Are low interest rates firing back? Interest rate risk in the banking book and bank lending in a rising interest rate environment*

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Abstract

We match granular supervisory and credit register data to assess the implications of banks' exposure to interest rate risk on monetary policy transmission to bank lending supply in the euro area. We exploit the largest and swiftest increase in interest rates since the creation of the euro and find that banks with a higher exposure to interest rate risk, i.e., with a larger duration gap after accounting for hedging, curtailed corporate lending more than their peers. Ceteris paribus, greater interest rate risk entails closer supervisory scrutiny and potential capital surcharges in the short term, and lower expected profitability and capital accumulation in the medium to long term. We then proceed to dissect banks' credit allocation and find that banks with higher net duration reshuffled their loan portfolio away from long-term loans in an attempt to limit the increase in interest rate risk and targeted their lending contraction to small and micro firms. Firms exposed to banks with a larger exposure to interest rate risk were unable to fully rebalance their borrowing needs with other lenders, thus experiencing a relatively larger decrease in total borrowing during the monetary tightening episode.
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Non-technical summary

Banks' engagement in maturity transformation, by borrowing "short" and lending "long", allows them to earn the spread between the interest rates charged on longer-term assets and the interest rate paid on the shorter-term liabilities. However, this intrinsic feature of their business model exposes them to *interest rate risk*. Indeed, rapid and unexpected increases in interest rates can adversely impact banks' net worth due to changes in the present value and timing of future cash flows. Conventional wisdom holds that, on aggregate, increases in interest rates lead to a decline in banks' net worth as the value of assets declines more than the value of liabilities. This effect is most pronounced for banks that exhibit a large positive mismatch between the duration of their assets and liabilities, i.e., banks with a large *duration gap*.

We show that banks increased the duration of their asset side during the low for long interest rate environment in an attempt to search for yield. Interest rate risk, however, remained mostly muted during this period because of the large inflow of overnight deposits which behaviourally have a relatively long duration. Since the ECB started raising interest rates in July 2022, a large shift from sticky overnight towards more rate-sensitive term deposits led to an increase in the duration gap, causing a materialisation of interest rate risk.

We empirically analyse whether banks' exposure to interest rate risk affects the transmission of monetary policy to bank lending supply in a rising interest rate environment using extensive and granular euro area supervisory and credit register data. Our sample covers the period from 2021Q1 to 2023Q2 for 73 significant institutions. Using bank-firm level panel estimations that control for credit demand and multiple bank-level characteristics that could impact bank lending supply, we find that, when interest rates increase, banks with a larger duration gap after accounting for hedging contract lending more and are less likely to issue new loans to firms compared to banks with a lower exposure to interest rate risk. This occurs because banks generally tend to match the duration of their assets and liabilities to maintain a stable duration gap and minimise their exposure to interest rate risk. Following this strategy, they aim to avoid a decline in the economic value of their equity and accordingly closer supervisory scrutiny and potential capital surcharges in the short term, and, *ceteris paribus*, lower expected profitability and capital accumulation in the medium to long term. In line with this, our findings show that banks with a larger duration gap reallocate their loan portfolios away from loans with a longer duration and fixed rates. Our results show that micro, small, and medium enterprises (MSMEs) are the most affected by the contraction in lending supply. Additionally, we show that firms cannot (fully) substitute the contraction in credit coming from banks with a larger duration gap by borrowing more from banks with a lower duration gap, resulting in an additional reduction in borrowing during a monetary tightening episode for these firms relative to other firms.

Our findings have important policy implications. In terms of financial stability, an excessive contraction in (long-term) lending supply may aggravate the economic downturn. Moreover, since MSMEs, who are most affected by this contraction, cannot rely on market-based funding as a substitute to bank credit, the impact might be especially pronounced for these types of firms. Next, from a monetary policy perspective, we provide evidence showing that the transmission of monetary policy is heterogeneous across euro area banks, with a stronger effect for banks with a large duration gap. This is an important parameter for monetary policymakers to take into account when deciding on (the extent and pace of) monetary policy changes.

1 Introduction

Maturity transformation is at the core of banks' business models and it is well investigated in the academic literature (Diamond, 1984; Diamond and Dybvig, 1983; Flannery, 1981; Kaufman, 1984). Banks' engagement in maturity transformation, by borrowing "short" and lending "long", allows them to earn the spread between the interest rates charged on longer-term assets and the interest rate paid on shorter-term liabilities. At the same time, though, this intrinsic feature of their business model exposes them to interest rate risk. Indeed, rapid and unexpected changes in interest rates can adversely impact banks' net worth due to changes in the present value and timing of future cash flows.[1] Conventional wisdom holds that, on aggregate, increases in interest rates lead to a decline in banks' net worth as the value of assets declines more than the value of liabilities, with *ceteris paribus* potentially negative repercussions in the medium to long term for bank earnings, capital accumulation and, therefore, for their propensity to grant credit (Van den Heuvel, 2012). Overall, banks' exposure to interest rate risk changes over time. Its level and evolution vary depending on a combination of multiple factors, including the structure of banks' balance sheets, specific bank business models, and macro-financial developments.

In this paper, we first provide descriptive evidence that the *low for long* interest rate environment that characterised the euro area economy in the aftermath of the global financial crisis (GFC) resulted in a build-up of interest rate risk by banks. While there is evidence that low interest rates had positive effects on economic activity (Gambacorta et al., 2014; Ulate, 2021), improved consumers' demand, reduced borrowing cost for firms, and increased investments (Bottero et al., 2022; Joyce et al., 2012), a large literature argues that low interest rates created incentives for banks to *search for yield* by moving away from lower-yield shorter-term liquid assets to

[1] Fluctuations in interest rates can also impact banks' profitability by changing interest-sensitive income and expenses. On aggregate banks' profitability is expected to benefit from an increase in interest rates.

higher-yield longer-term less liquid assets (Borio and Zhu, 2012; Dell'Ariccia and Marquez, 2013; Rajan, 2006), taking on more duration risk (Hanson and Stein, 2015). We show that, during the low interest rate environment, although banks extended the maturity of their asset side, interest rate risk remained mostly muted because of the large inflow of overnight deposits which behaviourally are assumed to have a longer duration.[2] However, interest rate risk began to materialise in July 2022 when the European Central Bank (ECB) started to ramp up interest rates which induced deposits to flow away from stickier overnight towards more rate-sensitive term deposits. Leveraging on the concept of *duration* pioneered by Macaulay (1936), we measure interest rate risk using the *duration gap*, which is defined as the difference between the duration of banks' assets and liabilities.[3] Proper measurement for banks' duration gap necessitates detailed data about the maturity structure and repricing terms of all bank balance sheet items. In addition, it requires accounting for the use of derivatives for interest rate risk hedging purposes (Purnanandam, 2007). To this aim, we rely on granular confidential cash flow data provided by banks to the ECB for supervisory purposes for all on and off-balance assets and liabilities, which allows us to measure banks' duration gap *net of hedging*.

We then proceed by empirically investigating the effect of interest rate risk on the transmission of monetary policy to bank lending supply during the steepest series of interest rate increases in decades. The rapid exit from a low interest rate environment offers an ideal empirical setting to understand how interest rate risk affects bank lending supply in a higher interest rate environment. Although the increase in interest rates was to some extent expected by banks as it responded to a spike in inflation connected to exogenous shocks (Gagliardone and Gertler, 2023), the pace and the magnitude of the increases were largely unexpected. Indeed, results from the

[2] As per Regulation ECB/2013/33, overnight deposits are deposits convertible into currency and/or transferable on demand by cheque, banker's order, debit entry or similar means, without significant delay, restriction or penalty.

[3] See Section 3.1 for more details. The concept of duration has also been used by the Bank for International Settlements (BIS) for guidance on interest rate risk in the banking book.

publicly available ECB Survey of Monetary Analysts (SMA)[4] show that market participants' expectations about the ECB monetary policy stance before the July 2022 ECB Governing Council meeting were largely downward-biased relative to the effective realised rate, limiting anticipation effects by banks to adjust their duration gap (Figure 1).

Interest rate risk can affect the transmission of monetary policy to bank lending in several ways. Drechsler et al. (2017) show that interest rate hikes trigger an outflow of deposits causing a contraction in lending as banks cannot replace cheaper deposits with more expensive wholesale funding. *Ceteris paribus*, overnight deposit outflows shorten the duration of liabilities, therefore widening the duration gap. In principle, this may appear contradictory as overnight deposits are floating rate liabilities which contractually have zero duration. However, this happens in practice because banks employ internal models to estimate the duration of overnight deposits based on historical customers' behaviours (BCBS, 2016; Hoffmann et al., 2018). During the low and negative interest rate environment banks modelled these overnight deposits to be very sticky reflecting the impact that the economic environment had on customers' behaviour which further increased their assumed duration. However, if the behavioural assumptions on the duration of these deposits are not timely modified in a rising interest rate environment, there could be an underestimation of interest rate risk.

Since banks generally tend to have a stable duration gap over time (Drechsler et al., 2021) and match the duration of assets and liabilities (Kirti, 2020) to lock in long-term profits with stable funding, a reduction of the liability leg of the duration gap may prompt banks to reduce lending. Greenwald et al. (2023) stress the importance of the implications of dynamic deposit betas for bank lending, indicating that rising interest rates quickly leave banks holding more net duration

[4] The SMA collects information on market participants' expectations about the future evolution of key monetary policy parameters, financial market variables, and the economy around the time of the Governing Council meetings. https://www.ecb.europa.eu/stats/ecb_surveys/sma/html/index.en.html.

which impairs bank lending supply.

Interest rate risk can also affect bank lending supply due to the long-term impact on bank profits and, consequently, on capital accumulation. English et al. (2018) show that a rise in interest rates has a positive but short-lived effect on bank margins, with the effect becoming negative after one year. Compressed margins may erode bank capital bases via a reduction in retained earnings impairing bank lending capabilities. As per English et al. (2018), the decline in bank margins following a parallel upward shift in the yield curve is determined by the shift from inexpensive core (or overnight) deposits to more expensive non-core (or term) deposits. Since banks model overnight deposits to be stickier more sticky than term deposits, this shift widens the duration gap.

Additionally, we inspect whether interest rate risk encourages credit portfolio re-allocations. During a monetary policy hiking cycle, banks with higher duration gap may reshuffle their lending portfolio away from longer-term towards shorter-term lending to reduce their duration gap.[5] Paligorova and Santos (2017) find that banks with a shorter maturity of liabilities (wholesale-funded banks) shorten both the maturity of newly issued loans and the maturity of their loan portfolios relative to banks with longer liability duration (deposit-based banks). Shortening loans' maturity has several implications for firms. First, it exposes firms to refinancing risk (Harford et al., 2014), which may impair firms' decisions about long-term projects, leading to sub-optimal investment strategies (Almeida et al., 2012). Second, if firms are forced to substitute long-term bank funding with bond issuance in a higher interest rate environment, this can lead to greater interest expenses for firms, forgoing the unique benefits of bank loans.

To estimate the impact of interest rate risk on the transmission of monetary policy to bank

[5]It is possible that banks not only reshuffle their lending portfolio, but also use the other instruments on the asset side to reduce their duration gap. This is, however, out of the scope of the current research project.

lending supply in a rising interest rate environment, we employ bank-firm level panel regressions from the first quarter of 2021 to the second quarter of 2023. Several empirical challenges must be overcome to answer our research questions. The first challenge arises from the possibility of a non-random matching between lenders and borrowers. If banks with a higher duration gap systematically lend more to borrowers whose credit demand is less sensitive to changes in interest rates, then the decline in borrowing from banks with a higher duration gap could be merely driven by a lower demand for credit. We address this endogeneity concern by exploiting multiple bank relationships and borrower-time fixed effects as in Khwaja and Mian (2008), as well as single bank relationships and industry-location-size (ILS) fixed effects estimators, in line with the approach used by Acharya et al. (2019), Degryse et al. (2019) and Berg et al. (2021). A second source of endogeneity comes from the possibility that a firm borrowing from multiple banks may have outstanding credit at a floating rate with one bank while at fixed rate with another bank. This confounding effect could be potentially correlated with the duration gap, leading to biased estimates. Indeed, a loan interest rate type (whether floating or fixed) affects banks' duration gap in opposite direction. Therefore, banks with larger duration gap may increase lending to firms borrowing at a floating rate while crowding out fixed-rate borrowers. To address this issue, we augment the approach of Khwaja and Mian (2008) by including *firm-time-interest rate type* fixed effects in the estimations, thus effectively comparing how loan supply responds to changes in the policy rate for two banks with a different duration gap lending with the same interest rate type to the same firm. Third, we need to account for the positive short-term effect of higher interest rates on bank earnings and, consequently, on lending. As aforementioned, an increase in the policy rate bolsters bank margins in the short-term with the effect phasing out over a one year horizon (English et al., 2018). In this respect, Gomez et al. (2021) find that banks with a higher *income gap* - calculated as the difference between the amount of assets and liabilities that reprice or mature within a year - generate stronger earnings and contract their lending by less than other banks when the Fed Funds rate rises. The duration gap and the income gap are two different concepts as they capture the two different dimensions of banks' exposure to interest rate risk and they are not necessarily correlated. The former gauges the sensitivity of banks' economic value of equity to changes in interest rates while the latter is a metric of the sensitivity of bank's net interest income to changes in interest rates. However, to control for the possibility that the effect on lending is driven by the income gap rather than the duration gap, we control for heterogeneity in the income gap across banks in the econometric specification. Finally, although lending growth as such does not directly impact the duration gap as it is the change in duration of loans that matters, we take multiple steps to limit any reverse causality concerns. In our baseline regressions, we use the duration gap lagged by one quarter. Moreover, as robustness checks, we fix the duration gap at its value before the start of the monetary policy hiking cycle and we collapse our dataset into a pre- and post-tightening period in the spirit of Bertrand et al. (2004) to assess the impact of the pre-monetary policy tightening duration gap on the change in lending pre- and post-monetary policy tightening.

To preview our main results, we find that when interest rates increase by 100 basis points (bps), a bank at the 75^{th} percentile of the duration gap distribution reduces lending by 91-94 bps more than a bank at the 25^{th} percentile. A higher duration gap results also in a lower probability of expanding credit volumes to firms with existing lending relationships (around 5-6 percentage points (p.p.) lower for each p.p. increase in the duration gap). Moreover, we document a *reshuffling* of banks' loan portfolios away from loans with longer duration and fixed rates, with the effect being mostly insignificant for short-term credit and floating rate loans. Next, we find that banks with a larger duration gap contract lending to micro, small, and medium enterprises

(MSMEs), while the effect is not statistically significant for large corporations. Finally, our results show that firms that are exposed to banks with a large duration gap face a reduction in their total borrowing, signalling that these firms cannot (fully) substitute their borrowing to banks with a smaller duration gap.

These findings have important implications for both monetary policy transmission and financial stability. From a monetary policy perspective, our results show that the transmission of monetary policy is heterogeneous across euro area banks, with a stronger effect for banks with a large duration gap. Our paper here is closely linked to the literature on the bank lending channel (Bernanke and Blinder, 1988; Bernanke and Gertler, 1995). Empirical work has extensively focused on the bank-specific characteristics that amplify or weaken the transmission of monetary policy to the real economy. Banks that are: better capitalised (Gambacorta and Shin, 2018; Jiménez et al., 2017; Kishan and Opiela, 2000), larger (Campello, 2002; Cetorelli and Goldberg, 2012; Kashyap and Stein, 1995), and less liquidity constrained (Jiménez et al., 2012; Kashyap and Stein, 2000) are better able to shield their lending supply from monetary policy shocks. To the best of our knowledge, there are only two recent contributions (Beutler et al. (2020) and Gomez et al. (2021)) that investigate whether the transmission of monetary policy depends on the heterogeneity of banks' exposure to interest rate. Beutler et al. (2020) document a stronger lending contraction by banks with higher interest rate risk exposure - accounted from an economic value of equity perspective - when the nominal interest rate increase, while Gomez et al. (2021) find that, when the Fed Funds rate rises, banks that generate stronger earnings contract lending by less. However, Beutler et al. (2020) employ aggregate bank-level data and therefore fail to control for the endogenous matching of banks and borrowers. Compared to this work, we have access to rich micro-level data that allows to control for demand effects and other confounding factors. In addition, we also add to the findings of Gomez et al. (2021), which use a different metric of interest rate exposure (the income gap). In our empirical setting, by controlling for the income gap, we can shed light on whether a decline in banks' economic capital determined by movements in interest rates affect bank lending behaviour.

Our paper is also close to the literature on the bank deposit channel (Drechsler et al., 2017; Drechsler et al., 2021). In particular, Drechsler et al. (2017) find that banks react to an outflow of deposits by curtailing lending, with a stronger effect for banks enjoying more market power on deposits. We add to this literature by documenting the role of banks' duration gap for bank lending supply in a fast-growing interest rate environment. Contrarily to focusing only on the deposit betas or on their stickiness, the duration gap allows us to capture the cash-flows across the whole maturity/repricing structure of the balance sheet (for both assets and liabilities), including information on interest rate hedging derivatives. In addition, we match data on the duration gap with *AnaCredit*, the pan-European credit register that stores detailed data on the universe of bank loans to non-financial corporations which allows to identify the borrowers affected by the credit contraction and possible substitution effects across banks. The latter point is also important from a financial stability perspective, as a reduction in the availability of (longer-term) credit could be detrimental for financial stability during an economic recovery.

