate reduces the yield on safe assets, and banks increase their demand for risky assets (portfolio rebalancing). On the liability side, profits typically increase because of falling short-term funding costs. Due to limited liability, higher profitability diminishes risk-taking incentives (risk-shifting). However, when rates are negative, banks funded by deposits do not see their short-term funding costs fall, and their profits will be under pressure. This reverses the moderating risk-shifting effect and thereby amplifies the risk-taking channel. Put differently, when negative interest rates are expected to last for a longer time, deposit funding effectively turns into a fixed-rate liability, and banks may display a search-for-yield behavior similar to other financial institutions with longer dated liabilities such as insurers, investment funds, and pension funds (Rajan, 2005). In contrast to the bank lending and bank balance-sheet channel mechanism, where marginal costs to expand the balance sheet change, the intuition here is that banks try to make a profit with a given amount of deposit funding at a given cost.[8]

On the behavioral side, Lian et al. (2018) provide experimental evidence that investors take on more risk when risk-free rates are low. That effect is considerably stronger when interest rates are negative, consistent with prospect theory and loss aversion (Kahneman and Tversky, 1979). This would mean that, with a positive interest rate environment, a bank may be willing to accept a small margin for a safe project (e.g., 0.1 basis points). With negative interest rates, however, due to loss aversion, it will not invest in a project with a small negative margin but will prefer riskier projects with a – non-risk-adjusted – positive margin.

In summary, theory leads to the following testable hypotheses on the role of deposits when rates are negative. If the moderating (or reversing) effect of deposit funding on the bank lending and bank balance-sheet channels dominates, we expect high-deposit banks to lend less and at higher prices than their peers in response to a rate cut. If, on the other hand, the risk-taking channel dominates, we expect high-deposit banks to take more risks by a) attempting to expand their lending business by offering looser terms and b) by granting loans to riskier firms.

In addition to deposit funding, the amount of excess liquidity that is subject to negative interest rates may have an effect on monetary transmission that is specific to a negative rate environment (Basten and Mariathasan, 2018; Bottero et al., 2019). More precisely, there is the possibility of portfolio rebalancing that would work similarly to quantitative easing policies (Kandrac and Schlusche, 2017; Christensen and Krogstrup, 2018). Under portfolio rebalancing, banks adjust their portfolios towards assets with a higher yield to avoid negative interest rates on central bank balances. Under that hypothesis, we would expect banks with more charged reserves to grant more credit at more attractive terms. Although it is not the main focus of the paper, we will discuss

[8]The motivation for banks to move away from safe securities towards loans is also apparent in a statement by the CEO of PostFinance, the Swiss postal bank, which relies mainly on deposit funding. The law prohibits this bank from granting loans (see PostFinance, Annual Report Post 2017): "[The fall in revenue from the interest differential business] makes it clear that in the current negative interest rate environment in particular, it is a serious disadvantage for us not to be able to issue our own loans and mortgages. There is a need for action in this area, because our interest margin remains under pressure."

this mechanism in Section 5.3.

4 Empirical strategy and data

4.1 Data

We use confidential loan-level data on nonfinancial corporate loans. Corporate loans make up around a third of total domestic credit in Switzerland. We match these data with individual bank balance-sheet information and regulatory reportings. All data are collected by the SNB and publicly available only in aggregate form.

The corporate loan-level data are taken from the SNB lending rate statistic. For each loan agreement, we have information on various lending terms (interest rate, loan size, fixed or variable rate, commission, maturity, collateralization) and borrower characteristics (sector, number of employees, location of headquarters). The statistic also covers off-balance-sheet loan commitments. For each loan agreement, we know the exact date when it was paid out. Importantly, loan commitments are recorded when they are granted, not when they are first drawn upon.

The data cover all banks whose loans to nonfinancial domestic companies exceed CHF 2 bn. Coverage is comprehensive, as the 20 banks that have to report their loans grant approximately 80% of corporate loans in Switzerland. The banks are required to report information on all new loan agreements with nonfinancial firms that exceed CHF 50k in Swiss francs. New loan agreements comprise newly granted loans as well as major modifications in conditions of existing loans.[9] All reported loans have either a fixed maturity of at least one month or are open ended. Banks report data from mid-2006 onwards, and as of end 2017, the whole data set contained approximately 1.3 million loan agreements.

Our main source for bank balance-sheet information is the SNB monthly banking statistic, which contains detailed information on the composition of banks' assets and liabilities. We combine this information with regulatory data on minimum reserves, capital adequacy and liquidity.

To check whether our results also apply to other loan markets, we use data on residential mortgage loans. The data are from the SNB's interest rate survey. Banks report published end-of-month interest rates for new transactions. Our analysis focuses on fixed residential mortgage rates for different maturities (one to ten years). This data set differs from our corporate loan-level data set in several ways: first, banks report published interest rates as opposed to actual loan transactions. Second, there is no information about borrowers. Third, it covers a broader sample of banks than the corporate loan data (45 banks).[10] Therefore, the corporate loan-level data allow for a more granular analysis, whereas the aggregate residential mortgage data set comprises a larger number of banks. It also covers a larger share of overall credit (at end-2014, residential mortgages accounted for approximately two-thirds of total domestic bank

[9]Major modifications are defined as changes in loan terms that can be considered the result of a renegotiation. In particular, new loan agreements include changes from a variable rate to a fixed rate, prolongations of fixed-term loan contracts, and changes in ratings for open-ended contracts.

[10]Banks whose total Swiss-franc-denominated customer deposits and cash bonds in Switzerland exceed CHF 500 million.

Table 1: Loan characteristics: Descriptive statistics

	N	mean	median	std	p1	p99
Data at individual loan level						
lending spread (in pp)	109,420	2.494	1.939	1.622	0.478	7.278
interest rate (in pp)	109,420	2.161	1.550	1.544	0.460	6.750
log(loan size) (in CHF k)	109,420	6.162	5.991	1.409	3.912	9.908
loan size (in CHF mn)	109,420	1.695	0.400	6.154	0.050	22.915
fixed rate	109,420	0.619	1.000	0.486	0.000	1.000
commission	109,420	0.167	0.000	0.373	0.000	1.000
maturity (in years)	77,230	2.364	0.758	2.954	0.081	10.153
collateralized	109,420	0.809	1.000	0.393	0.000	1.000
High Risk Sector	109,420	0.276	0.000	0.447	0.000	1.000
Export Sector	109,420	0.044	0.000	0.205	0.000	1.000
Data at bank firm type level						
vol. of new loan agreements (in CHF mn)	13,125	12.198	1.300	92.160	0.050	164.390
log(vol. of new loan agreements) (in CHF k)	13,125	7.299	7.170	1.844	3.912	12.010
Number of loans	13,125	7.005	2.000	24.365	1.000	78.000
log(avg. loan size)	13,125	6.227	6.064	1.295	3.912	9.903
log(Net Revenue)(in CHF k)	13,125	8.194	8.046	1.667	5.104	12.476
log(lending spread) (in pp)	13,125	0.893	0.874	0.592	-0.547	1.985
new firm-type post rate cut	6,881	0.072	0.000	0.258	0.000	1.000
exit firm-type post rate cut	13,964	0.027	0.000	0.162	0.000	1.000

Notes: The data are at the loan level and cover the period of a symmetric 180-day window around 15 January 2015. The lending spread is the interest rate charged at the beginning of the loan minus the risk-free rate at the same maturity (as defined in Section 4.1); the loan size is the amount that is paid out or committed; fixed rate is a dummy that takes a value of one if the interest rate was fixed over the maturity of the contract; commission is a dummy that takes a value of one if a commission was charged on top of the interest rate; the maturity of the loan is expressed in number of days divided by 360 (open-ended loan contracts not reported); and collateralized is a dummy that takes a value of one if the loan was collateralized. High-risk sector is a dummy that takes a value of one if the average lending spread (equally weighted across banks) in this sector was above the median in the year before the rate cut (15 January 2014 to 14 January 2015); the dummy export sector takes a value of one if the sector is in the top third of sectors by export intensity, which is defined as a sector's exports over its total output (as calculated by Egger et al. (2018).)

credit to the private sector).

4.2 Variables

4.2.1 Dependent variables

Descriptive statistics for the dependent variables are shown in Table 1.

Our first main variable of interest is the lending spread, which is defined as the difference between the interest charged on a loan at inception and the yield on a Swiss government bond with the same maturity (daily government bond yields are calculated with a Nelson and Siegel (1987) term structure model). For variable rate loans, we use the maturity of the base rate, and where the base rate is not reported, we assume a maturity of 90 days. As a simpler measure of loan pricing, we also look at the lending rate, i.e., without subtracting the risk-free rate.

The lending spread may be interpreted as an indicator for bank risk-taking when firm risk is properly controlled for. As Paligorova and Santos (2017) argue, increased risk appetite may manifest itself in a lower required compensation for risk, i.e., loan spread. In the same vein, Ioannidou et al. (2015) point out that if granting riskier loans is supply-driven, the average price per unit of risk should drop. In a theoretical model by Martinez-Miera and Repullo (2017) with asymmetric information and costly monitoring, lower spreads induce banks to monitor less, thereby increasing the riskiness of their loan portfolios.

In addition to the lending spread, we look at the following relevant nonprice lending terms:

- *Loan size*: If a bank grants a larger loan, it increases its exposure.
- *Fixed/variable rate loan*: If a bank grants more fixed rate loans, it increases duration risk.
- *Commission*: A bank may try to offset lower lending spreads by demanding higher commissions. Lepetit et al. (2008) found that banks may rely more on fees to try to compensate for lower lending rates. Charging a commission instead of a higher lending spread also decreases duration.
- *Maturity*: If a bank grants longer maturity loans, it takes on more risk since the probability of unforeseen bad events over the life of the loan increases.[11]
- *Collateralization*: If the loan is collateralized, the bank takes on less risk, as the losses in the event of default are smaller.

The continuous dependent variables are winsorized at the 1 percent level, grouped by month.

All data above are at the individual loan level. In some specifications, we aggregate the data to the bank/firm type level. This is described in Section 4.4.

4.2.2 Independent Variables

Descriptive statistics of the independent variables are shown in Table 2 and 3.

Our main independent variable is the ratio of Swiss franc deposits to total assets (deposit ratio). Deposits are the sum of Swiss franc sight and savings deposits.

We include further balance-sheet characteristics to ensure that our results are not driven by other banking characteristics. In our baseline specification, we employ the following controls. The charged reserve ratio is the difference between Swiss franc central bank deposits and the exemption threshold (see Section 3), i.e., the bank-specific amount of deposits subject to negative interest rates. This ratio accounts for the possibility of a portfolio rebalancing channel acting through the asset side of the balance sheet (Basten and Mariathasan, 2018; Bottero et al., 2019). The total capital ratio accounts for the bank capital channel of monetary policy and is defined as total regulatory capital over total assets (Van den Heuvel, 2006). Finally, the log of total assets controls for effects related to bank size (Stein and Kashyap, 2000).

[11] We exclude all loans with open-ended maturity in these regressions. The number of observations is therefore smaller.

Table 2: Bank characteristics: Descriptive statistics

	N	mean	median	std	p1	p99
Deposit Ratio	20	0.482	0.526	0.144	0.125	0.688
Charged Reserve Ratio	20	-0.045	-0.039	0.042	-0.145	0.043
log(Total Assets) (in CHF k)	20	17.543	17.077	1.269	16.394	20.784
Capital Ratio	20	0.074	0.077	0.012	0.053	0.102
LCR	20	1.530	1.349	0.491	0.790	2.631
SME Loan Ratio	20	0.454	0.495	0.163	0.087	0.652
Net FX Pos./TA	20	-0.017	-0.011	0.027	-0.078	0.023
RoA (in pp)	20	0.245	0.243	0.087	0.075	0.401

Notes: The deposit ratio is defined as Swiss franc savings and sight deposits divided by total assets; the charged reserve ratio is the reserves at the Swiss National Bank subject to negative interest rates divided by total assets; the capital ratio is total regulatory capital divided by total assets; LCR is the regulatory liquidity coverage ratio; Net FX Pos./TA is the net long position in foreign currency divided by total assets; the SME loan ratio is loans and loan commitments to small and medium-size enterprises divided by total loans; and RoA is the return on assets, i.e., profits divided by total assets. All data are reported for December 2014.

In extensions, we look at the following further controls for bank characteristics. The share of loans granted to small and medium enterprises (SMEs) to total assets accounts for differences in business models. The FX ratio, defined as the net long position in foreign currency (assets minus liabilities) divided by total assets, controls for possible supply-side effects of currency mismatches. The regulatory liquidity coverage ratio (LCR) and the loan-to-deposits ratio (total loans over total deposits) measure liquidity position and funding model. The return on assets (RoA), defined as total profit over total assets, captures the profitability of the banks.

For all bank characteristics, we use ex ante information to avoid endogeneity problems. Specifically, we take the latest value of the bank characteristic before the rate change, i.e., as of 31 December 2014.

Table 3 compares the mean of bank characteristics of high-deposit banks (deposit rate above median) with those of low-deposit banks (below median). Apart from the deposit ratio itself (58 percent vs. 39 percent), we find no statistical differences in average bank characteristics, suggesting that these banks are not systematically different in other dimensions.

We also explore heterogeneity across firms, in particular whether effects are different for risky firms. To this end, we use two indicators. First, the “high risk sector” indicator takes a value of one if the average lending spread (equally weighted across banks) in this sector was above the median. To avoid endogeneity issues, we calculate this indicator based on the year before the rate cut (15 January 2014 to 14 January 2015). Second, the “export sector” indicator takes a value of one if the sector is export oriented. Firms in export-oriented sectors can be expected to have become relatively riskier after the monetary policy decision, because the sudden exchange rate appreciation made them less competitive. To identify export-oriented sectors, we rely on Egger et al. (2018), who calculate export intensities based on OECD Inter-Country Input-Output tables. Our indicator captures the top third of sectors by export intensity, which is defined as a sector’s exports over its total output.

Table 3: Bank characteristics: High-deposit vs. low-deposit banks

	N	Mean Low Deposits	Mean High Deposits	Difference	t-Statistic	p-Value
Deposit Ratio	20	0.388	0.575	-0.187	-3.817	0.001
Charged Reserve Ratio	20	-0.036	-0.054	0.018	0.941	0.359
log(Total Assets) (in CHF k)	20	17.873	17.212	0.661	1.176	0.255
Capital Ratio	20	0.071	0.077	-0.006	-1.105	0.284
LCR	20	1.445	1.616	-0.171	-0.772	0.450
SME Loan Ratio	20	0.470	0.437	0.033	0.447	0.660
Net FX Pos./TA	20	-0.021	-0.013	-0.008	-0.674	0.509
RoA (in pp)	20	0.230	0.259	-0.029	-0.732	0.474

Notes: In this table, we compare average bank characteristics of banks with deposit ratios above the median with those below the median. The deposit ratio is defined as Swiss franc savings and sight deposits divided by total assets; the charged reserve ratio is the reserves at the Swiss National Bank subject to negative interest rates divided by total assets; the capital ratio is total regulatory capital divided by total assets; LCR is the regulatory liquidity coverage ratio; Net FX Pos./TA is the net long position in foreign currency divided by total assets; the SME loan ratio is loans and loan commitments to small and medium-size enterprises divided by total loans; and RoA is the return on assets, i.e., profits divided by total assets. All data are reported for December 2014.