The remainder of the paper is structured as follows. Section 2 presents stylised facts on the evolution of interest rate risk for euro area banks during and after the low interest rate environment. Section 3 describes the data used in our analysis, while section 4 outlines the empirical setting and discusses the results at the bank-firm level. In section 5, we evaluate the effects on total borrowing at the firm level. The results of the robustness checks to our baseline are shown in section 6, while the last section concludes (section 7).

2 Interest rate risk and low interest rates: Some stylised facts

In this section, we provide descriptive evidence about banks' build-up of interest rate risk in the banking book during the prolonged period of low interest rates. Banks had an incentive to earn a higher term premium associated with longer maturities in order to partially offset margin compression and the related drop in profitability. In addition, customers preferred to borrow at fixed rates with a view of locking in very convenient low rates for a longer period. Since the peak of the GFC, the share of outstanding volumes of loans to households and non-financial corporations with a maturity above 5 years increased by 10 p.p., pushed by a 20 p.p. surge in the share of new business volume of loans to households and non-financial corporations with a maturity above 10 years (Figure 2a). Despite the shorter time frame, Figure 2b shows that the duration of fixed rate loans almost doubled in the 5 years preceding the monetary policy tightening.[6] Interest rate risk in the low interest rate environment remained mostly silent due to the inflow of sticky overnight deposits that increased by almost 30 p.p. since 2008 (Figure 3a), driven by a combination of unconventional monetary policies, regulations, and customers' preferences to hold liquidity when interest rates are low. With these unconditional correlations we don't claim causality as the relationship between the extended duration of fixed rate loans and deposits could be, *de facto*, endogenous: an increase in the duration of deposits could also incentivise banks to increase the duration on the asset side of the balance sheet.

However, interest rate risk became evident since the central bank started to ramp up interest rates in July 2022. Higher interest rates altered the stickiness of overnight deposits, triggering a shift from overnight to term and redeemable at notice deposits (Figure 3a). The pace and magnitude of the interest rate rise coupled with this rapid shift was largely unexpected by banks.

[6] The short period covered by Figure 2b is owed to data availability constraints.

This is visible from Figure 3b, where banks in their modelling assumptions about the duration of deposits the quarter prior to the monetary policy tightening assumed a higher duration of overnight deposits relative to term and redeemable at notice deposits. Moreover, Figure 3c shows that banks assumed overnight deposits to reprice within a very similar (even slightly longer) time period in 2022Q2 compared to 2019Q2.[7] This suggests that, despite expectations of a monetary policy tightening, banks assumed deposits to have a relatively long duration, in line with the period of low interest rates. In this environment, the opportunity cost to hold higher yielding deposits or to withdraw deposits was low and overnight deposits tended to be very sticky, leading to an overestimation of the duration of deposits and, consequently, to an underestimation of interest rate risk in a fast growing interest rate environment.

This rapid shift from overnight to term deposits occurring since July 2022 reduced the duration of liabilities (Greenwald et al., 2023) and lead to a widening of the duration gap (Figure 4). In this paper, we test whether banks reacted to the widening of the duration gap by modifying their lending behaviour to non-financial corporations. A first look at the latest data point in Figure 4, which shows a contraction in the duration gap, appears to confirm a fast reaction by banks on the asset side. This will be the focus of our empirical investigation.

3 Data and descriptive statistics

3.1 Measuring interest rate risk in the banking book

In this paper, we consider interest rate risk from an *economic value perspective*. More specifically, we consider the impact of changes in interest rates on the economic value of banks' equity. To do this, we leverage on the concept of duration originally introduced by Macaulay (1936) and

[7] Due to data availability limitations, we do not have information on average repricing times of overnight deposits before 2019Q2.

use the duration gap as a metric for interest rate risk. The duration gap captures net duration, i.e., the mismatch between the repricing schedule of cash inflows (assets) and cash outflows (liabilities) of on- and off-balance sheet items. By exploiting granular confidential quarterly cash flow data on significant institutions collected by the ECB for supervisory purposes, we compute the duration gap as follows:[8]

$$DurationGap = \sum_{j=1}^{14} \frac{DUR_j}{1+i} \left(\frac{A^j - L^j}{Z} \right) \quad (1)$$

The reported cash-flows are ordered across 14 time bands (j) according to their remaining time to maturity or their repricing schedule. We obtain *net cash-flows* as on-balance sheet and off-balance sheet asset cash flows, less on-balance sheet and off-balance sheet liability cash flows ($A^j - L^j$). We scale the net cash-flows by total assets (Z) to make them comparable across the banks in our sample. On the asset side, cash flows are available for debt securities, loans and advances, derivatives, and other assets, while on the liability side they are available for debt securities, non-maturity deposits, deposits other than non-maturity, derivatives, and other liabilities. Off-balance sheet items comprise contingent assets and liabilities. Overall, the cash flows of all interest rate sensitive items in the banking book are included in the computation.

Each net cash-flow is weighted by their modified duration ($\frac{DUR}{1+i}$).[9] As such, the duration gap captures the difference between the time to receive the cash-flows coming from assets and liabilities, where cash-flows are weighted by their present value. A positive duration gap signals a loss in the economic value of equity when interest rates increase as assets have a longer duration

[8]Similar measures have also been used by Esposito et al. (2015), Hoffmann et al. (2018), and Beutler et al. (2020).

[9]The modified duration reflects the percentage change in the economic value of the instrument for a given percentage change in $1 + i$ (BCBS, 2016). It assumes a linear relationship between percentage changes in value and percentage changes in interest rates, which is assumed to be equal for all on- and off-balance sheet items.

than liabilities, indicating that the value of assets is more sensitive to changes in interest rates than the value of liabilities.

In contrast to the income gap, which captures the difference between cash-flows stemming from assets and liabilities maturing/repricing within 1 year and therefore measures the sensitivity of banks' net interest income to changes in interest rates in the short run,[10] the duration gap gives an indication of the impact of changes in interest rates on banks' economic value of equity in the short run and on bank profitability in the medium to long run.

Importantly, to calculate the income and duration gap, we use cash-flows reported by banks that account for behavioural assumptions. This is relevant for the calculation of banks' effective exposure to interest rate risk, in particular for mortgages and overnight deposits as their contractual repricing does not account for loan prepayments and the fact that overnight deposits typically stay longer on the balance sheet. Accordingly, under behavioural assumptions, mortgages (overnight deposits) tend to have a shorter (longer) duration than under contractual assumptions (BCBS, 2016; Hoffmann et al., 2018). Another important feature of these data is that they include information on banks' derivative positions, which allows us to measure the duration mismatch of banks *net of hedging* and thus controlling for hedging positions against interest rate risk exposure.

3.2 Bank-firm and bank-level data

Our analysis relies on data collected from multiple confidential sources. We use loan-level data from *AnaCredit*, the credit register the European System of Central Banks which contains information on all individual bank loans to firms above €25,000 in the euro area. We aggregate the

[10]We refer to the data appendix for a detailed explanation of the computation of the income gap.

loan-level data at the bank-firm level across different credit instrument types.[11] *AnaCredit* contains information on multiple loan characteristics such as outstanding loans volume, interest rate (type), maturity, impairments amount, and probability of default. For the majority of instrument types, we capture credit supply by looking at the outstanding loan amounts. However, as credit supply through credit lines is determined by the commitment amount at initiation of the contract, we use the commitment amount rather than the outstanding amounts for credit lines. In addition, *AnaCredit* includes information on the borrowing firms (size, location, industry) and the lending banks (location, structure).

We complement the bank-firm level data with bank-level balance sheet data from the ECB Supervisory Statistics and bank-level data on the duration and income gap as illustrated in the previous section. Our final matched sample includes quarterly data from 2021Q1 to 2023Q2 and covers 73 significant institutions across 18 euro area countries. This time frame allows us to focus on the monetary policy tightening period, limiting the impact of confounding factors such as fiscal and monetary policy measures that affected bank lending during the COVID-19 period. Figure 5 visualises the country coverage in terms of number of banks included in the sample.[12]

Table 1 shows the descriptive statistics for the variables used in the baseline regressions. All variables are winsorised at the 1% level.[13] It is worth noting that the bank-firm lending growth was negative on average across the sample period. With respect to the duration gap scaled by total assets (hereafter: duration gap), the average bank in our sample has a positive duration gap, although a considerable share of banks has a negative duration gap. More specifically, a

[11] In *Anacredit*, credit instruments are categorised into revolving credit other than overdrafts and credit card debt, credit lines other than revolving credit, term loans, overdrafts, credit card debt, trade receivables, and finance leases. For items such as maturity, interest rate (type), and probability of default, the aggregation from loan-level to bank-firm level is done using a weighted average principle.

[12] For more figures on the coverage of *AnaCredit* for our sample, we refer to Figure 9 in the online appendix.

[13] Our results are robust to winsorising the data at 2.5% and 5%.

bank at the 25^{th} percentile of the distribution has a duration gap scaled by total assets of -11.3% while this is 19.8% for a bank at the 75^{th} percentile of the distribution. At first glance, it might seem counter-intuitive that banks show a negative duration gap, since in normal times they typically invest in long-term assets, funded by short-term liabilities. Although the asset and liability items entering in the computation of the duration gap cannot be further decomposed, we provide an intuitive explanation for the share of banks having a negative duration gap. The prolonged period of low interest rates in combination with unconventional monetary policy has altered the duration of the balance sheet for some banks. As aforementioned, many banks model deposits to be very sticky based on customer behaviour in the low-for-long period, increasing the duration of the liability side. Moreover, banks that participated in the TLTRO programs, which had a maturity of 3/4 years, have seen an increase in the duration of the liability side as well. Following central bank asset purchase programs in light of quantitative easing, banks have been holding central bank reserves with very short maturities. Banks with abundant central bank liquidity experienced a shortening of the duration on the asset side of the balance sheet. In combination, this means that around a third of the banks in our sample, which are often also characterised by a large share of floating rate loans, exhibits a negative duration gap.

The summary statistics for the other bank-specific characteristics are in line with previous literature using euro area credit registry data (Couaillier et al., 2023; Dautović et al., 2023). As shown in Table 2, the duration gap at the bank-level is not significantly correlated to any of our control variables.[14]

[14] In the online appendix, we show that the income gap is significantly correlated with multiple bank-specific characteristics (Table 13) which strengthens the argument to use the duration gap as a measure of interest rate risk in the econometric analysis. Moreover, in the online appendix we show that our results are robust to a covariate-balancing approach using propensity scores.

4 Bank-firm level analysis

To shed light on bank lending behaviour in response to the monetary policy tightening, we start by examining whether banks with a different duration gap after accounting for hedging adjust their balance sheet following a 100 bps increase in the policy rate. We do this by estimating the following equation:

$$\begin{aligned}\Delta log(loans)_{c,b,f,t} = \gamma DurationGap_{c,b,t-1} + \beta\left(DurationGap_{c,b,t-1} * \Delta PolicyRate_t\right) \\ + \kappa \tilde{X}_{c,b,t-1} + \lambda\left(\tilde{X}_{c,b,t-1} * \Delta PolicyRate_t\right) + \eta_{f,t,i} + [\alpha_{c,t}] + \epsilon_{b,f,t}\end{aligned} \tag{2}$$

where $\Delta log(loans)_{c,b,f,t}$ represents lending growth from bank b in country c to firm f at time t. β is our coefficient of interest, as it captures whether the effect of a change in the policy rate on bank lending supply depends on banks' duration gap. We employ the bank-firm-level data to disentangle credit supply from credit demand. Specifically, we follow the approach of Khwaja and Mian (2008) and exploit firms with multiple bank relationships to control for firm credit demand effects by including firm-time fixed effects. Additionally, we interact the firm-time level fixed effects with interest rate type (i.e., fixed, floating, or mixed rate loans) fixed effects ($\eta_{f,t,i}$). In other words, we compare how much credit with the same interest rate type a given firm received from multiple banks with a different duration gap. In some specifications, we additionally include country-time fixed effects ($\alpha_{c,t}$) to control for the business cycle and/or country-specific regulations that could be correlated with the duration gap, potentially affecting bank lending. The inclusion of time fixed effects makes that any time-variant factor which is common to all bank-firm relationships, such as changes in the monetary policy rate, will be captured by these fixed effects.

We control for multiple lagged bank-level characteristics ($\tilde{X}_{c,b,t-1}$) which also affect bank-firm lending. More specifically, we include (the log of) total assets to control for bank size. To measure the credit quality of the banks' loan portfolio, we use the non-performing loans (NPL) ratio. The return on assets (ROA) and the income gap control for bank profitability, while the ratio of cash (incl. cash held at central banks) captures bank liquidity and proxies the take up of TLTROs. The ratio of debt securities to total assets accounts for differences in bank funding structures and reliance on market funding. The CET1 distance to the maximum distributable amount (MDA) is a measure of voluntary capital held by banks above their capital requirements which controls for bank solvency and capitalisation. Importantly, we also allow for these control variables to have a heterogeneous impact on lending following the monetary policy tightening by interacting them with the change in the policy rate ($\tilde{X}_{c,b,t-1} * \Delta PolicyRate_t$), as in Gomez et al. (2021). Together with the results in Table 2, this ensures that our coefficient of interest is not driven by the heterogeneous impact of other bank-specific characteristics on lending.

Although a change in lending as such does not necessarily impact the duration gap, as it is a change in duration of loans that matters, we use the lagged duration gap in our baseline estimations and check the robustness of our effects by using a pre-post event averaging approach and taking the independent variables in the pre-tightening period (Bertrand et al., 2004) as well as using the pre-determined duration gap as a robustness check to limit reverse causality concerns. In the same spirit, all bank-specific control variables are lagged by one quarter. All standard errors are two-way clustered at the bank and firm level.[15]

4.1 Empirical results

Table 3 shows the results for our baseline estimations. Columns (1) and (3) show the results without including the bank-level control variables. Column (1) includes the firm-time-interest

[15] In the online appendix, we report the results when clustereing the standard errors only at the bank level.

rate type fixed effects, while column (3) additionally includes country-time fixed effects. Columns (2) and (4) similarly show the results when including the bank-level control variables. Because of the inclusion of firm-time fixed effects, our sample includes only firms with multiple bank relationships. The baseline estimations include between 66 and 69 banks and around 170,000 firms.

We first start by looking at lending growth at the bank-firm level, i.e., the intensive margin. The coefficient of the interaction of the (lagged) duration gap and the change in the policy rate is negative and statistically significant at the 1% and 5% level depending on the econometric specification. This suggests that, when interest rates increase by 100 bps, banks with a 1 p.p. larger duration gap reduce the bank-firm lending supply by about 2.8-2.9 bps more on a quarter-on-quarter basis compared to banks with a smaller duration gap.[16] When comparing the effects for specific banks, the results show that if interest rates increase by 100 bps, a bank at the 75^{th} percentile of the duration gap distribution reduces lending by 91-94 bps more than a bank at the 25^{th} percentile. This effect is economically meaningful considering an overall quarter-on-quarter lending contraction post tightening of about 3.4%.

Next, we turn our attention to the probability to issue new loans.[17] In the spirit of De Jonghe et al. (2019), we replace our endogenous variable in equation (2) with a dummy variable taking the value of 1 when the credit volume in lending relationships increases between *t-1* and *t* and perform a linear probability model estimation. The model is saturated with the same combination of fixed effects employed in equation (2). Columns (1) to (4) in Table 4 show the differential effects of the duration gap following a change in the policy rate on the probability of issuing a new loan. We find that for banks with a larger duration gap, the probability that

[16]This effect is comparable to the bank-level findings of Beutler et al. (2020), who find a cumulative reduction of loan growth of 7 bps after one year for a bank with a 1 p.p. larger duration gap.

[17]In the online appendix B.3, we also look at the probability of starting a new bank-firm relationship, i.e., the extensive margin.

banks expand credit volumes to firms in existing lending relationships decreases when interest rates increase, with the effect being around 5-6 p.p. for each p.p. increase in the duration gap.

We propose several reasons to explain why a larger exposure to interest rate risk leads to a stronger lending contraction in a rising interest rate environment. First, since banks tend to match their asset and liability duration to minimise their exposure to interest rate risk, an unexpected and rapid shortening of the duration of liabilities, as experienced since July 2022, forces banks to adjust the duration of their asset side via an immediate and stronger lending contraction. This is particularly visible for loans with a longer maturity as also confirmed by the results of Table 5 and 6 (see infra). Second, if banks do not immediately react to reduce the widening of the duration gap, they will experience a decline in their economic value of equity and therefore expect lower earnings, profitability, and lower capital accumulation over the long term. Figure 6 shows that banks with a larger duration gap project a smaller increase in net interest income over the medium run (1 year horizon) following an increase in interest rates, confirming that the positive impact of increasing interest rates on bank margins phases out over time (English et al., 2018), especially for banks with a larger duration gap. Since banks' retained earnings are an important determinant of banks' capital and banks have to remain in compliance with their capital requirements, banks will respond by deleveraging (Jiménez et al., 2012). Third, banks want to avoid an excessive duration gap and thus an excessive exposure to interest rate risk as this may trigger supervisory scrutiny. Indeed, the change in the economic value of equity conditional on changes in interest rates is one of the metrics considered in the Supervisory Review and Evaluation Process (SREP), a supervisory assessment of banks' risk profile.[18] A wide duration gap may encourage supervisors to ask for additional capital surcharges

[18] More information on the supervisory process can be found here: https://www.bis.org/basel_framework/chapter/SRP/31.htm.

to cover interest rate risk, in the form of Pillar 2 requirements and Pillar 2 guidance.

To determine the *net impact* of the control variables based on the results reported in Table 3, we have to consider both the coefficient on the control variable itself as well as the coefficient of the interaction of the control variable with the change in the policy rate. Therefore, we evaluate the effect of the control variable at a 400 bps increase in the policy rate, reflecting the actual change in the policy rate during our sample period.[19] In what follows, the coefficient interpretations relate to the net impact of the control variables. We find a positive and significant relationship between the CET1 distance to the MDA and bank lending growth. This is in line with the fact that additional capital headroom on top of capital requirements increases bank lending (Couaillier et al., 2023). Moreover, the positive and significant coefficient on the interaction of the distance to the MDA and the change in the policy rate is in line with related literature on the bank lending channel for banks with a different level of capitalisation (Gambacorta and Shin, 2018; Jiménez et al., 2017; Kishan and Opiela, 2000). A positive and statistically significant effect is also shown for banks with a larger income gap, confirming our prior expectations. In particular, the positive and significant sign of the interaction term of the (lagged) income gap and the change in the policy rate confirms that banks with a larger income gap increase lending more when interest rates increase compared to banks with a smaller income gap, driven by the boost in retained earnings and profitability (Gomez et al., 2021). Importantly, even when controlling for the positive impact from increasing interest rates in the short-run, as captured by the income gap, we still find a significant negative impact on bank lending when interest rates increase for banks that expect harmful effects of rising interest rates to their economic value in the medium to long run, as captured by the duration gap. A positive (negative) and

[19] More specifically, we look at the sign and significance of the sum of (1) the coefficient of the control variable and (2) the coefficient of the interaction term, multiplied by 400 bps.

statistically significant relationship is also displayed between the NPL (ROA) ratio and bank lending, which could signal higher risk-tolerance/risk-taking by these banks in a higher interest rate environment. Other control variables do not have a significant net impact on bank lending during our sample period. In the same spirit, one can look at the overall net effect of the duration gap in our sample, which is found to be negative and significant. This suggests that over the period of 2021Q1 to 2023Q2, banks with a larger exposure to interest rate risk have reduced their lending more compared to banks with a smaller exposure.

Previously in the paper, we hypothesise that the rapid and mostly customer-driven evolution of banks' liability side prompt banks to act on the asset side to counterbalance the widening of the duration gap by contracting lending supply to readjust their duration gap. If this hypothesis holds, we should observe a stronger lending contraction for loans with a longer duration. Indeed, in columns (5) to (8) of Table 5, we find that banks with a larger duration gap reduce long-term lending (defined as growth of loans with a maturity above 2 years) more strongly compared to banks with a smaller duration gap when interest rates increase. In terms of magnitude, the effect is twice as large compared to the baseline results (between -5.5 and -6.1 bps). On the other hand, the results for short-term lending (defined as growth of loans with a maturity equal to or below 2 years) are mainly positive but not significant (columns (1) to (4)).[20] Also on the probability of issuing a new loan, we find that for loans with a maturity above 2 years, the probability decreases for banks with larger duration gap (Table 6, columns (5) to (8)). Columns (1) to (4) show that the probability of issuing a new loan with a maturity below or equal to 2 years increases, although the coefficients are only marginally significant. These results support our hypothesis that banks with a large duration gap reshuffle their asset side by shifting from

[20] Our results are robust to using 1 or 3 years as a threshold to define short- vs long-term lending. We refer to the online appendix for the full tables (Tables 17 and 18).

long-term to short-term lending to reduce their exposure to interest rate risk.

Until now, because of the inclusion of interest rate type fixed effects, the results reflected a stronger decrease in lending when interest rates increase by banks with a larger duration gap for loans with the same interest rate type. However, banks with a larger duration gap might reduce especially fixed rate lending as opposed to floating rate lending to reduce their exposure to interest rate risk. Therefore, we estimate the effects on the intensive margin and on the probability of issuing a new loan *without* the inclusion of interest rate fixed effects. This allows us to add a triple interaction with an indicator for bank-firm relationships with purely fixed (base category) or floating rate loans to equation (2).[21] As can be seen from the interaction of the double interaction term *Duration gap/TA* $\times$ Δ*policy rate* in Table 7, banks with a larger duration gap significantly reduce their fixed rate lending when interest rates increase. We also find a lower probability of issuing a new loan at a fixed rate for banks with a larger duration gap when interest rates increase, although the results are only moderately significant when including the bank-level control variables. In contrast, the effect for floating rate loans, evaluated using an F-test on the joint significance of the coefficients of the double and triple interaction, is not significant in the majority of specifications. Table 7 shows that there is only weak evidence that banks with a larger duration gap also have a lower probability of issuing a loan with a floating rate when interest rates increase. These findings are in line with Greenwald et al. (2023), who show that acquiring fixed-rate assets brings the bank closer to their risk limit on net duration exposure, decreasing the marginal net income from lending, motivating banks to constrain lending.

To summarise, our results point towards a larger reduction in lending when interest rates increase

[21] We exclude bank-firm relationships with mixed rates from this analysis since there is no clear a priori assumption on the link between the duration gap and mixed rate loans. In section 6, we show that our baseline results are not sensitive to excluding mixed rate loans from the sample.

for banks that have a larger exposure to duration risk, showing that the transmission of monetary policy is reinforced for these types of banks and thus heterogeneous across euro area banks. It is therefore important for monetary policymakers to take this into account when deciding on (the pace of) monetary policy changes.

Our findings have important implications for financial stability in the euro area as well. On the one hand, an excessive lending supply contraction from high duration gap banks to firms urging funds to roll over liquidity and working capital needs may excessively exacerbate the downturn. Moreover, a reduction in the availability of longer-term credit for firms' capital investments could be detrimental during an economic recovery (Black and Rosen, 2016). In principle, this situation could be avoided if firms demand more credit to banks benefiting from higher interest rates. In practice, however, firms exposed to high duration gap banks may struggle to replace existing sources of financing with alternative ones or to establish new credit relationships during turbulent times. In the next sections we therefore dive deeper into: a) the types of firms that are more affected by lending contractions by banks more exposed to interest rate risk (section 4.2) and; b) possible firms credit substitution effects from banks with higher interest rate risk to banks less exposed to interest rate risk (section 5).

4.2 Which borrowers are most affected?

While from a monetary policy perspective a reduction in bank lending supply is warranted and a by-product of higher interest rates, from a financial stability perspective it is important to ensure that, during interest rate hikes, the lending supply contraction is not targeted only to MSMEs (Gertler and Gilchrist, 1994). Contrarily to large corporations, MSMEs do not rely on market-based funding as a substitute to bank credit (Becker and Ivashina, 2014; Becker and Ivashina, 2018). In addition, MSMEs are subject to greater lender discretion facing a disadvantage to large firms when requesting credit from banks (Chodorow-Reich et al., 2022). Therefore, in this section, we look at whether the contraction in lending supply from banks with a higher duration gap is targeted to MSMEs or heterogeneous across firms with different size (i.e., micro, small, medium, and large firms as defined in *AnaCredit*).[22] For this exercise, we augment our baseline regression by triple interacting the (lagged) duration gap with the change in the policy rate and an indicator of the size of the firm, where the base category is represented by large firms.

Table 8 summarises the results. We find that banks with a higher exposure to interest rate risk reduce their lending more to *MSMEs* compared to *large* firms when interest rates increase. In fact, the coefficient of the double interaction term *Duration gap/TA* $\times$ Δ*policy rate* is negative but not statistically significant, indicating that banks with a larger duration gap do not significantly reduce lending to large firms when interest rates increase. Although the coefficients for medium-sized firms are negative, the statistical significance is, in 3 out of 4 specifications, only marginally significant (10% level) suggesting that the negative effect is largely driven by small and micro firms. In particular, large and strongly statistically significant effects are found for small firms. For micro-sized firms, the magnitude of the effects are smaller in size but still statistically significant at the 5% level. When comparing two types of banks, we find that a bank at the 75^{th} percentile of the duration gap distribution significantly reduces lending to small firms by 90-97 bps when interest rates increase, while this is between 40-56 bps for micro- and medium-sized firms.

[22] *AnaCredit* follows the EU Commission standard classification for MSMEs (https://single-market-economy.ec.europa.eu/smes/sme-definition_en). In accordance with this definition, we use the following dummy variables to classify enterprise size: 'Micro' is a dummy variable that is equal to 1 for enterprises that employ less than 10 employees and whose annual turnover and/or annual balance sheet total does not exceed EUR 2 million, and 0 otherwise. 'Small' is a dummy variable that takes the value 1 for enterprises that employ less than 50 employees and have an annual turnover and/or annual balance sheet total that does not exceed EUR 10 million, and 0 otherwise. 'Medium' is a dummy variable that takes the value of 1 for enterprises that employ less than 250 but more than 50 employees, have an annual turnover not exceeding EUR 50 million and/or an annual balance sheet total not exceeding EUR 43 million, and 0 otherwise.

5 Firm-level analysis

In this section, we investigate whether duration risk results in lower borrowing at the firm level. In theory, firms could replace the additional contraction in credit from banks with a higher duration gap by borrowing more from banks with a lower duration gap. In practice, however, firms' borrowing substitution could be impaired as a tightening of monetary policy potentially entails lower economic growth and higher probabilities of default. Therefore, banks with a lower duration gap may be less willing to pick up the slack in a higher interest rate environment. Contrarily, if banks with a lower duration gap are able/willing to cover the additional credit contraction coming from banks with higher duration gap, we should observe a redistribution of market shares across banks. To delve into this empirical question, we adopt the following firm-level econometric identification strategy:

$$\begin{aligned}\Delta log(borrowing)_{f,t} = \gamma HighExposure_{f,t} + \beta\left(HighExposure_{f,t} * \Delta PolicyRate_t\right) \\ + \kappa \tilde{X}_{b,t-1} + \lambda\left(\tilde{X}_{f,t-1} * \Delta PolicyRate_t\right) + \eta_{ILS,t,i} + \epsilon_{f,t}\end{aligned} \tag{3}$$

where $\Delta log(borrowing)_{f,t}$ represents the change in borrowing of firm f at time t. The dummy $HighExposure_{f,t}$ takes the value of 1 when a firm borrows for more than 50% from a bank with a high exposure to duration risk. A bank is considered to have a high exposure to duration risk when it is in the top quartile of the distribution in the first time period of our sample (2021Q1).[23] The regressions include the same bank-level characteristics as in equation (2), using the bank-firm-quarter level exposures to compute the weighted average at firm-quarter level ($\tilde{X}_{c,f,t-1}$). To control for credit demand, we make use of ILS-time-interest rate type fixed effects, since the use of firm-time fixed effects is not possible on firm-time level data. Standard errors are clustered at the firm level.

[23] Our results are robust to using different thresholds to define highly exposed firms and banks.

The results are shown in Table 9. Following a 100 bps increase in interest rates, firms exposed to banks with higher duration gap exhibit about 75 bps lower borrowing in relative terms. When considering the cumulative interest rate increase since the start of the tightening (400 bps), we find a 3 p.p. lower borrowing from firms exposed to banks with a higher duration gap, relative to firms exposed to banks with a lower duration gap. These findings confirm that firms cannot easily substitute loans from their main lender, i.e., the bank with a high duration gap, with other sources of financing during stressed times (Iyer et al., 2014; Khwaja and Mian, 2008).

6 Robustness checks

6.1 Sample selection biases and bank-firm specific demand

Throughout the paper, we control for the heterogeneity in credit demand across firms by exploiting firms with multiple bank relationship and firm-time-interest rate type fixed effects, augmenting the approach of Khwaja and Mian (2008). However, one limitation of the Khwaja and Mian (2008) approach is the exclusion of single bank relationships that are absorbed by firm-time fixed effects. Since firms with single bank relationships represent a substantial share of the overall bank-firm relationships in some euro area countries (Figure 7), we follow the approach used by Acharya et al. (2019), Degryse et al. (2019), and Berg et al. (2021), and extend the baseline estimation to also account for firms with a single bank relationship. Specifically, we replace the firm-time-interest rate type fixed effects in equation (2) with ILS-time-interest rate type fixed effects.[24]

Columns (1) to (4) in Table 10 show the results for the estimations when including both firms with multiple and single bank relationships. The results show that the negative effects on

[24]The industry classification is based on the NACE4 codes, while the locations are categorised at the NUTS3 level. The size classification includes micro, small, medium, and large firms, as in section 4.2.

lending supply since the monetary tightening coming from banks with a larger duration gap are stronger when including firms with single bank relationships compared to the results when only considering firms with multiple bank-firm relationships. More specifically, we find a contraction of lending by 105-112 bps when interest rates increase for a bank with a duration gap at the 75^{th} percentile compared to a bank at the 25^{th} percentile, while this was around 91-94 bps in the baseline sample. This is most likely driven by the fact that firms with a single bank relationship cannot easily find alternative funding sources, impairing their ability to invest.

In column (5) to (8) of Table 10, we exclude firms borrowing from multiple banks and *only* look at firms with a single bank relationship. This test aims at further controlling for the heterogeneity in credit demand. Indeed, during a downturn, firms with multiple bank relationships may decide, within the pool of lenders, to borrow from banks less exposed to interest rate risk. If this is the case, the contraction in lending from banks with higher duration gap observed in Table 3 may be driven by firms' preference about the lender and not necessarily by a supply driven effect. Considering only single-bank relationships removes firms borrowing from multiple banks, limiting self-selection concerns by firms with more bank relationships. In this specification, we control for credit demand effects by employing ILS-time-interest rate type fixed effects, acknowledging limitations related to the omissions of time-varying firm-specific characteristics that may affect the demand for loans across firms operating within the same ILS fixed effects cluster.[25] The interaction coefficient of interest is still negative, sizeable, and statistically significant, suggesting that greater interest rate risk results in a more material lending contraction also when considering firms with only one bank relationship. Moreover, considering that banks with

[25] Since firms with single bank relationships are generally small firms, the inclusion of firm-specific characteristics would largely reduce the sample size because of missing values from publicly available databases. Nevertheless, we reckon the construction of our ILS cluster to be particularly strict (using granular levels of industry (NACE4) and location (NUTS3) to determine the clusters) and therefore the demand for loans homogeneous within the ILS-quarter cluster.

only single-bank relationships are generally MSMEs, this result further supports the empirical findings that MSMEs face a stronger lending contraction by banks with a higher duration gap when interest rates increase.

6.2 Predetermined duration gap

In this section, we test whether our results are robust to using a purely predetermined duration gap in the regressions to avoid any reverse causality concerns. We use two approaches to limit reverse causality concerns. Firstly, instead of using the lagged duration gap as in equation (2), we fix the duration gap at its level right before the monetary policy tightening (i.e., in 2022Q2). Second, in the spirit of Bertrand et al. (2004), we collapse the quarterly data into pre (2022Q2)- and post (2023Q2)-tightening observations, meaning that we only consider one observation per bank-firm relationship. More specifically, the dependent variable at the bank-firm level captures the change in outstanding volumes between 2022Q2 and 2023Q2, while all bank-level variables are determined at 2022Q2. As such, we compare the change in lending to firms pre- and post-tightening by multiple banks with a different exposure to interest rate risk pre-tightening. Since this regressions is purely cross-sectional, it does not require an interaction term of the duration gap and the bank-level control variables with the change in the policy rates or the inclusion of time fixed effects. Although this approach strongly reduces the number of observations and variation in our sample, it has some important advantages. First, this setting avoids issues of serial correlation by aggregating the data into two periods. Second, it limits endogeneity concerns by ruling out reverse causality between the change in lending between the pre and post period and the duration gap as defined in the pre period. Finally, in this approach, including bank-specific characteristics is equivalent to including bank fixed effects.[26]

[26]We use the collapsed approach also to examine the effects on the extensive margin. More specifically, we construct an *exit-* and *entry-dummy* at the bank-firm level in the spirit of Jasova et al. (2021) and use them

The results in Table 11 (first row of column (1) and (2) and third row of column (3) and (4)) show that overall we still find that banks with a larger duration gap reduce their lending significantly more during the monetary policy tightening episode compared to a bank with a smaller duration gap, although the magnitude of the effect is smaller.

6.3 Excluding mixed rate loans

For this robustness check, we exclude all bank-firm observations that do not have purely fixed or floating rate loans. At the loan-level it is possible that certain loan instruments are subject to a mixed interest rate. On top of that, since we aggregate multiple loan instruments, possibly with different interest rate types, this leads to a mixed rate observation at the bank-firm level. In column (5) and (6) of Table 11, we show that our coefficient of interest is not affected by excluding these mixed rate loans.