We also run a specification where we control for other lending terms (see above) when analyzing the lending spread. Since these lending terms can be considered outcome variables, this specification suffers from endogeneity problems. Nonetheless, it may be helpful in detecting irregularities, e.g., if a lower spread is only due to better collateralization.

4.3 Empirical Strategy

In general, analyzing the transmission of monetary policy through banks faces three important challenges. First, market participants may anticipate policy rate moves and thus frontload adjustments in their lending behavior. Moreover, policy rate decisions may be made in response to domestic lending conditions, giving rise to endogeneity issues. Second, lending supply and demand need to be disentangled. Third, demand effects may vary across firms, calling for some level of granularity of demand controls. To address these challenges, we base our identification on three pillars.

In our first pillar, we exploit the fact that the interest rate cut on 15 January 2015 was unexpected, exogenous to the domestic economy, and large. Figure 1 shows that there were no anticipation effects, as market rates suddenly dropped at the exact date of the rate cut. This is important for our empirical strategy because our estimates would likely underestimate the effect of the rate cut if it had been anticipated. Additionally, anticipation would violate the common trends assumption behind the difference-in-differences approach explained below.

Furthermore, as discussed above, the monetary policy move was a response to exogenous foreign developments. This alleviates any endogeneity concerns that arise if the monetary policy decision was influenced by developments in the domestic lending market.

The monetary policy decision on 15 January 2015 was clearly the most important shock to market interest rates in the sample period we study. This is, for example, evident in Figure 1, where we observe large movements at the decision date, but not before or afterwards. A large event ensures that our results are not driven by smaller shocks before or after the monetary policy decision.

A possible concern is that the concurrent exchange rate appreciation had a separate supply effect due to currency mismatches on bank balance sheets. This channel is prominent in many emerging markets (Eichengreen and Hausmann, 1999). We consider it unlikely that currency mismatches played an important role. No bank in our sample reported large valuation losses or gains because of exchange rates in the three subsequent years. This is probably because these banks had either small FX exposures (median net FX long position: -1% of total assets) or were well hedged. In extensions, we nonetheless add controls for currency mismatches.

Our second pillar is a difference-in-differences specification similar to that of Heider et al. (2019). We compare lending i) before and after the rate cut and ii) between banks with different deposit ratios. With this approach, we account for changes in demand that are the same for all banks as well as time-invariant variation in the supply polices of banks. A possible concern may be that banks change their operational efficiency. For example, negative interest rates may be a trigger for high-deposit-share banks to streamline their operations, allowing for lower spreads because of higher efficiency. We do not directly control for this possibility but consider in extensions short horizons where such an adjustment is very unlikely.

Our third pillar is the use of granular firm characteristics to control for changes in credit demand specific to firm types. We follow a similar approach to Khwaja and Mian (2008) and compare loan terms of multiple banks to the same firm type in the same time period. The identification assumption is that when all banks grant a loan to the same firm type, any differences in lending decisions are due to supply, i.e., bank characteristics. Changes in a firm type's credit demand or creditworthiness are absorbed by the firm type*time fixed effect.

Granular firm controls are potentially important because demand effects are likely to vary across firms because of the concurrent exchange rate appreciation. Efing et al. (2015) show that export-oriented firms with costs primarily denominated in Swiss francs suffered from larger declines in profits. If the composition of credit portfolios is correlated with funding structure (e.g., if banks that lend to export-oriented firms rely less on deposit funding), assuming only a common credit demand effect would bias our results.

In addition, we use bank*firm type fixed effects to control for special lender-borrower relationships. For example, some banks and firm types might keep long-standing relationships, which could result in systematically lower loan spreads (Boot, 2000). Alternatively, since some cantonal banks are legally required to promote lending to small and medium-size enterprises in their home cantons, they might charge lower spreads to these firm types.

Our data set contains detailed information on firm characteristics from which we construct firm types (see Auer and Ongena, 2019, for a similar approach) as a combination of the borrowers' sector (81 sectors), location (26 cantons, administrative divisions in Switzerland) and number of employees (4 categories) and the time the loan was granted (14 periods in our baseline).[12] We require every firm type in a given pe-

[12]We exclude all observations where an employee category is not reported, which is why the total

riod to receive loans from at least two distinct banks. As a result of this restriction, our sample is reduced to 7'074 distinct firm type*time fixed effects (72'573 observations). On average, a firm type*time fixed effect has 3.0 relationships, with a maximum of 16 and a median of 2. There is some concentration in firm characteristics. For example, approximately 29% of all observations in our baseline specification are in the real estate sector, and approximately 14% of observations are in the canton of Zurich. In robustness checks, we will verify that our results are not driven by these clusters.

Note that our data set does not contain unique firm identifiers; thus, we cannot identify loans from multiple banks to the same firm, as in Khwaja and Mian (2008). However, as Degryse et al. (2019) shows for Belgium, fixed effects that account for variation in industry, location and firm size are sufficient to absorb firm-specific demand effects. Moreover, this approach has the advantage that firms with only one bank lending relationship are included. As the authors show, including singe-bank firms can lead to vastly different bank credit supply shock estimates. These firms are essential to properly account for supply movements when single-bank firms are abundant. In the case of Belgium, 82% of firms are single-bank firms. Switzerland is similar in this respect, with a share of single-bank firms of 75% (Dietrich et al., 2017).

4.4 Specification

Our simplest specification for the loan-level analysis takes the following form:

$$y_{l,b,f,t} = \beta depRatio_b \cdot D_t + \alpha_1 \cdot D_t + \alpha_2 \cdot depRatio_b + \epsilon_{l,b,f,t} \tag{1}$$

where $y_{l,b,f,t}$ is the lending spread (or an alternative lending term) charged on loan l by bank b to firm type f paid out at date t (t measured in days).[13] D_t is a dummy indicating the period after the 15 January 2015 rate cut, and $depRatio_b$ is the ratio of Swiss franc sight and saving deposits to total assets at the end of December 2014. $\epsilon_{l,b,f,t}$ is the error term.

The coefficient of interest is β. A negative β means that after the rate cut, banks with a high deposit ratio lowered the lending spread more compared to banks with a low deposit ratio. This indicates that reliance on deposit funding acts in an expansionary way under negative interest rates, i.e., high-deposit banks loosen their lending terms compared to low-deposit banks.

Starting from this simple specification, we successively add controls and increase the granularity of the fixed effects. Our main regression specification takes the following form:

$$y_{l,b,f,t} = \beta depRatio_b * D_t + \gamma BChar_b * D_t + F_{f,m} + F_{b,f} + \epsilon_{l,b,f,t}, \tag{2}$$

$BChar_b$ stands for other bank characteristics (size, capitalization, and charged reserves) that may affect the response to the rate cut. $F_{f,m}$ are firm type*month fixed effects, which control for firm type- and year-month-specific demand effects.[14] $F_{b,f}$

number of observations is different from those reported in Table 2. Our main results are similar if we treat "not reported" as a separate category.

[13] A bank can grant multiple loans to a firm type in any period t.

[14] More precisely, we additionally interact the firm type*year-month*D_t, effectively splitting the month of January 2015 into a pre-rate cut and a post-rate cut period.

are bank*firm type fixed effects to control for time-invariant unobserved bank heterogeneity by firm type. The sample period in the baseline covers the window between 180 days before and 180 days after the rate cut, with loans granted at the date of the rate cut removed from the sample. In an extension, we will look at alternative window sizes.

To explore whether the effects are more pronounced for risky firms, we run a separate regression for risky sectors and other sectors. We implement this approach with triple interactions:

$$y_{l,b,f,t} = \beta \mathrm{depRatio}_b * D_t + \delta \mathrm{depRatio}_b * \mathrm{Risk}_f * D_t + F_{f,m} + F_{b,f} + \epsilon_{l,b,f,t}, \quad (3)$$

where Risk_f is an indicator function for the riskiness of the sector, as described in Section 4.2.