6.4 Controlling for overnight deposits composition

In Section 2, we provided descriptive evidence that higher interest rates altered the stickiness of overnight deposits, triggering a shift from overnight to term and redeemable at notice deposits and, consequently, widening the duration gap. Arguably, the extent of the shift from overnight to more remunerative deposit types depends on banks' customers base. Higher interest rates have increased NFCs' appetite for better remunerated deposits more than that of households, which are less likely to shift their deposit mix away from stickier overnight deposits towards rate-sensitive term deposits (Messer and Niepmann, 2023). This is clear from Figure 8, where

as dependent variables in our regressions. The *exit dummy* takes the value of 1 when a bank-firm relationship appears in the pre-tightening period but does not exist in the post-tightening period and zero otherwise, vice versa for the *entry dummy*. The results, reported in appendix B.3, show that banks with a larger duration gap before the monetary policy tightening are more likely to terminate relationships with firms after the tightening, although the effect is not statistically significant. On the other hand, banks with a larger duration gap before the monetary policy tightening are statistically significantly less likely to start a new bank-firm relationship after the tightening.

the shift from overnight to term and redeemable at notice deposits following the monetary policy tightening is more pronounced for NFCs compared to households. Since banks' customers base is likely to be correlated to the duration gap in a rising interest rate environment, we add (the lag of) the share of overnight deposits to households as an additional control variable to our baseline regressions, which we also interact with the change in the policy rate. We still find a negative and statistically significant relationship between the duration gap and lending growth when interest rates increase (Table 11, column (7) and (8)). This confirms that it is not only the deposit composition and their stickiness that matters, but more specifically the entire maturity/repricing structure of the balance sheet.

7 Conclusion

This paper investigates how differences in banks' exposure to interest rate risk affects the transmission of monetary policy to bank lending supply in a rising interest rate environment. We show descriptively that banks increased the duration of their asset side during the low for long interest rate environment in an attempt to search for yield. Interest rate risk, however, remained mostly muted during this period because of the large inflow of overnight deposits, which behaviourally have a relatively long duration. Since the ECB started raising interest rates in July 2022, a large shift from sticky overnight towards more rate-sensitive term deposits led to an increase in the duration gap, causing a materialisation of interest rate risk.

To our knowledge, this paper is the first to empirically assess the effects of this materialisation of interest rate risk on the transmission of monetary policy to bank lending during the steepest series of interest rate hikes since the introduction of the euro. We find that, when interest rates increase, banks with a larger duration gap after accounting for hedging contract lending more and are less likely to issue new loans to non-financial corporations compared to banks with a narrower duration gap. On the one hand, this is because banks generally tend to match the duration of assets and liabilities to maintain a stable duration gap and minimise their exposure to interest rate risk in order to avoid potential supervisory scrutiny. This is supported by the evidence that banks with a larger duration gap reallocate their loan portfolios away from loans with a longer duration and fixed rates. On the other hand, higher interest rate risk entails lower expected profitability and therefore lower capital accumulation, pushing those banks to deleverage more. Our results show that micro, small, and medium enterprises are the most affected by this deleveraging. Additionally, we show that firms cannot (fully) substitute the contraction in credit coming from banks with a higher duration gap by borrowing more from banks with a lower duration gap, resulting in an additional reduction in borrowing during a monetary tightening episode for these firms relative to other firms. Our results are robust to a series of robustness and sensitivity checks.

To summarise, our findings have important policy implications. From a monetary policy perspective, we provide evidence showing that the transmission of monetary policy is heterogeneous across euro area banks, with a stronger effect for banks with a large duration gap. This is an important parameter for monetary policymakers to take into account when deciding on (the pace of) monetary policy changes. In terms of financial stability, an excessive contraction in (long-term) lending supply may exacerbate the economic downturn. Moreover, since MSMEs, who are most affected by this excessive contraction, cannot rely on market-based funding as a substitute to bank credit, the impact might be especially pronounced for these types of firms.

The focus of this paper lies in analysing bank lending behaviour in response to higher exposure to interest rate risk during a monetary tightening period. However, it is possible that banks also use other instruments on their asset side to reduce their exposure to interest rate risk. Moreover, as our sample only covers a period of increasing interest rates, we cannot examine whether the impact of differential exposures to duration risk on the transmission of monetary policy is (a)symmetric. These could be interesting avenues for further research.

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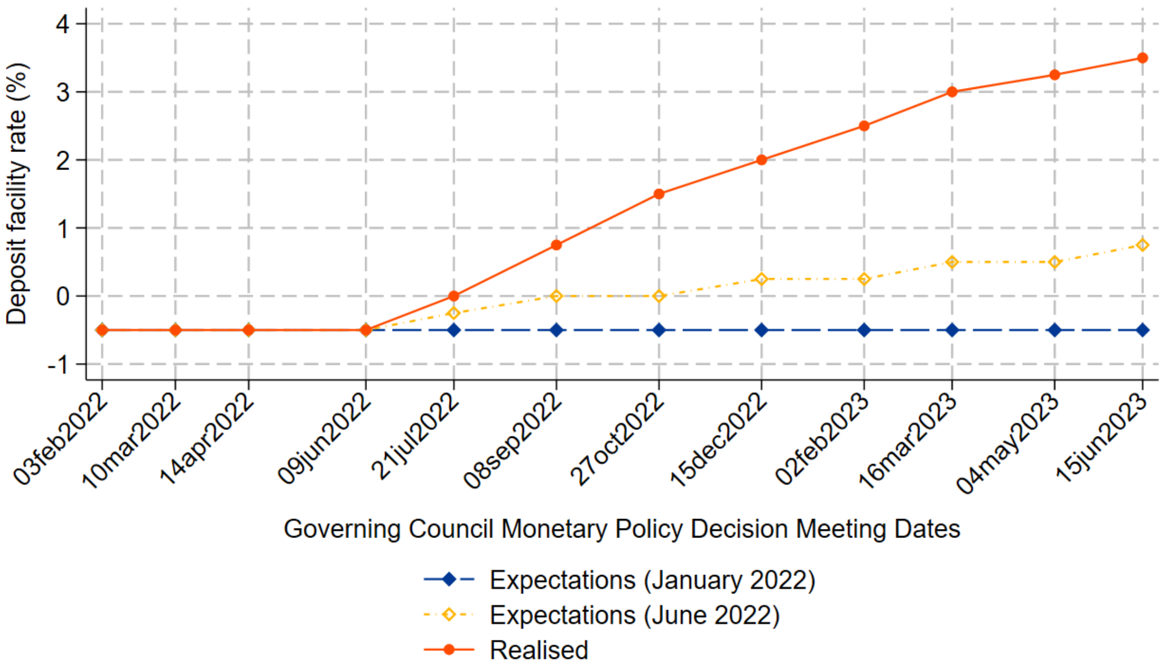
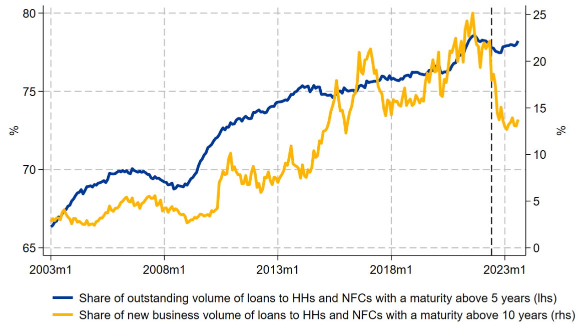
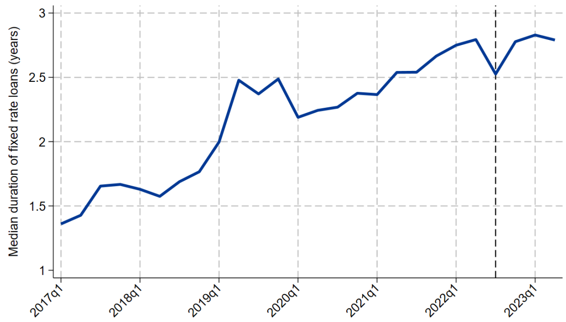


Figure 1: Interest rate increase expectations. Source(s): Survey of Monetary Analysts

Figure 2: Evolution of duration of banks' asset side

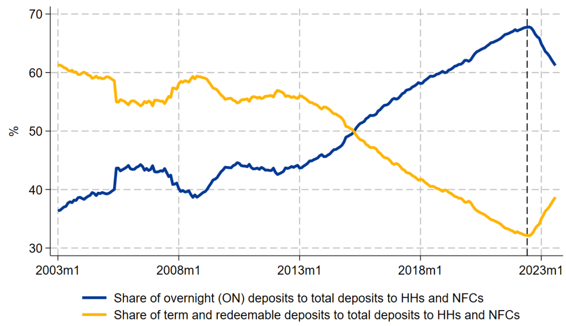


(a) The dashed line shows the start of the hiking cycle. Loans to euro-area HHs and NFCs with a maturity over 5 years as a share of total loans to euro-area HHs and NFCs by MFIs excl. ESCB in the euro area, all currencies combined (left-hand side). Loans other than revolving loans and overdrafts, convenience and extended credit card debt to euro-area HHs and NFCs with a maturity over 10 years as a share of total loans to euro-area HHs and NFCs by deposit-taking corporations except the central bank, in euro (right-hand side). Source(s): ECB Balance Sheet Items and MFI Interest Rate Statistics.

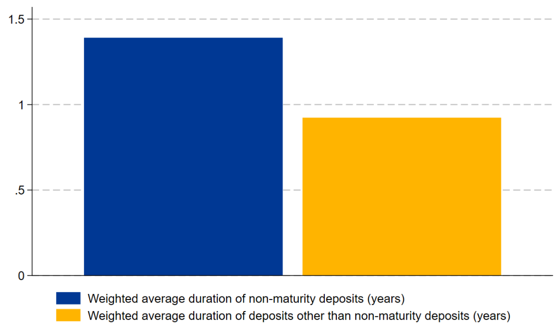


(b) The dashed line shows the start of the hiking cycle. Median of the weighted average duration of the cash-flows from fixed rate loans, across a balanced panel of 74 significant institutions. Source(s): ECB Supervisory data.

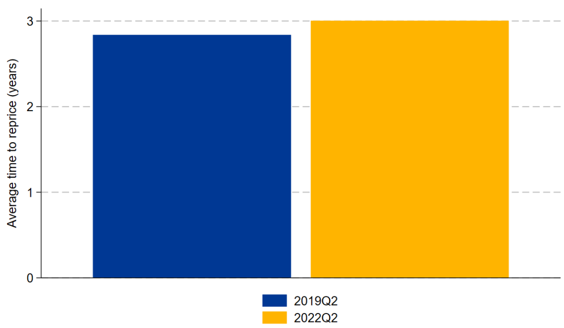
Figure 3: Evolution of duration of banks' liability side



(a) The dashed line shows the start of the hiking cycle. Source(s): ECB Balance sheet Items.



(b) Median of the weighted average duration for deposits in 2022Q2 for a balanced sample of 73 significant institutions. The difference between the two variables is statistically significant at the 1% significance level. Source(s): ECB Supervisory data.



(c) Average time to reprice for euro-denominated retail transactional non-maturity deposits, as self-reported by banks, for a balanced sample of 73 significant institutions. The difference between the two time periods is not statistically significant. Source(s): ECB Supervisory data.

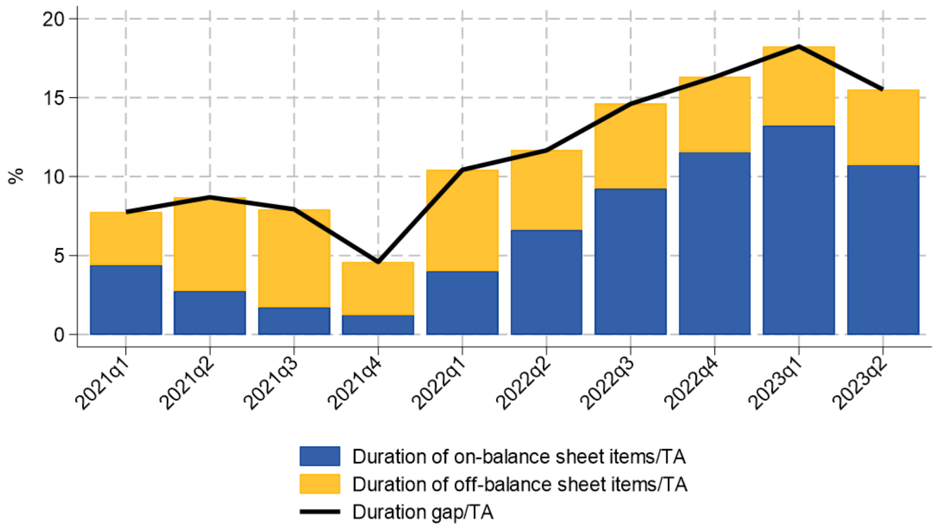


Figure 4: Evolution of banks' duration gap. The duration gap scaled by total assets is calculated as explained in section 3.1 and winsorized at 1%. Average based on a balanced sample of 73 significant institutions. Source(s): ECB Supervisory data.

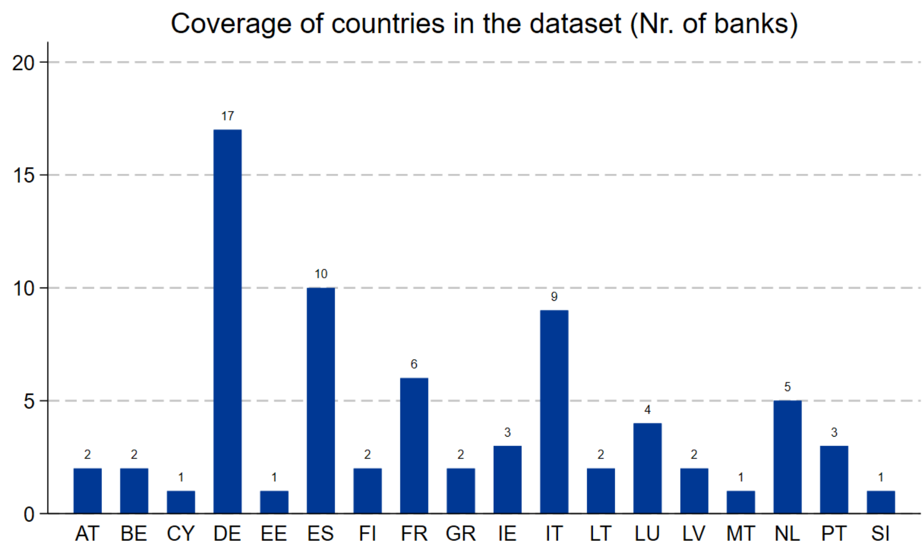


Figure 5: Coverage per country in the *AnaCredit* sample matched with supervisory bank-level data.

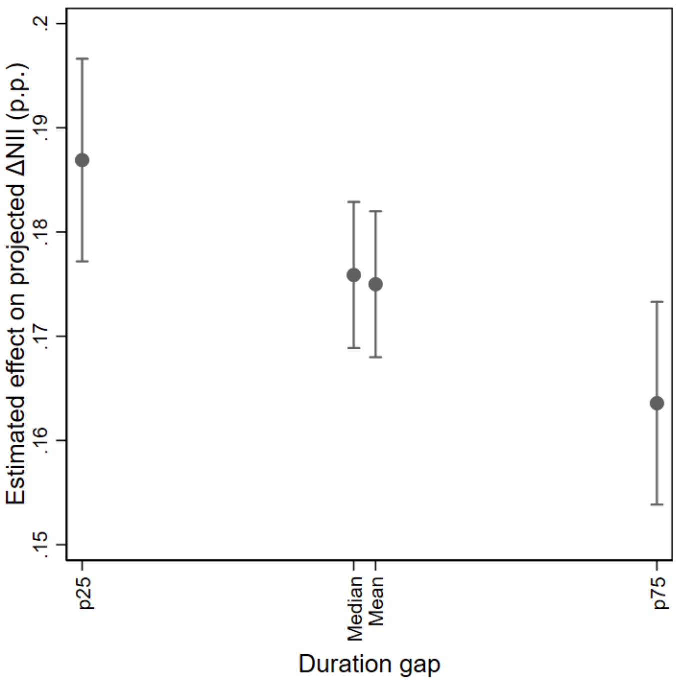


Figure 6: Outcome of bank-level regression of the self-reported forecasted change in net interest income within 12 months under a parallel interest rate shock of 200bps up on the (lagged) duration gap on the period 2021Q1-2023Q2. We include other bank-level characteristics as in our baseline regressions and the regressions include time and bank fixed effects. The coefficient of the duration gap is negative and significant at the 1% level. The dots show the estimated impact on the forecasted change in NII following an increase in interest rates for banks with a different level of the duration gap. The bars show the confidence bands at the 95% significance level.

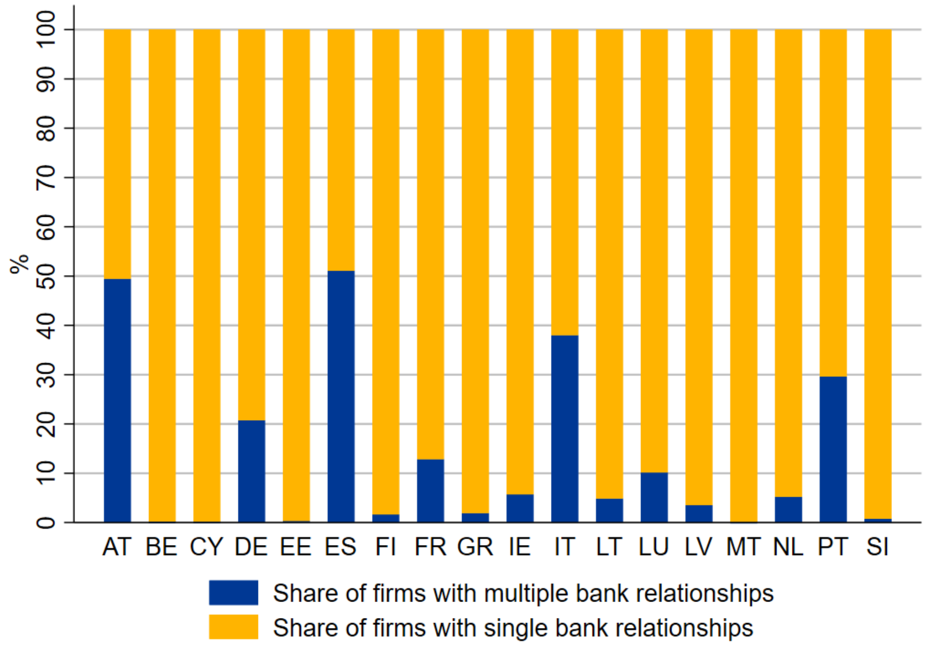


Figure 7: Share of firms with single/multiple bank relationships per country in the *AnaCredit* sample matched with supervisory bank-level data. The numbers show the average across the time period (2021Q1-2023Q2).

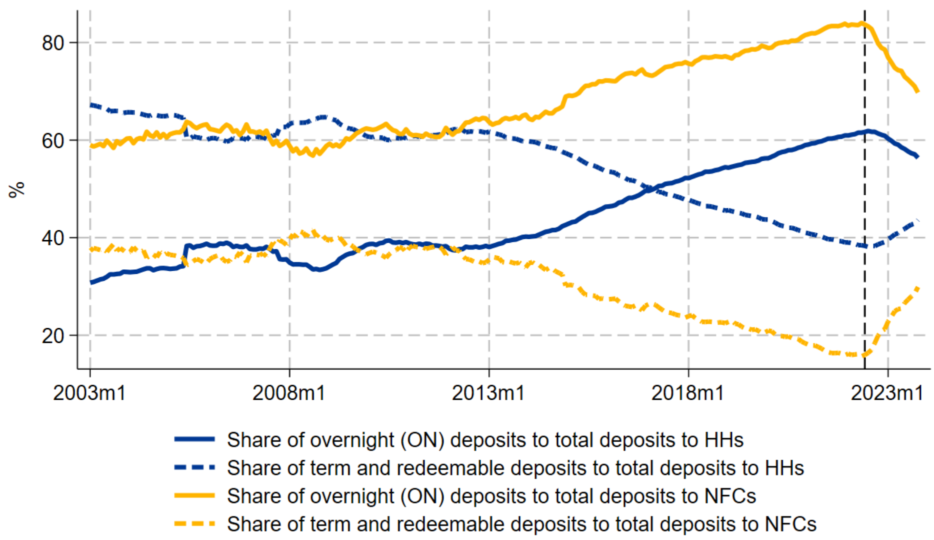


Figure 8: Banks' deposit composition by customer type. The dashed line shows the start of the hiking cycle. Source(s): ECB Balance sheet Items.

Table 1: Descriptive statistics

	N	Mean	Std.dev.	p25	p75	Min.	Max.
Endogeneous variables:							
$\Delta Log(loans)$ (%)	14,582,455	-2.407	25.415	-6.558	0	-100.606	119.647
Variable of interest:							
Duration gap/TA (%)	17,167,090	4.119	26.366	-11.335	19.791	-62.315	80.843
Bank control variables:							
Income gap/TA (%)	17,167,090	4.090	7.276	-1.152	9.776	-53.903	39.449
Log TA	17,167,090	12.909	1.183	11.896	13.671	8.057	14.718
Cash/TA (%)	17,167,090	14.599	4.461	11.800	17.376	1.025	36.560
ROA (%)	17,167,090	0.491	0.385	0.286	0.648	-0.907	1.941
Debt securities/TA (%)	17,129,892	10.554	6.403	7.971	11.139	0	37.618
NPL ratio (%)	17,167,052	3.534	1.422	2.769	4.197	0.465	13.303
Distance to MDA (%)	17,167,090	4.615	2.663	3.189	5.403	0.420	26.085

Descriptives for the period 2021Q1-2023Q2. For the definitions of the variables, we refer to Table 12.

Table 2: Regression of the duration gap on the set of control variables using bank-level data from the pre-tightening period.

	Dependent variable: Duration gap/TA							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Income gap/TA	-0.610 (-1.32)	-0.309 (-0.63)						
Log TA	-2.588 (-1.07)		-1.350 (-0.63)					
Cash/TA	-0.401 (-0.76)			-0.0601 (-0.14)				
ROA	4.80 (0.72)				4.32 (0.68)			
Debt securities/TA	0.254 (0.64)					0.198 (0.73)		
NPL ratio	-1.33 (-0.62)						-0.794 (-0.43)	
Distance to MDA	-0.607 (-0.83)							-0.0549 (-0.11)
Observations	403	418	418	418	418	406	412	418

*Note: ***: 0.01,**: 0.05,*: 0.1. Bank-level clustered standard errors are reported in parenthesis. For the definitions of the variables, we refer to Table 12. Column (1) includes all the control variables simultaneously, while column (2) to (8) show the results when including one control variable at a time.*

Table 3: Effects on the intensive margin

	Dependent variable: Δ Log (loans)			
	(1)	(2)	(3)	(4)
Duration gap/TA (lag)	0.000144	0.000193*	0.000144	0.000194*
	(1.34)	(1.75)	(1.33)	(1.72)
Duration gap/TA (lag) × Δpolicy rate	-0.0292**	-0.0300***	-0.0294**	-0.0302***
	(-2.26)	(-3.04)	(-2.25)	(-3.00)
Income gap/TA (lag)		-0.000460		-0.000467
		(-1.61)		(-1.60)
Income gap/TA (lag) × Δpolicy rate		0.0390*		0.0395*
		(1.75)		(1.73)
Log TA (lag)		0.00503**		0.00507**
		(2.11)		(2.08)
Log TA (lag) × Δpolicy rate		-0.422**		-0.413**
		(-2.16)		(-2.07)
Cash/TA (lag)		0.00150***		0.00151***
		(3.19)		(3.22)
Cash/TA (lag) × Δpolicy rate		-0.0694		-0.0704
		(-1.28)		(-1.29)
ROA (lag)		0.0130*		0.0131*
		(1.95)		(1.95)
ROA (lag) × Δpolicy rate		-2.30***		-2.35***
		(-3.17)		(-3.19)
Debt securities/TA (lag)		-0.000897***		-0.000902***
		(-2.77)		(-2.71)
Debt securities/TA (lag) × Δpolicy rate		0.0500		0.0494
		(1.15)		(1.12)
NPL ratio (lag)		0.00285		0.00287
		(1.27)		(1.25)
NPL ratio (lag) × Δpolicy rate		0.731***		0.746***
		(3.48)		(3.47)
Distance to MDA (lag)		-0.000848		-0.000837
		(-0.98)		(-0.95)
Distance to MDA (lag) × Δpolicy rate		0.282**		0.286**
		(2.36)		(2.34)
Observations	2028673	2013105	2028661	2013091
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 4: Effects on the the probability of issuing a new loan

	Dependent variable: new loan			
	(1)	(2)	(3)	(4)
Duration gap/TA (lag)	0.000369***	0.000380**	0.000375***	0.000388**
	(2.66)	(2.42)	(2.68)	(2.41)
Duration gap/TA (lag) × Δpolicy rate	-0.0503**	-0.0603***	-0.0504**	-0.0607***
	(-2.23)	(-3.59)	(-2.19)	(-3.53)
Income gap/TA (lag)		-0.000657		-0.000656
		(-1.09)		(-1.07)
Income gap/TA (lag) × Δpolicy rate		0.0459		0.0458
		(0.95)		(0.93)
Log TA (lag)		0.00336		0.00335
		(0.90)		(0.89)
Log TA (lag) × Δpolicy rate		-1.025***		-1.030***
		(-3.21)		(-3.20)
Cash/TA (lag)		0.00312***		0.00316***
		(3.52)		(3.57)
Cash/TA (lag) × Δpolicy rate		-0.0988		-0.0982
		(-1.26)		(-1.24)
ROA (lag)		0.0149		0.0152
		(1.55)		(1.57)
ROA (lag) × Δpolicy rate		-1.61**		-1.62**
		(-2.09)		(-2.09)
Debt securities/TA (lag)		-0.00224***		-0.00225***
		(-3.49)		(-3.46)
Debt securities/TA (lag) × Δpolicy rate		0.180***		0.180***
		(2.85)		(2.81)
NPL ratio (lag)		0.000637		0.000686
		(0.21)		(0.22)
NPL ratio (lag) × Δpolicy rate		0.0451		0.0438
		(0.17)		(0.16)
Distance to MDA (lag)		0.00189		0.00189
		(1.33)		(1.31)
Distance to MDA (lag) × Δpolicy rate		0.0662		0.0674
		(0.48)		(0.49)
Observations	2028673	2013105	2028661	2013091
Borrower/ILS*Time*Interest rate type FE	Borr	Borr	Borr	Borr
Country*Time FE	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 5: Effects on short- and long-term lending growth (intensive margin)

	Short-term loans (maturity ≤ 2 years)				*Long-term loans (maturity > 2 years)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (lag)	0.000182	0.000235	0.000113	0.000164	0.000227	0.000277	0.000223	0.000276
	(0.42)	(0.59)	(0.25)	(0.41)	(1.52)	(1.65)	(1.49)	(1.61)
Duration gap/TA (lag) × Δpolicy rate	-0.00230	0.0222	0.00615	0.0350	-0.0607***	-0.0557***	-0.0610***	-0.0561***
	(-0.05)	(0.48)	(0.12)	(0.74)	(-2.82)	(-3.08)	(-2.79)	(-3.04)
Income gap/TA (lag)		0.000649		0.000568		-0.000827**		-0.000834**
		(0.40)		(0.35)		(-2.06)		(-2.05)
Income gap/TA (lag) × Δpolicy rate		-0.0338		-0.0297		0.0767**		0.0772**
		(-0.27)		(-0.23)		(2.35)		(2.34)
Log TA (lag)		0.0127*		0.0124*		0.00635*		0.00645*
		(1.92)		(1.83)		(1.71)		(1.70)
Log TA (lag) × Δpolicy rate		-0.851		-0.723		-0.540		-0.531
		(-0.93)		(-0.74)		(-1.34)		(-1.30)
Cash/TA (lag)		0.00451**		0.00449**		0.00165**		0.00163**
		(2.22)		(2.16)		(2.63)		(2.57)
Cash/TA (lag) × Δpolicy rate		-0.168		-0.237		-0.0810		-0.0797
		(-0.55)		(-0.77)		(-1.08)		(-1.05)
ROA (lag)		0.0150		0.0162		0.0198*		0.0198*
		(0.62)		(0.66)		(1.70)		(1.69)
ROA (lag) × Δpolicy rate		-4.01		-4.84		-4.22***		-4.33***
		(-1.31)		(-1.59)		(-3.06)		(-3.09)
Debt securities/TA (lag)		0.000786		0.000845		-0.000668		-0.000668
		(0.43)		(0.44)		(-1.26)		(-1.24)
Debt securities/TA (lag) × Δpolicy rate		0.187		0.200		0.000120		0.000296
		(0.79)		(0.76)		(0.00)		(0.00)
NPL ratio (lag)		-0.00182		-0.00249		0.00561		0.00571
		(-0.20)		(-0.27)		(1.52)		(1.51)
NPL ratio (lag) × Δpolicy rate		1.22		1.38		1.65***		1.67***
		(1.12)		(1.28)		(3.58)		(3.54)
Distance to MDA (lag)		0.00458		0.00438		-0.00283**		-0.00283**
		(1.11)		(1.06)		(-2.18)		(-2.17)
Distance to MDA (lag) × Δpolicy rate		0.789		0.652		0.538**		0.549**
		(1.30)		(1.10)		(2.11)		(2.11)
Observations	43873	43178	43847	43158	1781033	1767958	1781017	1767942
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 6: Effects on short- and long-term new loans

	New loan (maturity ≤ 2 years)				*New loan (maturity > 2 years)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (lag)	0.0000188	-0.0000506	-0.00000241	-0.0000898	0.000392***	0.000415***	0.000397***	0.000421***
	(0.07)	(-0.18)	(-0.01)	(-0.31)	(3.08)	(3.02)	(3.10)	(2.97)
Duration gap/TA (lag) × Δpolicy rate	0.0460	0.0630*	0.0503*	0.0676*	-0.0611***	-0.0649***	-0.0616***	-0.0654***
	(1.60)	(1.75)	(1.73)	(1.85)	(-3.26)	(-4.40)	(-3.24)	(-4.33)
Income gap/TA (lag)		0.00104		0.000920		-0.000813*		-0.000823
		(0.84)		(0.73)		(-1.67)		(-1.66)
Income gap/TA (lag) × Δpolicy rate		-0.0908		-0.0820		0.0579		0.0586
		(-0.91)		(-0.81)		(1.47)		(1.46)
Log TA (lag)		-0.00132		-0.00228		0.00646*		0.00642*
		(-0.21)		(-0.36)		(1.81)		(1.79)
Log TA (lag) × Δpolicy rate		-0.399		-0.194		-0.981***		-0.989***
		(-0.50)		(-0.24)		(-3.17)		(-3.17)
Cash/TA (lag)		0.00334**		0.00364**		0.00324***		0.00328***
		(2.18)		(2.38)		(3.90)		(3.95)
Cash/TA (lag) × Δpolicy rate		-0.0583		-0.109		-0.107		-0.105
		(-0.27)		(-0.51)		(-1.30)		(-1.27)
ROA (lag)		0.0326		0.0339		0.0144		0.0147
		(1.33)		(1.37)		(1.53)		(1.55)
ROA (lag) × Δpolicy rate		-6.622**		-6.974**		-1.989**		-2.019**
		(-2.28)		(-2.38)		(-2.60)		(-2.61)
Debt securities/TA (lag)		-0.00352**		-0.00332**		-0.00136**		-0.00134**
		(-2.38)		(-2.16)		(-2.58)		(-2.49)
Debt securities/TA (lag) × Δpolicy rate		0.580***		0.535**		0.145**		0.145**
		(2.75)		(2.44)		(2.38)		(2.36)
NPL ratio (lag)		-0.00529		-0.00601		0.00300		0.00299
		(-0.65)		(-0.73)		(1.00)		(0.98)
NPL ratio (lag) × Δpolicy rate		-0.0458		0.0802		0.262		0.261
		(-0.05)		(0.09)		(0.98)		(0.96)
Distance to MDA (lag)		0.00202		0.00199		0.00120		0.00117
		(0.69)		(0.66)		(0.93)		(0.89)
Distance to MDA (lag) × Δpolicy rate		-0.675		-0.714		0.124		0.124
		(-1.55)		(-1.60)		(0.92)		(0.91)
Observations	43873	43178	43847	43158	1781033	1767958	1781017	1767942
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 7: Effects on fixed and floating rate lending growth

	Dependent variable: Δ Log (loans)				*Dependent variable: new loan*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (lag)	0.000197*	0.000243**	0.000197*	0.000240**	0.000287*	0.000251	0.000292*	0.000252
	(1.80)	(2.11)	(1.80)	(2.07)	(1.94)	(1.44)	(1.96)	(1.43)
Duration gap/TA (lag) × Δpolicy rate	-0.0249*	-0.0272**	-0.0248*	-0.0268**	-0.0299	-0.0394*	-0.0304	-0.0395*
	(-1.76)	(-2.58)	(-1.75)	(-2.53)	(-1.06)	(-1.88)	(-1.07)	(-1.89)
Duration gap/TA (pre/lag) × Δpolicy rate × Floating	-0.00361	0.00458	-0.00394	0.00410	-0.0124	-0.0233	-0.0114	-0.0234
	(-0.19)	(0.29)	(-0.21)	(0.25)	(-0.32)	(-0.65)	(-0.29)	(-0.65)
Income gap/TA (lag)		-0.000310		-0.000326		-0.000382		-0.000396
		(-1.41)		(-1.45)		(-0.69)		(-0.70)
Income gap/TA (lag) × Δpolicy rate		0.0260		0.0273		0.0237		0.0249
		(1.51)		(1.55)		(0.53)		(0.55)
Log TA (lag)		0.00422**		0.00420**		0.00268		0.00264
		(2.17)		(2.12)		(0.72)		(0.71)
Log TA (lag) × Δpolicy rate		-0.509***		-0.500***		-1.147***		-1.148***
		(-2.88)		(-2.79)		(-3.93)		(-3.88)
Cash/TA (lag)		0.00149***		0.00150***		0.00328***		0.00331***
		(3.73)		(3.75)		(3.78)		(3.82)
Cash/TA (lag) × Δpolicy rate		-0.0735		-0.0741		-0.119		-0.118
		(-1.21)		(-1.22)		(-1.39)		(-1.37)
ROA (lag)		0.0116**		0.0116**		0.0146*		0.0147*
		(2.16)		(2.15)		(1.80)		(1.79)
ROA (lag) × Δpolicy rate		-2.165***		-2.204***		-1.570**		-1.570**
		(-3.44)		(-3.44)		(-2.19)		(-2.12)
Debt securities/TA (lag)		-0.00104***		-0.00103***		-0.00206***		-0.00204***
		(-3.43)		(-3.31)		(-2.92)		(-2.86)
Debt securities/TA (lag) × Δpolicy rate		0.0782**		0.0771**		0.182***		0.181***
		(2.15)		(2.08)		(3.42)		(3.32)
NPL ratio (lag)		0.00276		0.00268		-0.0000771		-0.000159
		(1.53)		(1.45)		(-0.02)		(-0.05)
NPL ratio (lag) × Δpolicy rate		0.671***		0.692***		-0.174		-0.163
		(2.91)		(2.96)		(-0.67)		(-0.60)
Distance to MDA (lag)		-0.0644		-0.0637		0.134		0.134
		(-1.23)		(-1.22)		(1.53)		(1.52)
Distance to MDA (lag) × Δpolicy rate		0.207**		0.209**		0.031		0.032
		(2.11)		(2.09)		(0.38)		(0.39)
F-test floating rate loans	-0.0285	-0.0226*	-0.0288	-0.0227	-0.0424	-0.0627**	-0.0417	-0.0629**
	(-1.66)	(-1.77)	(1.62)	(-1.67)	(-1.37)	(2.16)	(-1.32)	(-2.06)
Observations	2803531	2780145	2803522	2780140	2803531	2780145	2803522	2780140
Double interactions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Borrower*Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 8: Heterogeneous effects for firms with a different size