Since at the loan level we only see the size of the loan but not the changes in the number of loans granted to a specific firm type, we complement our analysis by aggregating our loan-level data to the bank/firm level. This allows us to analyze whether a bank changed loan quantities granted to a specific firm type (intensive margin) and to check whether a bank entered new or terminated existing lending relationships (extensive margin).

Specifically, for the analysis of the intensive margin, we sum up the size of the individual loans to a given firm type in a given period, which gives us the volume of new loan agreements at the firm type level.[15] We look at two periods: the 180 days before and after the rate cut. In addition to volume, we look separately at the average loan size and the number of loans. For comparison purposes, we also consider the average lending spread to a given firm type in a given period and net revenues from credit intermediation, defined as the product of the lending spread and the volume of new loan agreements. For each dependent variable, we end up with a two-period panel of bank/firm types and apply the corresponding variant of equation (2). Note that due to bank*firm type fixed effects, by design, we only include firm type/bank relations in which a loan was granted in both periods.

For the extensive margin, we follow Khwaja and Mian (2008) and compute two sets of dummies. One set designates newly created bank/firm type relationships (entry), and the other designates bank/firm type relationships that were terminated (exit). Regarding entry, we check for each loan granted by a bank to a firm type after the rate cut whether that bank has granted a loan to the same firm type in the previous five years. If this is not the case, we interpret this as a newly formed relationship, and the entry dummy equals one. Regarding exit, we check whether loan agreements granted before the rate cut from a bank to a firm type expire after the rate cut. If that is the case and no new loan is granted after the rate cut, the exit dummy equals one.[16] For the analysis of the extensive margin, the specification is again similar to equation 2,

[15] As described above, new loan agreements cover new loans and major modification to existing contracts, with no separate identification. For loan contracts with open-ended maturities, a change in the bank internal rating is classified as a modification. To ensure that our results for lending volumes are not driven by changes in the internal rating, we exclude loan contracts with open-ended maturities as a robustness check. The results are not affected.

[16] Since we have no information on when loans with open-ended maturities are paid back, we exclude such loans from the exit analysis.

but because the sample collapses into a cross-section, we drop bank fixed effects and use firm type fixed effects instead of firm type*time fixed effects.

Reported standard errors are always clustered at the bank level. To account for small cluster biases, we follow the recommendation of Brewer et al. (2018) and employ a conservative degree of freedom correction for the standard deviation and use for tests the critical values from a t distribution with N-1 degrees of freedom, where N is the number of clusters.

5 Results

5.1 Lending terms at loan level

5.1.1 Spread

High-deposit banks offer looser lending terms than other banks in a negative rate environment. Table 4 focuses on our main lending term, the lending spread. Starting from the simplest specification as described in equation (1) and shown in column (1), we successively add more controls until we reach our baseline specification in column (6). The variable of interest is the interaction term *Deposit Ratio*After Rate Cut*. Across all specifications, the coefficient on this term is negative and statistically significant. In column 2, we add bank fixed and time fixed effects. In column 3, we interact the monetary policy change dummy with further standard bank balance-sheet characteristics to account for alternative channels of transmission. In column 4, we add firm type fixed effects to control for time-invariant differences in lending spreads across firm types. In column 5, we allow differences in firm types to vary over time by adding firm type*time fixed effects.

In our baseline specification in column 6, we add firm type*bank fixed effects to control for the possibility that banks systematically offer better terms in some sectors or regions and worse terms in others.

The estimated coefficient from our baseline specification is minus 0.85. This implies that a one-standard-deviation increase in the deposit ratio lowers the response of the lending spread to the rate cut by approximately 12 basis points. Given the policy rate cut of 50 basis points, the deposit ratio leads to a considerable difference in pass-through between banks.[17]

5.1.2 Other lending terms

Banks with more deposit funding also loosen other lending terms more or do not offset the relatively lower spreads by tightening other lending terms (Table 5). In particular, more reliance on deposits increases individual loan sizes (column 1). It also raises the likelihood of issuing a fixed rate loan (column 2), which, all else constant, increases duration. Furthermore, banks are less likely to charge a commission on a loan (column 3). Finally, there is no discernable influence on the maturity of the loan or whether it is collateralized (columns 4 and 5).

[17] The average lending spread in our sample amounts to 249 basis points, with a standard deviation of 161 basis points.

Table 4: Lending spread

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Ratio	0.07					
	(0.78)					
After Rate Cut	1.25***					
	(0.14)					
Deposit Ratio*After Rate Cut	-1.10***	-1.08***	-1.05***	-1.13***	-0.89***	-0.85***
	(0.27)	(0.27)	(0.30)	(0.28)	(0.15)	(0.11)
Charged Reserve Ratio*After Rate Cut			-1.67	-1.80	-1.88*	-2.17**
			(1.44)	(1.31)	(0.90)	(0.79)
Capital Ratio*After Rate Cut			-1.06	-1.33	-0.50	-0.18
			(5.68)	(5.71)	(3.78)	(3.23)
log(Total Assets)*After Rate Cut			0.01	-0.01	0.00	-0.01
			(0.04)	(0.04)	(0.03)	(0.03)
Time FE	No	Yes	Yes	Yes	No	No
Bank FE	No	Yes	Yes	Yes	Yes	No
Firm Type FE	No	No	No	Yes	No	No
Firm Type *Time FE	No	No	No	No	Yes	Yes
Bank*Firm Type FE	No	No	No	No	No	Yes
Constant	Yes	No	No	No	No	No
Observations	109420	109420	109420	91170	74491	72573
R^2	0.072	0.189	0.189	0.423	0.484	0.562
Number of Banks	20	20	20	20	20	20

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The data are at the loan level and cover the period of a symmetric 180-day window around 15 January 2015. The dependent variable is the lending spread over the risk-free rate, as defined in section 4.1. Our main continuous differencing variable is the deposit ratio (Swiss franc savings and sight deposits divided by total assets). After Rate Cut is a dummy variable that takes the value of 1 after the interest rate change on 15 January 2015. Column (1) shows the result of the simplest regression specification, as defined in equation 1 in section 4.4. We successively add fixed effects (indicated by "Yes") to control for bank fixed effects, firm type fixed effects, time fixed effects, and interactions thereof. From column (3) on, we add further balance-sheet controls: the ratio of reserves at the Swiss National Bank subject to negative interest rates, normalized by total assets (Charged Reserve Ratio); the overall capital position, normalized by total assets (Capital Ratio); and the log of total assets as a measure of bank size (log(Total Assets)). In column (6), we arrive at our baseline specification, which controls for time-varying firm type fixed effects (Firm Type*Time FE) and for specific bank-firm relationships (Bank*Firm Type FE). Standard errors are clustered at the bank level.

5.1.3 Varying the window size

Reliance on deposit funding has a persistent effect on lending terms in a negative interest rate environment. In addition to our baseline window of +/-180 days, we let the window size vary from +/-90 days to +/-1080 days, focusing on those lending terms where we obtained statistically significant results for the baseline window. Figure 5 shows the coefficient of Deposit Ratio*After Rate Cut for different window sizes and lending terms. For larger windows, the negative effect on lending spreads is roughly halved but remains statistically and economically significant. The positive effect on loan size is persistent as well. The effects on the likelihood to grant fixed rates and to charge a commission are less persistent. They are smaller for larger window sizes and lose statistical significance.