	Dependent variable: Δ Log (loans)			
	(1)	(2)	(3)	(4)
Duration gap/TA (lag)	0.0000182	0.0000170	0.0000154	0.0000187
	(0.16)	(0.18)	(0.13)	(0.19)
Duration gap/TA (lag) × Δpolicy rate	-0.00443	-0.00233	-0.00475	-0.00316
	(-0.35)	(-0.22)	(-0.36)	(-0.28)
Medium-sized firm × Duration gap/TA (lag) × Δpolicy rate	-0.0210*	-0.0222**	-0.0205*	-0.0210*
	(-1.95)	(-2.09)	(-1.90)	(-1.97)
Small-sized firm × Duration gap/TA (lag) × Δpolicy rate	-0.0461***	-0.0491***	-0.0456***	-0.0479***
	(-4.03)	(-4.56)	(-3.92)	(-4.38)
Micro-sized firm × Duration gap/TA (lag) × Δpolicy rate	-0.0214**	-0.0281**	-0.0211**	-0.0271**
	(-2.61)	(-2.55)	(-2.42)	(-2.36)
Income gap/TA (lag)		-0.000456		-0.000463
		(-1.59)		(-1.58)
Income gap/TA (lag) × Δpolicy rate		0.0386*		0.0391*
		(1.72)		(1.71)
Log TA (lag)		0.00550**		0.00553**
		(2.22)		(2.19)
Log TA (lag) × Δpolicy rate		-0.470**		-0.462**
		(-2.40)		(-2.31)
Cash/TA (lag)		0.00148***		0.00150***
		(3.05)		(3.08)
Cash/TA (lag) × Δpolicy rate		-0.0681		-0.0686
		(-1.24)		(-1.24)
ROA (lag)		0.0132*		0.0133*
		(1.95)		(1.94)
ROA (lag) × Δpolicy rate		-2.34***		-2.37***
		(-3.24)		(-3.25)
Debt securities/TA (lag)		-0.00103***		-0.00103***
		(-2.99)		(-2.93)
Debt securities/TA (lag) × Δpolicy rate		0.0621		0.0619
		(1.44)		(1.41)
NPL ratio (lag)		0.00307		0.00309
		(1.34)		(1.31)
NPL ratio (lag) × Δpolicy rate		0.709***		0.725***
		(3.38)		(3.38)
Distance to MDA (lag)		-0.000769		-0.000752
		(-0.86)		(-0.83)
Distance to MDA (lag) × Δpolicy rate		0.273**		0.275**
		(2.25)		(2.22)
Observations	1981398	1966119	1981386	1966105
Double interactions	Yes	Yes	Yes	Yes
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 9: Firm-level regressions

	Dependent variable: Δ *Log (borrowing)*	
	(1)	(2)
High exposure	0.0152***	0.0168***
	(24.61)	(21.67)
High exposure × Δpolicy rate	-0.750***	-0.744***
	(-9.17)	(-7.13)
Income gap/TA (lag)		-0.000103***
		(-3.02)
Income gap/TA (lag) × Δpolicy rate		-0.105***
		(-20.93)
Log TA (lag)		-0.00112***
		(-5.00)
Log TA (lag) × Δpolicy rate		0.560***
		(16.34)
Cash/TA (lag)		0.000313***
		(5.72)
Cash/TA (lag) × Δpolicy rate		-0.00104
		(-0.13)
ROA (lag)		0.00630***
		(12.81)
ROA (lag) × Δpolicy rate		-0.779***
		(-9.40)
Debt securities/TA (lag)		0.000132**
		(2.56)
Debt securities/TA (lag) × Δpolicy rate		-0.125***
		(-16.21)
NPL ratio (lag)		-0.00278***
		(-11.79)
NPL ratio (lag) × Δpolicy rate		0.621***
		(17.43)
Distance to MDA (lag)		-0.00167***
		(-16.99)
Distance to MDA (lag) × Δpolicy rate		0.748***
		(44.54)
Observations	6400463	6375657
ILS*Time*Interest rate type FE	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Clustered standard errors at the firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12. The bank characteristics are computed as a weighted average at the firm level.*

Table 10: Effects on lending growth when including firms with single bank relationships

	Dependent variable: Δ Log (loans)				*Dependent variable: Δ Log (loans)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (lag)	0.000212*	0.000267**	0.000237*	0.000289**	0.000232**	0.000292***	0.000268**	0.000319***
	(1.70)	(2.27)	(1.83)	(2.35)	(2.23)	(2.77)	(2.43)	(2.88)
Duration gap/TA (lag) × Δpolicy rate	-0.0338*	-0.0359***	-0.0349*	-0.0352***	-0.0334*	-0.0357***	-0.0349*	-0.0335***
	(-1.82)	(-3.07)	(-1.84)	(-3.08)	(-1.89)	(-3.12)	(-1.91)	(-3.07)
Income gap/TA (lag)		-0.000183		-0.000147		-0.000107		-0.0000538
		(-0.68)		(-0.53)		(-0.40)		(-0.20)
Income gap/TA (lag) × Δpolicy rate		0.0194		0.0170		0.0146		0.0111
		(0.92)		(0.79)		(0.71)		(0.54)
Log TA (lag)		0.00393		0.00418		0.00348		0.00377
		(1.42)		(1.44)		(1.37)		(1.40)
Log TA (lag) × Δpolicy rate		-0.517		-0.397		-0.508		-0.327
		(-1.66)		(-1.24)		(-1.54)		(-0.95)
Cash/TA (lag)		0.000987*		0.00102*		0.000706		0.000728
		(1.81)		(1.80)		(1.53)		(1.48)
Cash/TA (lag) × Δpolicy rate		-0.0410		-0.0441		-0.0235		-0.0271
		(-0.69)		(-0.70)		(-0.45)		(-0.47)
ROA (lag)		0.00988*		0.00981*		0.00977**		0.00972**
		(1.87)		(1.85)		(2.15)		(2.16)
ROA (lag) × Δpolicy rate		-2.18**		-2.49**		-2.20***		-2.66***
		(-2.45)		(-2.65)		(-2.72)		(-3.04)
Debt securities/TA (lag)		-0.000710		-0.000796*		-0.000626		-0.000736*
		(-1.66)		(-1.78)		(-1.54)		(-1.70)
Debt securities/TA (lag) × Δpolicy rate		0.0518		0.0308		0.0401		0.0108
		(0.86)		(0.48)		(0.66)		(0.16)
NPL ratio (lag)		0.000768		0.00127		0.0000110		0.000617
		(0.33)		(0.51)		(0.01)		(0.27)
NPL ratio (lag) × Δpolicy rate		0.590*		0.788**		0.575*		0.871***
		(1.87)		(2.53)		(1.82)		(2.78)
Distance to MDA (lag)		-0.000943		-0.000819		-0.00102		-0.000887
		(-1.07)		(-0.87)		(-1.27)		(-1.01)
Distance to MDA (lag) × Δpolicy rate		0.260		0.341*		0.266		0.379**
		(1.55)		(1.98)		(1.46)		(2.03)
Observations	8511563	8437194	8511563	8437194	6463860	6405467	6463868	6405479
ILS*Time*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 11: Robustness checks

	Dependent variable: Δ Log (loans)							
	Collapsed regressions		*Pre-determined duration gap*		*Excluding mixed rate loans*		*Overnight deposit composition*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (pre/lag)	-0.00103*	-0.00108	0.000223**	0.000240**	0.000194*	0.000195*	0.000230**	0.000234**
	(-1.68)	(-1.66)	(2.41)	(2.43)	(1.75)	(1.73)	(2.08)	(2.06)
Duration gap/TA (pre/lag) × Δpolicy rate			-0.0202**	-0.0215*	-0.0304***	-0.0305***	-0.0306***	-0.0308***
			(-2.01)	(-1.99)	(-3.08)	(-3.03)	(-3.32)	(-3.27)
Income gap/TA (pre/lag)	-0.00372	-0.00387*	-0.000641**	-0.000646**	-0.000461	-0.000468	-0.000561**	-0.000561**
	(-1.65)	(-1.71)	(-2.21)	(-2.19)	(-1.62)	(-1.60)	(-2.13)	(-2.09)
Income gap/TA (pre/lag) × Δpolicy rate			0.0531**	0.0535**	0.0392*	0.0398*	0.0469**	0.0469**
			(2.30)	(2.28)	(1.75)	(1.74)	(2.28)	(2.24)
Log TA (pre/lag)	-0.0203*	-0.0202*	0.00416*	0.00419*	0.00502**	0.00505**	0.00431*	0.00435*
	(-1.81)	(-1.78)	(1.91)	(1.89)	(2.10)	(2.07)	(1.92)	(1.91)
Log TA (pre/lag)× Δpolicy rate			-0.339*	-0.329	-0.415**	-0.405**	-0.410**	-0.402**
			(-1.71)	(-1.61)	(-2.12)	(-2.02)	(-2.10)	(-2.01)
Cash/TA (pre/lag)	0.834***	0.828***	0.00158***	0.00161***	0.00149***	0.00151***	0.00160***	0.00161***
	(4.66)	(4.52)	(3.62)	(3.69)	(3.16)	(3.19)	(3.85)	(3.87)
Cash/TA (pre/lag)× Δpolicy rate			-0.0616	-0.0631	-0.0682	-0.0692	-0.0587	-0.0594
			(-1.24)	(-1.26)	(-1.20)	(-1.20)	(-1.08)	(-1.08)
ROA (pre/lag)	-4.30*	-4.53*	0.0109*	0.0110*	0.0130*	0.0131*	0.0153**	0.0155**
	(-1.76)	(-1.83)	(1.77)	(1.77)	(1.95)	(1.94)	(2.37)	(2.37)
ROA (pre/lag)× Δpolicy rate			-2.11***	-2.14***	-2.25***	-2.29***	-2.216***	-2.252***
			(-3.02)	(-3.03)	(-3.08)	(-3.09)	(-3.28)	(-3.29)
Debt securities/TA (pre/lag)	0.233	0.236	-0.000667**	-0.000664**	-0.000894***	-0.000898***	-0.000226	-0.000217
	(1.23)	(1.22)	(-2.18)	(-2.13)	(-2.75)	(-2.69)	(-0.59)	(-0.55)
Debt securities/TA (pre/lag)× Δpolicy rate			0.0381	0.0364	0.0464	0.0456	0.0219	0.0209
			(0.84)	(0.78)	(1.05)	(1.01)	(0.40)	(0.37)
NPL ratio (pre/lag)	4.38***	4.37***	0.00311	0.00324	0.00285	0.00287	0.00428*	0.00442*
	(3.42)	(3.29)	(1.49)	(1.50)	(1.27)	(1.24)	(1.82)	(1.81)
NPL ratio (pre/lag)× Δpolicy rate			0.762***	0.769***	0.730***	0.746***	0.652***	0.665***
			(3.84)	(3.77)	(3.40)	(3.39)	(2.85)	(2.83)
Distance to MDA (pre/lag)	0.191	0.220	-0.00124	-0.00127	-0.000855	-0.000844	-0.000904	-0.000914
	(0.48)	(0.54)	(-1.35)	(-1.35)	(-0.99)	(-0.96)	(-1.30)	(-1.32)
Distance to MDA (pre/lag)× Δpolicy rate			0.292**	0.299**	0.287**	0.291**	0.268**	0.272**
			(2.29)	(2.28)	(2.39)	(2.38)	(2.25)	(2.22)
Share OV deposits to HH (lag)							0.000561***	0.000574***
							(3.83)	(3.77)
Share OV deposits to HH × Δpolicy rate							-0.0174	-0.0174
							(-1.04)	(-0.99)
Observations	187845	187845	2013105	2013091	2010213	2010199	2012319	2012305
Borrower*Interest rate type FE	Yes	Yes	-	-	-	-	-	-
Country FE	No	Yes	-	-	-	-	-	-
Borrower*Time*Interest rate type FE	-	-	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	-	-	No	Yes	No	Yes	No	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

A Data appendix

Table 12: Definitions of variables and their sources

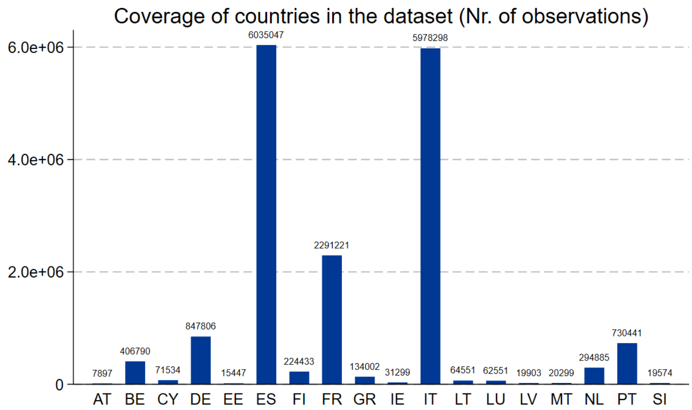
Variable	Label	Definition	Source
Endogeneous variables:			
Lending growth	Δ Log (loans)	Change in the logarithm of the outstanding amounts granted from bank b to firm f	AnaCredit
Short-term lending growth		Change in the logarithm of the outstanding amounts granted from bank b to firm f for loans with an original maturity less or equal to 2 years	AnaCredit
Long-term lending growth		Change in the logarithm of the outstanding amounts granted from bank b to firm f for loans with an original maturity above 2 years	AnaCredit
New loan		Dummy variable equal to 1 when the outstanding credit volume in lending relationships increases between $t-1$ and t, and equal to 0 otherwise	AnaCredit
New bank-firm relationship		Dummy variable equal to 1 if: a) at time t a new firm did not have a relationship in the previous quarter enters the AnaCredit registry, and b) a firm that was in the sample in $t-1$ because it borrowed from the bank x also starts borrowing from bank y at time t, and equal to 0 otherwise.	AnaCredit
Entry dummy		Dummy variable equal to 1 when a bank-firm relationship appears in the post-tightening period but does not in the pre-tightening period.	AnaCredit
Exit dummy		Dummy variable equal to 1 when a bank-firm relationship appears in the pre-tightening period but does not in the post-tightening period.	AnaCredit
Variable of interest:			
Duration gap	Duration gap/TA	The duration gap is computed as the difference between cash-flows coming from assets and liabilities plus cash-flows coming from off-balance sheet items, weighted by their modified duration. It is scaled by total assets. The metric considers cash-flows from all currencies, expressed in euro.	ECB Supervisory Statistics
Duration gap dummy		Dummy variable equal to 1 if the duration gap (as defined above) is equal or above zero, and 0 otherwise	ECB Supervisory Statistics

Continued on the next page

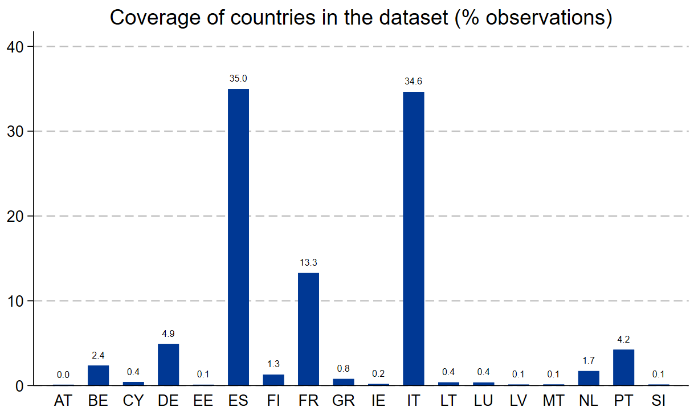
Variable	Label	Definition	Source
Bank control variables:			
Income gap	Income gap/TA	The income gap measures the difference between cash-flows coming from assets and liabilities plus cash-flows coming from off-balance sheet items that reprice or maturity within 1 year (see also section B.2). The metric considers cash-flows from all currencies, expressed in euro.	ECB Supervisory Statistics
Bank size	Log (TA)	Logarithm of bank total assets	ECB Supervisory Statistics
Liquidity	Cash/TA	The ratio of cash incl. cash held at the central bank to total assets	ECB Supervisory Statistics
Profitability	ROA	The ratio of net income to total assets	ECB Supervisory Statistics
Funding structure	Debt securities/TA	The ratio of debt securities issued to total assets	ECB Supervisory Statistics
	Deposits/TA	The ratio of deposits to total assets	ECB Supervisory Statistics
Non-performing loans	NPL ratio	The ratio of non-performing loans to gross loans	ECB Supervisory Statistics
Capitalisation	Distance to MDA	The CET1 ratio in excess of the maximum distributable amount	ECB Supervisory Statistics
Off-balance sheet	Off BS/TA	The ratio of off balance sheet activities to total assets	ECB Supervisory Statistics
Overnight deposit composition	Share OV deposits to HH	The ratio of overnight deposits to households to total overnight deposits	ECB Supervisory Statistics
Bank-firm level variables:			
Loan maturity	Log Weighted maturity	The logarithm of the maturity at bank-firm level, weighted by the loan-level exposures	AnaCredit
Firm level variables:			
Firm size		Indicator for micro, small, medium and large firms	AnaCredit
High exposure to duration risk	High exposure	Dummy variable equal to 1 when a firm borrows for more than 50% from a bank with a high exposure to duration risk, i.e., a bank in the top quartile of the distribution in 2021Q1	AnaCredit, ECB Supervisory Statistics

B Online appendix

B.1 Coverage of countries in the matched sample



(a)



(b)

Figure 9: Coverage per country in the *AnaCredit* sample matched with supervisory bank-level data.

B.2 Computation of the income gap

The income gap is constructed using quarterly data on cash-flows for significant institutions following equation (4):

$$IncomeGap = \sum_{j=1}^{1y} \left(\frac{A^j - L^j}{Z} \right) \tag{4}$$

This metric measures the difference between cash-flows coming from on- and off balance sheet assets and cash-flows coming from on- and off balance sheet liabilities that reprice or maturity within 1 year ($A^j - L^j$). The cash-flows are scaled by total assets (Z). A positive income gap signals a positive impact of increasing interest rates on net interest income in the short term. In Table 13, we show that the income gap is significantly correlated with some bank-level characteristics using data from the pre-tightening period, such as the Cash/TA ratio, the ROA, and the NPL ratio.

Table 13: Regression of the income gap on the set of control variables using bank-level data from the pre-tightening period.

	Dependent variable: Income gap/TA							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log TA	-0.720	-1.332						
	(-0.96)	(-1.58)						
Cash/TA	-0.458**		-0.289*					
	(-2.64)		(-1.74)					
ROA	5.35***			7.13***				
	(2.71)			(3.38)				
Debt securities/TA	-0.130				0.0294			
	(-1.22)				(0.31)			
NPL ratio	-1.11*					-0.893		
	(-1.70)					(-1.36)		
Distance to MDA	0.147						0.104	
	(0.88)						(0.65)	
Observations	403	418	418	418	406	412	418	

*Note: ***: 0.01,**: 0.05,*: 0.1. Bank-level clustered standard errors are reported in parenthesis. For the definitions of the variables, we refer to Table 12.Column (1) includes all the control variables simultaneously, while column (2) to (8) show the results when including one control variable at a time.*

B.3 Extensive margin: new bank-firm relationship

In our main analysis, we evaluate the effects on the probability of issuing a new loan. In this section, we look at the probability of starting a new bank firm relationship, i.e., the extensive margin. More specifically, we follow Iyer et al. (2014) and define a dummy endogenous variable equal to 1 if: a) at time t a new company that did not have a relationship in the previous quarter enters the *AnaCredit* registry, and b) a company that was in the sample in $t-1$ because it borrowed from bank x also starts borrowing from bank y at time t, therefore establishing a new borrowing relationship. In order to allow the inclusion of new companies that did not have a relationship in the previous quarter, this set of regressions includes ILS fixed effects instead of firm fixed effects. Although we find a negative coefficient of interest, pointing towards a lower probability of establishing new bank-firm relationships for banks with a high duration gap when interest rates increase, the results are not significant (Table 14).

Following Jasova et al. (2021), we use a second approach to investigate the effect of duration gap on the extensive margin in a rising interest rate environment. Specifically, we collapse the dataset as explained in Section 6.2 and construct an *exit-* and *entry-dummy* at the bank-firm level that are used as endogenous variables. The *exit dummy* takes the value of 1 when a bank-firm relationship appears in the pre-tightening period but does not exist in the post-tightening period and zero otherwise, vice versa for the *entry dummy*. While we do not find any statistically significant relationship between a bank's duration gap in the pre-tightening period and the probability of terminating bank-firm relationships in the post-tightening period, we do find that banks with a larger duration gap in the pre-tightening period (2022Q2) are statistically significantly less likely to initiate a new bank-firm relationship in the post-tightening period (2023Q2) (Table 15).

Table 14: Effects on the extensive margin (new bank-firm relationship)

	Dependent variable: New bank-firm relationship			
	(1)	(2)	(3)	(4)
gap/TA (lag)	-0.000137	0.0000461	-0.000120	0.0000560
	(-0.43)	(0.15)	(-0.36)	(0.18)
Duration gap/TA (lag) × Δpolicy rate	-0.00455	-0.0236	-0.00667	-0.0253
	(-0.14)	(-0.80)	(-0.19)	(-0.83)
Income gap/TA (lag)		-0.0000934		-0.000111
		(-0.12)		(-0.14)
Income gap/TA (lag) × Δpolicy rate		0.00215		0.00360
		(0.03)		(0.06)
Log TA (lag)		0.00347		0.00352
		(0.64)		(0.62)
Log TA (lag) × Δpolicy rate		-0.484		-0.453
		(-0.94)		(-0.85)
Cash/TA (lag)		-0.00117		-0.00117
		(-0.58)		(-0.56)
Cash/TA (lag) × Δpolicy rate		0.175		0.178
		(0.86)		(0.84)
ROA (lag)		0.000278**		0.000279**
		(2.17)		(2.10)
ROA (lag) × Δpolicy rate		-0.00811		-0.00869
		(-0.55)		(-0.57)
Debt securities (lag)		-0.00337***		-0.00336***
		(-3.77)		(-3.71)
Debt securities (lag) × Δpolicy rate		0.234**		0.228**
		(2.37)		(2.28)
NPL ratio		-0.0000889		-0.0000900
		(-1.23)		(-1.18)
NPL ratio × Δpolicy rate		0.00849		0.00883
		(1.24)		(1.21)
Distance to MDA (lag)		0.00262*		0.00262*
		(1.91)		(1.84)
Distance to MDA (lag) × Δpolicy rate		-0.238		-0.222
		(-1.60)		(-1.42)
Observations	9138235	9059521	9138235	9059521
ILS*Time*Interest rate type FE	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes

Table 15: Effects on the extensive margin (exit and entry dummies)

	Dependent variable: Exit dummy				*Dependent variable: Entry dummy*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (pre)	0.000432	0.000551	0.000359	0.000149	-0.000936**	-0.000862***	-0.000990**	-0.000993***
	(0.36)	(0.66)	(0.28)	(0.17)	(-2.15)	(-2.67)	(-2.22)	(-3.06)
Income gap/TA (pre)		0.00170		0.000261		-0.00157		-0.00197
		(0.57)		(0.08)		(-1.49)		(-1.65)
Log TA (pre)		0.0123		0.00444		-0.0105**		-0.0113**
		(0.62)		(0.21)		(-2.22)		(-2.42)
Cash/TA (pre)		-0.0740		-0.0555		0.0990		0.110
		(-0.21)		(-0.16)		(0.74)		(0.80)
ROA (pre)		-0.0415		-0.0171		0.0394*		0.0399
		(-0.84)		(-0.36)		(1.71)		(1.66)
Debt securities/TA (pre)		0.184		0.299		-0.128		-0.0966
		(0.34)		(0.53)		(-1.04)		(-0.76)
NPL ratio (pre)		0.00245		-0.0191		-0.00241		-0.00635
		(0.32)		(-1.29)		(-0.69)		(-1.16)
Distance to MDA (pre)		-0.547		-0.748		0.0366		0.0251
		(-0.91)		(-1.14)		(0.18)		(0.12)
Observations	1027663	1024987	1027663	1024987	925652	923053	925652	923053
Borrower*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

B.4 Further sensitivity checks

In this section, we perform multiple sensitivity checks to our baseline analysis. In particular, we: i) include additional time-varying bank-specific characteristics on top of the regressors already used in the baseline; ii) use different thresholds for defining short- and long-term lending; iii) employ a different clustering of standard errors; iv) test the baseline estimates via a generalised propensity score weighting approach; v) examine non-linearities of our results; vi) and change the endogenous variable. We find that our results are robust to all these sensitivity checks.

B.4.1 Additional control variables

In our baseline regressions, we use the share of debt securities to total assets to control for bank funding structures. Next to these debt securities, deposits are an important source of funding for banks, while off-balance sheet items reflect the extent to which banks rely on off-balance sheet financing. We therefore include (the lag of) deposits over total assets and off-balance sheet items to total assets as extra control variables to our baseline regressions, which we also interact with the change in the policy rate. At the bank-firm level, the data allows us to additionally control for the weighted maturity of the loan portfolio, which could impact lending growth with portfolios with a longer maturity often relating to more stable lending. We find similar results for our coefficient of interest when controlling for these additional factors, as shown in Table 16. The net effects of deposits and off-balance sheet items over total assets, evaluated at a 400 bps increase in the policy rate, are not significant. We find a negative and significant relationship between weighted maturity of the loan portfolio and quarter-on-quarter lending growth.

Table 16: Additional control variables

	Dependent variable: Δ Log (loans)	
	(1)	(2)
Duration gap/TA (lag)	0.000227***	0.000229**
	(2.68)	(2.63)
Duration gap/TA (lag) × Δpolicy rate	-0.0285***	-0.0283***
	(-4.14)	(-3.99)
Income gap/TA (lag)	0.000216	0.000239
	(0.73)	(0.79)
Income gap/TA (lag) × Δpolicy rate	-0.0128	-0.0147
	(-0.54)	(-0.60)
Log TA (lag)	0.00970***	0.00979***
	(4.27)	(4.31)
Log TA (lag) × Δpolicy rate	-0.327	-0.312
	(-1.60)	(-1.48)
Cash/TA (lag)	0.00103**	0.00103**
	(2.45)	(2.43)
Cash/TA (lag) × Δpolicy rate	-0.0617	-0.0636
	(-1.14)	(-1.15)
ROA (lag)	0.000147**	0.000150**
	(2.50)	(2.53)
ROA (lag) × Δpolicy rate	-0.0205***	-0.0209***
	(-3.56)	(-3.57)
Debt securities/TA (lag)	0.00166***	0.00171***
	(2.83)	(2.86)
Debt securities/TA (lag) × Δpolicy rate	-0.0180	-0.0182
	(-0.31)	(-0.31)
NPL ratio (lag)	0.00539***	0.00552***
	(3.17)	(3.16)
NPL ratio (lag) × Δpolicy rate	0.544**	0.557**
	(2.49)	(2.48)
Distance to MDA (lag)	-0.000445	-0.000500
	(-0.65)	(-0.73)
Distance to MDA (lag) × Δpolicy rate	0.339***	0.343***
	(3.57)	(3.52)
Deposits/TA (lag)	0.243***	0.247***
	(4.28)	(4.30)
Deposits/TA (lag) × Δpolicy rate	-3.986	-3.969
	(-0.96)	(-0.94)
Off BS/TA (lag)	0.00402	0.00282
	(0.12)	(0.08)
Off BS/TA (lag) × Δpolicy rate	-5.901	-6.070
	(-1.34)	(-1.36)
Log weighted maturity	-0.0135***	-0.0134***
	(-3.86)	(-3.84)
Observations	1808666	1808652
Borrower*Time*Interest rate type FE	Yes	Yes
Country*Time FE	No	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

B.4.2 Different thresholds for defining short- vs long-term lending

In our baseline analysis, we evaluate whether banks with a large duration gap reshuffle their lending from long- to short-term loans when interest rates increase, where we use 2 years as a cut-off to define short- vs long-term lending. We test the sensitivity to this cut-off by using 1 and 3 years as a threshold. As can be seen from Tables 17, 18, 19, and 18, regardless of the cut-off, we find that banks with a larger duration gap significantly reduce their long-term lending and have a lower probability of issuing a loan with a longer maturity when interest rates increase, while the effects on short-term lending and the probability of issuing a loan with a short maturity are not significant.

Table 17: Effects on short- and long-term lending growth (cut-off: 1 year)

	Short-term loans (maturity ≤ 1 years)				*Long-term loans (maturity > 1 years)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (lag)	-0.000307	0.000113	-0.000409	0.000000546	0.000233	0.000278*	0.000230	0.000278
	(-0.58)	(0.22)	(-0.78)	(0.00)	(1.53)	(1.67)	(1.49)	(1.64)
Duration gap/TA (lag) × Δpolicy rate	0.00123	-0.00348	0.0141	0.0105	-0.0612***	-0.0561***	-0.0617***	-0.0567***
	(0.02)	(-0.05)	(0.24)	(0.17)	(-2.84)	(-3.18)	(-2.82)	(-3.14)
Income gap/TA (lag)		0.00312		0.00303		-0.000815**		-0.000820**
		(1.20)		(1.14)		(-2.05)		(-2.03)
Income gap/TA (lag) × Δpolicy rate		-0.244		-0.236		0.0759**		0.0763**
		(-1.21)		(-1.14)		(2.37)		(2.34)
Log TA (lag)		0.0272***		0.0270***		0.00605*		0.00614*
		(2.99)		(2.87)		(1.68)		(1.67)
Log TA (lag) × Δpolicy rate		-1.158		-1.109		-0.526		-0.517
		(-0.88)		(-0.81)		(-1.35)		(-1.30)
Cash/TA (lag)		0.00250		0.00236		0.00185***		0.00183***
		(1.08)		(1.00)		(2.95)		(2.90)
Cash/TA (lag) × Δpolicy rate		-0.152		-0.126		-0.0865		-0.0854
		(-0.35)		(-0.28)		(-1.12)		(-1.09)
ROA (lag)		-0.00636		-0.00654		0.0195*		0.0194*
		(-0.21)		(-0.21)		(1.73)		(1.72)
ROA (lag) × Δpolicy rate		-2.12		-2.05		-4.12***		-4.21***
		(-0.58)		(-0.55)		(-3.08)		(-3.10)
Debt securities/TA (lag)		0.000312		0.000384		-0.000859		-0.000865
		(0.12)		(0.15)		(-1.65)		(-1.63)
Debt securities/TA (lag) × Δpolicy rate		0.0946		0.0876		0.00886		0.00838
		(0.29)		(0.26)		(0.10)		(0.09)
NPL ratio (lag)		0.00726		0.00609		0.00535		0.00547
		(0.58)		(0.48)		(1.50)		(1.49)
NPL ratio (lag) × Δpolicy rate		0.456		0.638		1.63***		1.65***
		(0.29)		(0.40)		(3.74)		(3.71)
Distance to MDA (lag)		-0.000524		-0.000578		-0.00248*		-0.00247*
		(-0.10)		(-0.11)		(-1.93)		(-1.91)
Distance to MDA (lag) × Δpolicy rate		1.228		1.375		0.519**		0.531**
		(1.45)		(1.58)		(2.10)		(2.11)
Observations	23868	23489	23828	23453	1868900	1854954	1868886	1854940
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 18: Effects on short- and long-term lending growth (cut-off: 3 years)

	Short-term loans (maturity ≤ 3 years)				*Long-term loans (maturity > 3 years)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (lag)	0.000374	0.000307	0.000317	0.000231	0.000134	0.000241	0.000129	0.000242
	(1.18)	(0.99)	(0.99)	(0.73)	(0.90)	(1.44)	(0.86)	(1.42)
Duration gap/TA (lag) × Δpolicy rate	-0.0668	-0.0514	-0.0606	-0.0409	-0.0476**	-0.0471**	-0.0477**	-0.0476**
	(-1.43)	(-1.33)	(-1.26)	(-1.02)	(-2.07)	(-2.45)	(-2.04)	(-2.42)
Income gap/TA (lag)		0.000376		0.000305		-0.000820*		-0.000822*
		(0.28)		(0.22)		(-1.98)		(-1.95)
Income gap/TA (lag) × Δpolicy rate		-0.0136		-0.00995		0.0778**		0.0779**
		(-0.13)		(-0.09)		(2.28)		(2.26)
Log TA (lag)		0.00644		0.00587		0.00833**		0.00847**
		(1.38)		(1.26)		(2.22)		(2.22)
Log TA (lag) × Δpolicy rate		-0.403		-0.345		-0.518		-0.517
		(-0.68)		(-0.55)		(-1.27)		(-1.24)
Cash/TA (lag)		0.00649***		0.00652***		0.000882		0.000855
		(5.79)		(5.70)		(1.49)		(1.43)
Cash/TA (lag) × Δpolicy rate		-0.306*		-0.331*		-0.0662		-0.0648
		(-1.77)		(-1.93)		(-0.92)		(-0.89)
ROA (lag)		0.00763		0.00778		0.0242*		0.0242*
		(0.44)		(0.44)		(1.99)		(1.98)
ROA (lag) × Δpolicy rate		-3.11		-3.63		-4.18***		-4.27***
		(-1.30)		(-1.51)		(-2.97)		(-2.99)
Debt securities/TA (lag)		-0.000670		-0.000498		-0.000704		-0.000726
		(-0.57)		(-0.42)		(-1.25)		(-1.26)
Debt securities/TA (lag) × Δpolicy rate		0.0855		0.0973		-0.0162		-0.0130
		(0.55)		(0.58)		(-0.17)		(-0.13)
NPL ratio (lag)		-0.00125		-0.00257		0.00602		0.00621
		(-0.21)		(-0.42)		(1.62)		(1.63)
NPL ratio (lag) × Δpolicy rate		1.18		1.34		1.72***		1.72***
		(1.28)		(1.45)		(3.57)		(3.49)
Distance to MDA (lag)		0.00457		0.00452		-0.00311**		-0.00310**
		(1.59)		(1.55)		(-2.38)		(-2.35)
Distance to MDA (lag) × Δpolicy rate		1.078***		0.968**		0.556**		0.561**
		(2.83)		(2.60)		(2.13)		(2.11)
Observations	91791	90860	91762	90837	1608646	1596189	1608630	1596173
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 19: Effects on short- and long-term new loans (cut-off: 1 year)