Table 5: Other loan terms

	(1) log loan size	(2) fixed rate	(3) commission	(4) maturity	(5) collateralized
Deposit Ratio*After Rate Cut	0.49***	0.20***	-0.17***	0.22	-0.04
	(0.09)	(0.03)	(0.01)	(0.44)	(0.03)
Charged Reserve Ratio*After Rate Cut	0.38	0.72***	-0.21	9.51***	-0.04
	(0.38)	(0.22)	(0.14)	(1.85)	(0.15)
Capital Ratio*After Rate Cut	-0.37	-0.57	-0.25	-19.58*	-0.30
	(1.53)	(1.06)	(0.47)	(9.92)	(0.69)
log(Total Assets)*After Rate Cut	0.04***	0.01	-0.01**	-0.30***	-0.01
	(0.01)	(0.01)	(0.00)	(0.09)	(0.01)
Firm Type*Time FE	Yes	Yes	Yes	Yes	Yes
Bank*Firm Type FE	Yes	Yes	Yes	Yes	Yes
Observations	72573	72573	72573	50375	72573
R^2	0.551	0.417	0.393	0.445	0.501
Number of Banks	20	20	20	20	20

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table reports the results of our difference-in-differences model (see equation 2 in section 4.4) using least squares. The data are at the loan level and cover the period of a symmetric 180-day window around 15 January 2015. We look at several lending terms as dependent variables: the log of the loan size (column 1), whether the loans had a fixed interest rate (column 2), whether a commission was charged on top of the interest rate (column 3), the maturity of the loan expressed in number of days divided by 360 (column 4), and whether the loan was collateralized (column 5; see section 4.1). Our main continuous differencing variable is the deposit ratio (Swiss franc savings and sight deposits divided by total assets). We interact it with a dummy variable that takes the value of 1 after the interest rate change. In addition, we control for the following bank characteristics: the ratio of reserves at the Swiss National Bank subject to negative interest rates, normalized by total assets (Charged Reserve Ratio); the overall capital position, normalized by total assets (Capital Ratio); and the log of total assets as a measure of bank size (log(Total Assets)). We control for time-varying firm type fixed effects (Firm Type*Time) and for specific bank-firm relationships (Bank*Firm Type). Standard errors are clustered at the bank level.

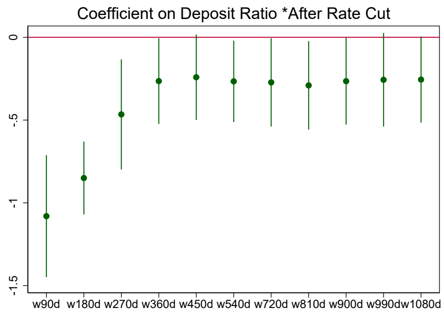
5.1.4 Firm heterogeneity

The loosening of lending terms of high-deposit banks is especially pronounced in the case of firms from risky sectors (Table 6). For both measures of sector riskiness (see Section 4.4), we find evidence that high-deposit banks loosened their lending terms relative to peers, particularly to risky sectors. Specifically, a one-standard-deviation increase in the deposit ratio lowers spreads by 16 basis points for high-risk sectors vs. 9 basis points for low-risk sectors (column 1). We find similar magnitudes on lending to export sectors vs. other sectors (18 basis points vs. 10 basis points, column 5)). In risky sectors, high-deposit banks also tend to loosen other lending terms more.[18] In particular, high-deposit banks grant larger individual loans to risky sectors (columns 2 and 6), their loans are more likely to have a fixed interest rate (columns 3 and 7), and they are less likely to charge loan commissions (columns 4 and 8).

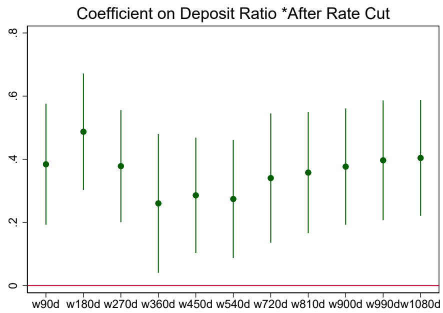
[18]We focus on those lending terms where we have found a statistically significant effect according to the specification shown in Table 5. For collateralization and maturity, we find no differences across sectors.

Figure 3: **Effect of deposit funding on lending terms for different window sizes**

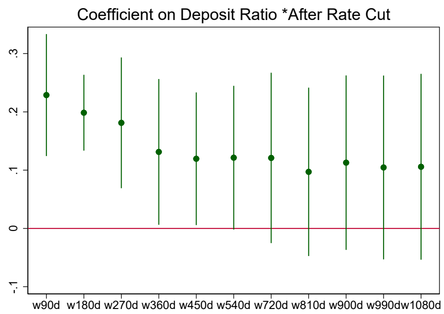
(a) lending spread



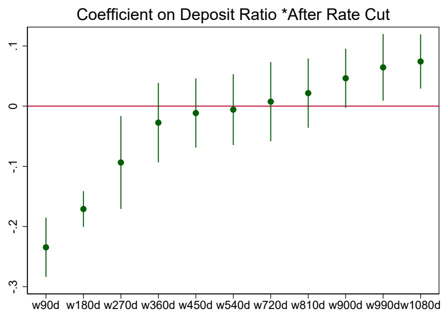
(b) log(loan size)



(c) fixed rate



(d) commission



The figure shows the β coefficient for equation 2 for alternative symmetric windows around the rate cut on 15 January 2015. Circles indicate the point estimate, and vertical lines show the 95% confidence bands based on standard errors that are clustered at the bank level. The labels on the x-axis indicate the size of one side of the window in days.

Table 6: Differences between risky and other sectors

	(1) lending spread	(2) log loan size	(3) fixed rate	(4) commission	(5) lending spread	(6) log loan size	(7) fixed rate	(8) commission
Deposit Ratio*After Rate Cut	-0.59***	0.08	0.07*	-0.06***	-0.70***	0.15	0.08**	-0.09***
	(0.06)	(0.12)	(0.03)	(0.02)	(0.06)	(0.10)	(0.03)	(0.02)
Deposit Ratio*High Risk Sector*After Rate Cut	-0.48***	0.30*	0.07**	-0.12***				
	(0.12)	(0.16)	(0.03)	(0.02)				
Deposit Ratio*Export Sector*After Rate Cut					-0.33**	0.35*	0.04	-0.11
					(0.15)	(0.18)	(0.07)	(0.09)
Firm Type*Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank*Firm Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	72573	72573	72573	72573	72573	72573	72573	72573
R^2	0.562	0.551	0.417	0.393	0.562	0.551	0.417	0.393
Number of Banks	20	20	20	20	20	20	20	20

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table reports our baseline difference-in-differences model with triple interactions (see equation 3 in section 4.4) using least squares. The data are at the loan level and cover the period of a symmetric 180-day window around 15 January 2015. Our main continuous differencing variable is the deposit ratio (Swiss franc savings and sight deposits divided by total assets). We interact it with a dummy variable that takes the value of 1 after the interest rate change and an indicator variable that takes a value of 1 if the sector is either a " a high risk sector" or an "export sector" (see equation 3). These terms are defined in Section 4.2.2. We control for time-varying firm type fixed effects (Firm Type*Time) and for specific bank-firm relationships (Bank*Firm Type). Standard errors are clustered at the bank level.

5.1.5 Robustness and Extensions

Alternative specifications: Table 7 reports various modifications to our baseline specification for lending spreads as described in equation (2) with regard to sample composition and changes in the specification.

First, we remove the 29 days before the 15 January rate cut to exclude the first policy announcement on 18 December 2014 from our data (see 3.1). After the rate cut, we remove the first two weeks to ensure that our results are not driven by the short-term volatility that followed the decision (column 1). Our result continues to hold.

Our results are also not driven by firm characteristics or by banks that carry a large weight in our sample. Columns (2) to (4) show that we obtain similar results when excluding the industry sector with the most observations (real estate sector, 28% of all observations), the canton with most observations (Zurich, 14% of all observations) and the bank with most observations (26% of all observations).

A number of changes to the econometric specification again do not change our conclusion. In particular, the result continues to hold if we control for other loan characteristics as described in Section 4.2.1 (column 5), complement our standard balance sheet controls with other bank characteristics (SME loan-to-asset ratio, net long FX position over total assets, return on assets, liquidity coverage ratio, loan-to-deposit ratio, column 6), weight by loan size (column 7), and replace the lending spread with a simple interest rate (column 8).

Table 7: Lending spread robustness checks

	(1) wo. cut per.	(2) wo. larg. sect.	(3) wo. larg. cant.	(4) wo. larg. bank	(5) Loan char.	(6) oth. bank char.	(7) Weighted	(8) Int. rate
Deposit Ratio*After Rate Cut	-0.70***	-0.78***	-0.76***	-0.81***	-0.58***	-0.90***	-0.66***	-0.76***
	(0.17)	(0.11)	(0.10)	(0.08)	(0.09)	(0.23)	(0.12)	(0.07)
Charged Reserve Ratio*After Rate Cut	-2.44***	-3.20**	-1.50	-3.10***	-1.10**		-2.08***	-1.20*
	(0.59)	(1.20)	(1.00)	(0.69)	(0.51)		(0.33)	(0.58)
Capital Ratio*After Rate Cut	0.07	-2.73	-2.15	-0.89	1.69		-0.28	-2.41
	(2.31)	(3.91)	(3.43)	(2.62)	(1.87)		(2.20)	(2.10)
log(Total Assets)*After Rate Cut	-0.01	0.00	-0.01	0.01	0.01		-0.01	-0.05**
	(0.02)	(0.03)	(0.03)	(0.02)	(0.01)		(0.02)	(0.02)
log(loan size)					-0.10***			
					(0.01)			
maturity					-0.01*			
					(0.01)			
fixed rate					0.26***			
					(0.05)			
commission					1.80**			
					(0.71)			
collateralized					-0.67***			
					(0.14)			
LCR*After Rate Cut						0.03		
						(0.07)		
Net FX Pos./TA*After Rate Cut						1.67		
						(1.11)		
SME Loan Ratio*After Rate Cut						0.15		
						(0.28)		
RoA*After Rate Cut						0.27		
						(0.50)		
Deposit to Loan Ratio*After Rate Cut						-0.14		
						(0.25)		
Firm Type*Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank*Firm Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	87599	46550	61333	52966	50375	72573	72573	72573
R^2	0.576	0.494	0.545	0.579	0.701	0.562	0.671	0.528
Number of Banks	20	20	20	19	20	20	20	20

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table reports various robustness checks. The data are at the loan level and, unless mentioned otherwise, cover the period of a symmetric 180-day window around 15 January 2015. Column (1) removes from the estimation the period between the rate cut on 15 January 2015 and the policy announcement on 18 December 2014 and the two weeks following the rate cut. Columns (2) to (4) exclude firm characteristics and banks that carry a large weight: column (2) excludes the real estate sector, column (3) excludes the canton of Zurich, and column (4) excludes the bank with the largest weight in terms of observations. Column (5) controls for additional individual loan characteristics. Column (6) adds further bank controls to our baseline specification: liquidity coverage ratio (LCR), the net long position in foreign currency divided by total assets (Net FX Pos./TA), loans and loan commitments to small and medium-size enterprises normalized by total loans (SME Loan Ratio), and profits normalized by total assets (RoA). In column (10), we weigh observations by loan size. Column (11) replaces lending spread with lending rate as the dependent variable. Deposit Ratio, Charged Reserve Ratio, Capital Ratio and log(Total Assets) are defined in Table 4.

Placebo tests: To exclude the possibility that we have simply uncovered a hitherto-unknown role of deposit funding in the transmission of monetary policy, we run the regressions for all 11 previous rate cuts in positive territory that our sample covers (2006m06 to 2014m12).[19] The rate change dummy takes a value of one if there was a rate cut and a value of minus one if there was a rate hike. Absent a lower bound on deposit rates, we would not expect to find a similar effect of deposit funding on lending terms. Our results confirm this hypothesis. All of the coefficients are insignificant, except for one case, where the coefficient is positive. This also indicates that the parallel trend assumption holds, because the dependent variable moves in parallel for different deposit ratios when there is no actual "treatment".

[19]These rate cuts are not necessarily unanticipated and exogenous. For example, they include responses to the financial crisis.

Table 8: Estimates for rate cuts in positive territory

	9/14/06	12/14/06	3/15/07	6/14/07	9/13/07	10/8/08	11/6/08	11/20/08	12/11/08	3/12/09	8/3/11
Deposit Ratio*After Rate Cut	-0.55	-0.5	-0.34	0.21	-0.20	-0.87	-1.45	-1.70	-1.80	0.44	1.31***
	0.63	0.36	0.25	0.32	0.29	0.78	1.01	1.03	1.16	0.80	0.44
Observations	31,206	46,541	56,233	50,882	51,578	70,589	72,317	73,163	76,083	85,997	76,180
R2	0.58	0.57	0.57	0.51	0.51	0.54	0.53	0.52	0.53	0.51	0.55
Number of banks	20	20	20	20	20	20	20	20	20	20	20

Standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table reports the estimated coefficients and bank-clustered robust standard errors (in parentheses) for all monetary policy rate changes since September 2006. The underlying baseline difference-in-differences model is described in equation 2 in section 4.4. The rate change dummy takes a value of one if there was a rate cut and a value of minus one if there was a rate hike. The data are at the loan level and cover the period of a symmetric 180-day window around the corresponding rate change. Our main continuous differencing variable is the deposit ratio (Swiss franc savings and sight deposits divided by total assets). We further control for bank characteristics, firm types and specific bank-firm relationships, as described in the baseline model (not reported in the table).

Table 9: Dependent variable: Lending spreads on residential mortgages

	(1) all mat	(2) mat <=5y (+-6m)	(3) mat >5y (+-6m)	(4) mat>5y (+-2m)	(5) mat>5y (+-18m)
Deposit Ratio*After Rate Cut	-0.11	-0.02	-0.19**	-0.22**	-0.17**
	(0.08)	(0.09)	(0.09)	(0.10)	(0.08)
Charged Reserve Ratio*After Rate Cut	0.26	0.00	0.44	0.34	-0.15
	(0.29)	(0.33)	(0.32)	(0.40)	(0.31)
log(Total Assets)*After Rate Cut	0.02**	0.01*	0.03***	0.03***	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Capital Ratio*After Rate Cut	0.75	0.51	0.91	1.41	-0.24
	(1.06)	(0.95)	(1.30)	(1.42)	(0.94)
Constant	1.47***	1.48***	1.46***	1.35***	1.70***
	(0.10)	(0.09)	(0.12)	(0.14)	(0.10)
Bank FE	Yes	Yes	Yes	Yes	Yes
Time*Maturity FE	Yes	Yes	Yes	Yes	Yes
Observations	4840	2301	2539	854	7571
R^2	0.937	0.959	0.928	0.903	0.938
Number of Banks	45	45	44	44	44

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table reports the estimated coefficients and bank-clustered robust standard errors (in parentheses) of a difference-in-differences model applied to a residential mortgage loan data set using least squares. In the first column, we look at all mortgage loans in the +/- 6-month window around December 2014 (similar to our baseline specification). In column (2), we restrict the data to all mortgages with a maturity of less than 5 years. In column (3), we restrict the data to all mortgages with a maturity of more than 5 years. In the last two columns, we focus on mortgages with a maturity of more than 5 years and vary the window size. We use a window of +/-2 months (column 4) and a window of +/-18 months (column 5) around the rate cut. Our main continuous differencing variable is the deposit ratio (Swiss franc savings and sight deposits divided by total assets). In addition, we control for the following bank characteristics: the ratio of reserves at the Swiss National Bank subject to negative interest rates, normalized by total assets (Charged Reserve Ratio), the overall capital position normalized by total assets (Capital Ratio) and the log of total assets as a measure of bank size (log(Total Assets)). We control for bank fixed effects (Bank FE) and for time-varying maturity fixed effects (Time*Maturity FE).

Validity of our results in other markets: To check whether our results hold for other credit markets and for a broader sample of 45 banks, we apply a similar analysis to the residential mortgage market (see section 4.1 for a description). We use lending spreads on fixed rate mortgages with a maturity of between one and ten years. We use a two-sided window of six months around the rate cut as baseline. Standard errors are again clustered at the bank level.

The results are shown in Table 9. We find a similar effect as for corporate loans, but for long maturities only (more than five years, column 3). Deposit funding has no effect in a specification with only short maturities (five years or less, column 2) or all maturities (columns 1). It appears that high-deposit-ratio banks primarily aim to expand their lending in a maturity bucket where yields are higher. The coefficient (-0.19) is approximately five times smaller than for corporate loans in absolute terms, but compared to the sample standard deviation of lending spreads for residential mortgages (approximately six times smaller, 25 basis points), this is a similar magnitude. We also find a statistically significant effect for a short two-sided 2-month window, indicating a quick response, and a long two-sided 18-month window (column 5), indicating that the effect is persistent.

5.2 Lending analysis at bank/firm type level

An analysis at the bank/firm type level shows that the looser lending terms of high-deposit banks translate into additional lending and additional revenues.

5.2.1 Intensive margin

In Table 5, we have already shown that after the rate cut, the individual loan size increases. To account for changes in the number of loans, we aggregate new loan agreements within existing bank/firm type relationships (see Section 4.2.1). Table 10 column (1) shows that a higher reliance on deposits leads to a higher volume of new loan agreements to a firm type within an existing bank/firm type relationship. According to the estimate of 1.96, a one-standard-deviation increase in the deposit ratio raises the volume of new loan agreements after the rate cut by 28 percent. The effect is both a result of a larger average loan size and a larger number of loans (columns 2 and 3).

To see how the rise in the volume of new lending contracts relates to the decrease in the lending spread described in Section 5.1, we also compute the lending spread in the pre- and post-rate cut period by taking the volume-weighted average of individual lending spreads. For direct comparability with volumes, we take the log. As seen by column (2), the estimated coefficient of minus 0.66 implies that a one-standard-deviation increase in the deposit ratio lowers spreads by 10 percent in a negative rate environment. Note that the estimated coefficients in columns (1) and (4) are directly comparable: The rise in volume (28 percent) exceeds the decrease in spreads (10 percent). The net effect is an increase in net revenue from credit intermediation (volume times spread). Concretely, a one-standard-deviation increase in the deposit ratio increases the rise in net revenues after the rate cut by 18 percent (column 3). Hence, through looser lending terms, high-deposit banks are able to increase their revenues relative to their peers and reap market shares.

5.2.2 Extensive margin

Deposit funding also encourages an expansion at the extensive margin. After the rate cut, a high-deposit bank is more likely to grant a loan to a new firm type and is less likely to let all outstanding loans to a firm type expire. As described in Section 4.2.1, we use as dependent variables the dummy variables Entry (set to one if a bank grants a loan to a new firm type) and Exit (set to one if a loan expires after the rate cut). A one-standard-deviation increase in the deposit ratio makes it 2.3 percentage points more likely that a loan a bank grants is granted to a new firm type (7.3 percent of all bank/firm type relationships in the post-rate cut sample are new relationships). An equally sized increase in the deposit ratio makes it 0.6 percentage points less likely that a bank lets all loans to a firm type expire without replacement (2.8% of all bank/firm type relationships expire after the rate cut).

5.3 Effect of charged reserves on transmission

Two recent studies (Basten and Mariathasan, 2018; Bottero et al., 2019) have focused on the asset side of banks, i.e., the initial amount of charged reserves or excess liquidity,

Table 10: Lending: Intensive and extensive margin

	(1) log volume	(2) log avg. loan size	(3) Number of loans	(4) log spread	(5) log net rev.	(6) new firm-type	(7) exit firm-type
Deposit Ratio*After Rate Cut	1.96***	0.79***	16.34***	-0.66***	1.31***	0.16***	-0.04***
	(0.30)	(0.15)	(4.74)	(0.05)	(0.30)	(0.02)	(0.01)
Charged Reserve Ratio*After Rate Cut	-1.12	-0.38	4.01	-0.33	-1.49	-0.04	0.08
	(0.99)	(0.66)	(14.02)	(0.50)	(1.26)	(0.17)	(0.07)
Capital Ratio*After Rate Cut	-0.20	1.33	-35.81	0.28	0.00	0.15	0.23
	(3.28)	(2.06)	(53.21)	(1.20)	(3.21)	(0.42)	(0.17)
log(Total Assets)*After Rate Cut	0.23***	0.07***	1.99**	-0.04***	0.19***	0.01	-0.01***
	(0.03)	(0.01)	(0.89)	(0.01)	(0.03)	(0.00)	(0.00)
Bank*Firm Type FE	Yes	Yes	Yes	Yes	Yes	No	No
Firm Type*Time FE	Yes	Yes	Yes	Yes	Yes	No	No
Firm Type FE	No	No	No	No	No	Yes	Yes
Observations	7172	7172	7172	7172	7172	5638	11881
R^2	0.928	0.923	0.981	0.883	0.919	0.377	0.303
Number of Banks	20	20	20	20	20	20	20

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The data are aggregated at the firm type/bank level. Columns (1)-(5) show estimates at the intensive margin for the period of a symmetric 180-day window around the rate cut on 15 January 2015. The dependent variables are log of the volume of new loan agreements, defined as the sum of all individual loan volumes granted by a given bank to a given firm type (column 1), the log of the average loan size (column 2), the number of loans (column 3), the log of the average lending spread (column 4) and net revenues from credit intermediation (column 5), defined as lending spread*volume of new loan agreements. Columns (6)-(7) show estimates at the extensive margin. In column (4), the dependent variable indicates whether a granted loan constitutes a new bank/firm type relationship. Column (5) it indicates whether an existing bank/firm type relationship has expired (see section 4.2.1 for exact definition). Our main continuous differencing variable is the deposit ratio (Swiss franc savings and sight deposits divided by total assets). We interact it with a dummy variable that takes the value of 1 after the interest rate change on 15 January 2015. In addition, we control for the following bank characteristics: the ratio of reserves at the Swiss National Bank subject to negative interest rates, normalized by total assets (Charged Reserve Ratio); the overall capital position, normalized by total assets (Capital Ratio); and the log of total assets as a measure of bank size (log(Total Assets)). In columns (1) to (5), we control for time-varying firm type fixed effects (Firm Type*Time) and for specific bank-firm relationships (Bank*Firm Type). In columns (6) and (7), we drop the time interaction from our fixed effects, since after taking first differences, we have a pure cross-section. Standard errors are clustered at the bank level.

to measure exposure to negative interest rates and transmission. We run a similar specification for charged reserves to account for this possible channel. In our baseline specification with a two-sided window of 180 days, we find evidence that banks with more charged reserves ask for lower spreads in response to the rate cut (see Table 4). A one-standard-deviation increase in the charged reserve ratio lowers the lending spread by approximately 9 basis points in response to the cut, a similar magnitude as for the deposit ratio. This is consistent with portfolio rebalancing, where high-deposit banks attempt to expand lending and reduce their reserves.

However, as shown in Figure 4, the effect fades out for longer estimation windows and is not statistically significant for +/- 360 days and larger windows. We find the same pattern for other lending terms.

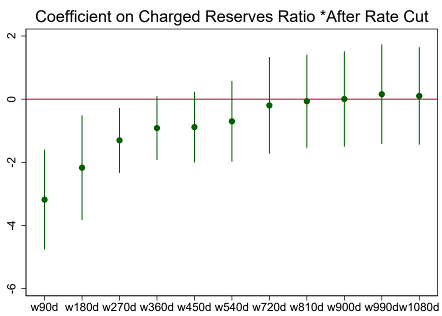
The fact that charged reserves only seem to have a short-term effect on lending terms indicates that initial differences in charged reserves are arbitraged away on the interbank market to some degree over the medium term. Banks with reserves below the exemption threshold (negative charged reserves) probably "sold" their spare capacity for reserve assets at the SNB by accepting interbank loans from banks with reserves above the threshold. This finding on liquidity reallocation is consistent with Basten and Mariathasan (2018). We provide further evidence on liquidity reallocation by showing strong convergence of charged reserves over total assets among Swiss banks in the 12 months after the rate cut. Figure 4 plots the change in the charged reserve ratio in the 12 months after the rate cut against the charged reserve ratio just before the rate cut, using a larger sample of all Swiss banks that are active in domestic lending.[20] There is a strong negative correlation. The slope of the fitted univariate regression line is 0.61, indicating that 61 percent of any deviation from the average is predicted to be compensated over 12 months.

For deposit ratios, on the other hand, there is no evidence of convergence. The fitted line is basically flat. This supports the notion that the deposit franchise is a fundamental part of some banks' business model, which is not easily adjusted.

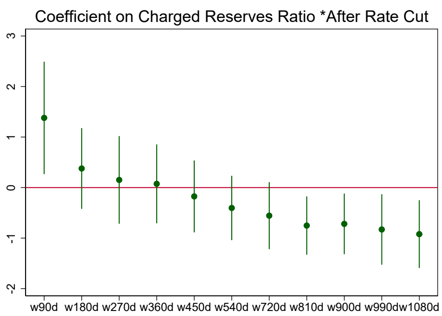
Overall, we conclude that while charged reserves have affected corporate lending spreads in the short term, they appear overall of lesser importance in explaining variation across banks in the transmission of negative interest rates in the medium term.

Figure 4: **Effect of charged reserves on lending terms for different window sizes**

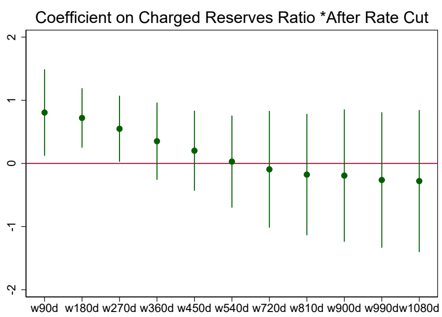
(a) lending spread



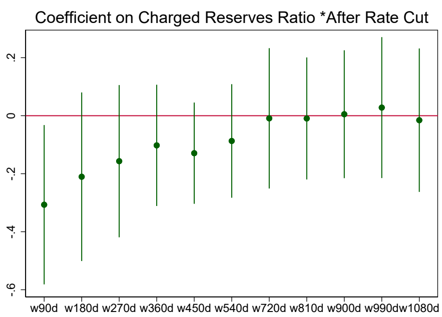
(b) log(loan size)



(c) fixed rate



(d) commission

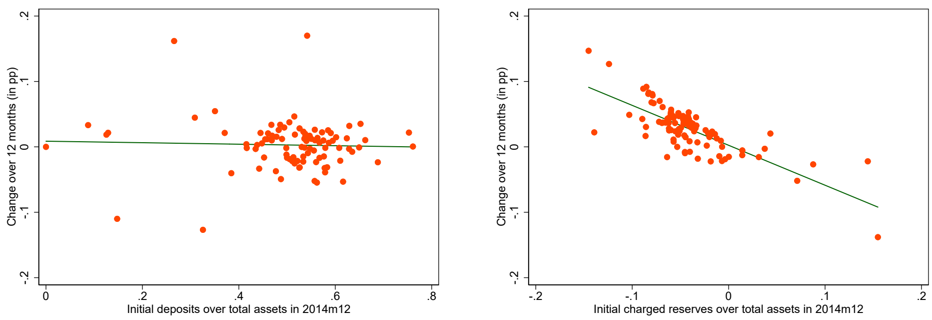


The figure shows the γ coefficient for equation 2for alternative symmetric windows around the rate cut on 15 January 2015. Circles indicate the point estimate, and the vertical lines show the 95% confidence bands, based on standard errors that are clustered at the bank level. The labels on the x-axis indicate the size of one side of the window in days.

[20] Except for missing data, this sample corresponds to the set of banks discussed in the SNB's financial stability report, i.e., the large international and the domestically oriented banks. Approximately 20 percent of the banks initially displayed charged reserves above the threshold.

Figure 5: **Convergence in deposit and charged reserve ratio**

(a) Deposit ratio (b) Charged reserves ratio



The figures plot the change in the deposit ratio and charged reserve ratio of bank b over 12 months against their initial levels before the rate cut ($y_{b,0}$). Data are at the bank level. The fitted regression lines correspond to the following regressions (robust standard errors in parenthesis):
For the deposit ratio: $\Delta_{12} y_{b,12} = \underset{(0.024)}{0.009} \underset{(0.043)}{-0.011} \, y_{b,0} + \epsilon_b$ ($N = 96$, $R^2 = 0.001$)
For the charged reserves ratio: $\Delta_{12} y_{b,12} = \underset{(0.002)}{0.005} + \underset{(0.095)}{-0.610} y_{b,0} + \epsilon_b$ ($N = 96$, $R^2 = 0.596$)

6 Conclusion

After several central banks pushed their monetary policy rates into negative territory, banks generally proved reluctant to pass on negative interest rates to their retail depositors. The existence of this zero lower bound on deposit rates raises the question of the effect on bank lending and monetary policy transmission when the policy rate becomes negative.

To evaluate the effects on transmission, we focus on an unexpected policy rate cut to minus 0.75 percent in Switzerland and analyze a comprehensive and granular data set on individual Swiss corporate loans. Our results indicate that banks relying more heavily on deposit funding loosen their lending terms and expand lending by more than other banks. This result is consistent with the risk-taking channel, where banks take their deposits as given and the lower policy rate spurs bank risk-taking to maintain profits.

Future research may, in particular, look at the following two issues. First, it would be interesting to better understand what drives the heterogeneity in transmission of negative interest rates across jurisdictions. Apart from the identification challenges described above, there may be important economic reasons for the differing results. For one, domestic economic conditions and the capital positions of banks might have an impact on banks' reactions to an interest rate cut (Dell'Ariccia et al., 2017; Eggertsson et al., 2017; Heider et al., 2019). In Switzerland, negative interest rates were introduced in an overall benign economic environment, with bank capital generally well above minimum requirements and historically low levels of nonperforming loans. In Brunnermeier and Koby (2018), a necessary condition for contractionary effects of interest rate cuts is that capital constraints are binding. For another, the zero lower bound on the deposit rate was not binding in some jurisdictions because of risk premia on deposits, leaving banks with room to cut deposit rates further (Eisenschmidt and Smets, 2017; de Sola and Kasongo, n.d.).

Second, a number of studies have documented that with negative interest rates, the transmission from policy rates to lending rates declines or even breaks down (Bech and Malkhozov, 2016; Eggertsson et al., 2019). In Switzerland, pass-through was incomplete as well. Our results, however, do not support the notion that deposit funding is to be blamed for the lack of transmission. In contrast, pass-through to lending rates for high-deposit banks is stronger. Other factors, possibly unrelated to credit supply, must be the reason for the phenomenon. A first possibility is borrower riskiness: there is evidence that the strong appreciation of the Swiss franc caused a worsening in borrower fundamentals (Efing et al., 2015) and an increase in uncertainty (Buchholz et al., 2018). It is possible that these factors masked looser lending terms due to increased risk premia. A second possibility is market power: the rate cut may have served as an informal coordination device to exert market power, i.e., there might have been an implicit understanding among banks not to adjust lending rates and thereby maintain profitability (Erikson and Vestin, 2019).

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