	New loan (maturity ≤ 1 years)				*New loan (maturity > 1 years)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (lag)	-0.000357	-0.000235	-0.000390	-0.000315	0.000378***	0.000395***	0.000383***	0.000401***
	(-0.99)	(-0.57)	(-1.07)	(-0.74)	(2.84)	(2.69)	(2.86)	(2.65)
Duration gap/TA (lag) × Δpolicy rate	0.0267	0.0415	0.0335	0.0512	-0.0562***	-0.0635***	-0.0567***	-0.0641***
	(0.76)	(0.95)	(0.94)	(1.15)	(-2.71)	(-4.19)	(-2.69)	(-4.12)
Income gap/TA (lag)		0.00155		0.00123		-0.000789		-0.000794
		(0.97)		(0.76)		(-1.45)		(-1.43)
Income gap/TA (lag) × Δpolicy rate		-0.129		-0.104		0.0560		0.0564
		(-1.01)		(-0.80)		(1.28)		(1.26)
Log TA (lag)		0.000366		-0.00165		0.00534		0.00530
		(0.05)		(-0.22)		(1.46)		(1.44)
Log TA (lag) × Δpolicy rate		0.392		0.625		-1.028***		-1.035***
		(0.39)		(0.61)		(-3.23)		(-3.21)
Cash/TA (lag)		0.00113		0.00144		0.00330***		0.00334***
		(0.69)		(0.89)		(3.78)		(3.83)
Cash/TA (lag) × Δpolicy rate		-0.302		-0.339		-0.110		-0.108
		(-1.15)		(-1.29)		(-1.32)		(-1.28)
ROA (lag)		0.0287		0.0320		0.0146		0.0149
		(1.09)		(1.21)		(1.53)		(1.55)
ROA (lag) × Δpolicy rate		-7.806**		-8.158**		-1.764**		-1.785**
		(-2.44)		(-2.51)		(-2.35)		(-2.36)
Debt securities/TA (lag)		-0.00354**		-0.00299		-0.00171***		-0.00171***
		(-2.03)		(-1.66)		(-2.96)		(-2.90)
Debt securities/TA (lag) × Δpolicy rate		0.578**		0.521*		0.130*		0.130*
		(2.29)		(1.98)		(1.95)		(1.92)
NPL ratio (lag)		0.000357		-0.00207		0.00232		0.00234
		(0.04)		(-0.21)		(0.76)		(0.75)
NPL ratio (lag) × Δpolicy rate		-0.177		0.137		0.192		0.192
		(-0.16)		(0.12)		(0.74)		(0.72)
Distance to MDA (lag)		0.000575		0.000526		0.00155		0.00153
		(0.17)		(0.15)		(1.13)		(1.10)
Distance to MDA (lag) × Δpolicy rate		-0.698		-0.622		0.132		0.133
		(-1.10)		(-0.96)		(0.93)		(0.92)
Observations	23868	23489	23828	23453	1868900	1854954	1868886	1854940
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 20: Effects on short- and long-term new loans (cut-off: 3 year)

	New loan (maturity ≤ 3 years)				*New loan (maturity > 3 years)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Duration gap/TA (lag)	0.000310	0.000219	0.000296	0.000192	0.000311**	0.000372***	0.000317***	0.000379***
	(1.47)	(0.88)	(1.39)	(0.75)	(2.63)	(2.88)	(2.66)	(2.85)
Duration gap/TA (lag) × Δpolicy rate	-0.0226	-0.0314	-0.0215	-0.0298	-0.0488***	-0.0535***	-0.0492***	-0.0539***
	(-0.75)	(-1.08)	(-0.70)	(-1.00)	(-3.28)	(-4.01)	(-3.26)	(-3.95)
Income gap/TA (lag)		0.00321		0.00348		-0.000858*		-0.000871*
		(1.11)		(1.16)		(-1.88)		(-1.87)
Income gap/TA (lag) × Δpolicy rate		-0.251		-0.271		0.0615		0.0625
		(-0.72)		(-0.77)		(1.66)		(1.65)
Log TA (lag)		0.00219		0.00171		0.00853**		0.00852**
		(0.42)		(0.33)		(2.50)		(2.48)
Log TA (lag) × Δpolicy rate		-0.302		-0.262		-0.999***		-1.013***
		(-0.49)		(-0.42)		(-3.21)		(-3.23)
Cash/TA (lag)		0.00405***		0.00423***		0.00287***		0.00291***
		(3.47)		(3.62)		(3.68)		(3.72)
Cash/TA (lag) × Δpolicy rate		-0.314**		-0.338***		-0.0855		-0.0834
		(-2.50)		(-2.68)		(-1.05)		(-1.02)
ROA (lag)		0.0141		0.0144		0.0167*		0.0170*
		(0.66)		(0.66)		(1.79)		(1.81)
ROA (lag) × Δpolicy rate		-2.909		-3.084		-2.097**		-2.124**
		(-1.38)		(-1.44)		(-2.58)		(-2.58)
Debt securities/TA (lag)		-0.00492***		-0.00489***		-0.00115**		-0.00113**
		(-3.74)		(-3.63)		(-2.38)		(-2.30)
Debt securities/TA (lag) × Δpolicy rate		0.301**		0.303*		0.148**		0.150**
		(2.04)		(1.99)		(2.58)		(2.60)
NPL ratio (lag)		-0.00162		-0.00210		0.00382		0.00382
		(-0.23)		(-0.29)		(1.31)		(1.28)
NPL ratio (lag) × Δpolicy rate		-0.362		-0.281		0.320		0.314
		(-0.58)		(-0.44)		(1.23)		(1.18)
Distance to MDA (lag)		0.00321		0.00348		0.000980		0.000962
		(1.11)		(1.16)		(0.78)		(0.76)
Distance to MDA (lag) × Δpolicy rate		-0.251		-0.271		0.105		0.101
		(-0.72)		(-0.77)		(0.80)		(0.76)
Observations	91791	90860	91762	90837	1608646	1596189	1608630	1596173
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

B.4.3 Clustering of standard errors

In the baseline regressions, we cluster the standard errors at the bank- and firm- level to account for serial correlation within bank-firm relationships. As suggested by Bertrand et al. (2004), we cluster the standard errors in this robustness check only at the bank level, which corresponds to the level of the treatment (i.e., variation in the duration gap). Our results are robust to this alternative clustering (see Table 21).

Table 21: Regression clustering standard errors only at bank level

	Dependent variable: Δ Log (loans)			
	(1)	(2)	(3)	(4)
Duration gap/TA (lag)	0.000144	0.000193	0.000144	0.000194
	(0.99)	(1.30)	(0.99)	(1.28)
Duration gap/TA (lag) × Δpolicy rate	-0.0292*	-0.0300**	-0.0294*	-0.0302**
	(-1.68)	(-2.28)	(-1.67)	(-2.24)
Income gap/TA (lag)		-0.000460		-0.000467
		(-1.20)		(-1.19)
Income gap/TA (lag) × Δpolicy rate		0.0390		0.0395
		(1.30)		(1.29)
Log TA (lag)		0.00503		0.00507
		(1.56)		(1.54)
Log TA (lag) × Δpolicy rate		-0.422		-0.413
		(-1.62)		(-1.55)
Cash/TA (lag)		0.00150**		0.00151**
		(2.37)		(2.39)
Cash/TA (lag) × Δpolicy rate		-0.0694		-0.0704
		(-0.95)		(-0.96)
ROA (lag)		0.0130		0.0131
		(1.44)		(1.44)
ROA (lag) × Δpolicy rate		-2.30**		-2.35**
		(-2.36)		(-2.37)
Debt securities/TA (lag)		-0.000897**		-0.000902**
		(-2.07)		(-2.02)
Debt securities/TA (lag) × Δpolicy rate		0.0500		0.0494
		(0.86)		(0.84)
NPL ratio (lag)		0.00285		0.00287
		(0.95)		(0.93)
NPL ratio (lag) × Δpolicy rate		0.731**		0.746**
		(2.61)		(2.60)
Distance to MDA (lag)		-0.000848		-0.000837
		(-0.73)		(-0.71)
Distance to MDA (lag) × Δpolicy rate		0.282*		0.286*
		(1.76)		(1.75)
Observations	2028673	2013105	2028661	2013091
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Bank-level clustered standard errors are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

B.4.4 Generalised propensity score weighting

In Table 2, we have already shown that prior to the tightening, the duration gap was not significantly correlated with any of the bank-level characteristics. However, it could be that for some banks, this assumption does not hold. In this robustness check, we go one step further by using the *covariate-balancing generalised propensity score weighting* proposed by Fong et al. (2018) and used by Gomez et al. (2021). More specifically, this method calculates weights that minimise the correlation between the (continuous) value of the duration gap and the value of the bank-level control variables based on the pre-tightening bank level sample. These weights are then used to re-estimate the baseline regressions. The results in Table 22 show that the coefficients are similar to the baseline results, albeit somewhat larger in magnitude. This confirms that the original sample was already considerably balanced in terms of bank-level characteristics.

Table 22: Covariate-balancing generalised propensity score weighting

	Dependent variable: Δ *Log (loans)*			
	(1)	(2)	(3)	(4)
Duration gap/TA (lag)	0.000178	0.000226**	0.000178	0.000228*
	(1.62)	(2.02)	(1.61)	(2.00)
Duration gap/TA (lag)× Δpolicy rate	-0.0326**	-0.0330***	-0.0328**	-0.0333***
	(-2.50)	(-3.32)	(-2.49)	(-3.27)
Income gap/TA (lag)		-0.000462		-0.000467
		(-1.59)		(-1.57)
Income gap/TA (lag) × Δpolicy rate		0.0397*		0.0401*
		(1.73)		(1.71)
Log TA (lag)		0.00531**		0.00535**
		(2.16)		(2.14)
Log TA (lag) × Δpolicy rate		-0.412**		-0.400*
		(-2.05)		(-1.95)
Cash/TA (lag)		0.00133***		0.00135***
		(2.83)		(2.86)
Cash/TA (lag) × Δpolicy rate		-0.0526		-0.0543
		(-0.95)		(-0.97)
ROA (lag)		0.000144*		0.000146*
		(1.90)		(1.90)
ROA (lag) × Δpolicy rate		-0.0226***		-0.0231***
		(-2.97)		(-2.98)
Debt securities/TA (lag)		-0.000947***		-0.000952***
		(-2.88)		(-2.82)
Debt securities/TA (lag) × Δpolicy rate		0.0396		0.0381
		(0.85)		(0.80)
NPL ratio (lag)		0.00275		0.00279
		(1.22)		(1.20)
NPL ratio (lag) × Δpolicy rate		0.785***		0.802***
		(3.78)		(3.78)
Distance to MDA (lag)		-0.000876		-0.000868
		(-0.96)		(-0.94)
Distance to MDA (lag) × Δpolicy rate		0.295**		0.301**
		(2.36)		(2.36)
Observations	2028673	2013105	2028661	2013091
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

B.4.5 Non-linearities

We examine the non-linearity of our results in this sensitivity check. More specifically, instead of using a continuous variable to measure the exposure to interest rate risk, we now move to a dummy variable which is equal to 1 when a bank has a positive duration gap (equal or bigger than 0) and 0 otherwise. As such, we compare how banks that are hurt by increasing interest rates in terms of economic value of equity (i.e., having a positive duration gap) alter their lending behaviour compared to banks that benefit from increasing interest rates (i.e., having a negative duration gap). Columns (1) to (4) in Table 23 show the results. We find that a bank with a positive duration gap reduces lending by 1.84 to 2.19 p.p. more than a bank with a negative duration gap when interest rates increase.

Given that our treatment variable in this case is binary, this analysis is suitable for a propensity score matching approach. As a first step, we examine whether bank-level characteristics during the pre-tightening period are significantly different for banks with a negative vs positive duration gap. As shown in Table 24, there are no significant differences between the averages of the bank-level characteristics for the two groups of banks. However, we proceed by performing our estimations on a sample of banks that are matched to other banks with similar characteristics.[27] Although this reduces our sample by around 10 to 12 banks, the propensity score distributions are closer in the matched sample compared to the unmatched sample (Figure 10). The results in columns (5) to (8) show that, when only considering banks that are closely related in terms of characteristics, we also find that banks with a positive duration gap significantly reduce lending more compared to banks with a negative duration gap when interest rates increase. The magnitude of the effect is slightly smaller, with coefficients ranging between 1.49 and 1.97 p.p.

[27] The banks are matched based on the bank-level control variables prior to the tightening using a propensity score matching logit estimation with caliper of 0.05 and a radius of 3 matches with replacement. The regressions in column (5) to (8) of Table 23 include between 53 and 55 banks.

Table 23: Non-linear effects

	Unmatched sample				Matched sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Positive duration gap (lag)	0.00636**	0.00473	0.00629**	0.00464	0.00826**	0.00373	0.00824**	0.00367
	(2.07)	(1.54)	(2.04)	(1.50)	(2.03)	(0.70)	(2.01)	(0.67)
Positive duration gap (lag) × Δpolicy rate	-2.189***	-1.859***	-2.187***	-1.839***	-1.968***	-1.512***	-1.969***	-1.494***
	(-4.85)	(-5.04)	(-4.84)	(-4.99)	(-3.63)	(-3.53)	(-3.61)	(-3.44)
Income gap/TA (lag)		-0.000606**		-0.000617**		-0.00127***		-0.00130***
		(-2.02)		(-2.02)		(-3.05)		(-3.06)
Income gap/TA (lag) × Δpolicy rate		0.0531**		0.0539**		0.115**		0.117**
		(2.25)		(2.25)		(2.52)		(2.49)
Log TA (lag)		0.00416*		0.00418*		0.00578*		0.00584*
		(1.87)		(1.84)		(1.72)		(1.69)
Log TA (lag) × Δpolicy rate		-0.315		-0.307		-0.405**		-0.406**
		(-1.52)		(-1.46)		(-2.09)		(-2.06)
Cash/TA (lag)		0.00147***		0.00149***		0.00160***		0.00161***
		(3.13)		(3.16)		(2.94)		(2.93)
Cash/TA (lag) × Δpolicy rate		-0.0799		-0.0802		-0.0924*		-0.0910*
		(-1.65)		(-1.65)		(-1.82)		(-1.79)
ROA (lag)		0.0111*		0.0111*		0.0127*		0.0128*
		(1.81)		(1.82)		(1.81)		(1.81)
ROA (lag) × Δpolicy rate		-1.785***		-1.821***		-1.789**		-1.818**
		(-2.95)		(-2.96)		(-2.62)		(-2.62)
Debt securities/TA (lag)		-0.000706**		-0.000707**		-0.000927**		-0.000937**
		(-2.29)		(-2.24)		(-2.14)		(-2.11)
Debt securities/TA (lag) × Δpolicy rate		0.00102		0.000736		0.0428		0.0449
		(0.03)		(0.02)		(1.31)		(1.39)
NPL ratio (lag)		0.00212		0.00210		0.00170		0.00166
		(1.00)		(0.97)		(0.67)		(0.64)
NPL ratio (lag) × Δpolicy rate		0.521***		0.539***		0.338		0.351
		(2.76)		(2.77)		(1.45)		(1.45)
Distance to MDA (lag)		-0.000952		-0.000936		0.000531		0.000598
		(-1.11)		(-1.07)		(0.46)		(0.51)
Distance to MDA (lag) × Δpolicy rate		0.339***		0.341***		0.170*		0.164
		(2.76)		(2.73)		(1.69)		(1.61)
Observations	2028673	2013105	2028661	2013091	1613866	1613827	1613856	1613813
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country*Time FE	No	No	Yes	Yes	No	No	Yes	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*

Table 24: Mean of bank-level characteristics during the pre-tightening period

Variable	Negative duration gap	Positive duration gap	Difference
Income gap/TA (%)	4.99	3.65	1.34
			(0.64)
Log TA	11.68	11.69	-0.01
			(0.98)
Cash/TA (%)	17.24	16.76	0.48
			(0.79)
ROA (%)	0.37	0.47	-0.10
			(0.27)
Debt securities/TA (%)	11.44	12.45	-1.01
			(0.72)
NPL ratio (%)	3.34	2.87	0.47
			(0.49)
Distance to MDA (%)	7.33	6.88	0.46
			(0.75)

*Note: ***: 0.01,**: 0.05,*: 0.1. The numbers are based on the pre-tightening period (2021Q1-2022Q2) for banks included in the regressions described in section B.4.5. There are 22 banks with a duration gap below zero, while there are 44 banks with a duration gap equal or above zero. The numbers in brackets represent the p-values related to the null hypotheses whether the difference is statistically different from zero. For the definitions of the variables, we refer to Table 12.*

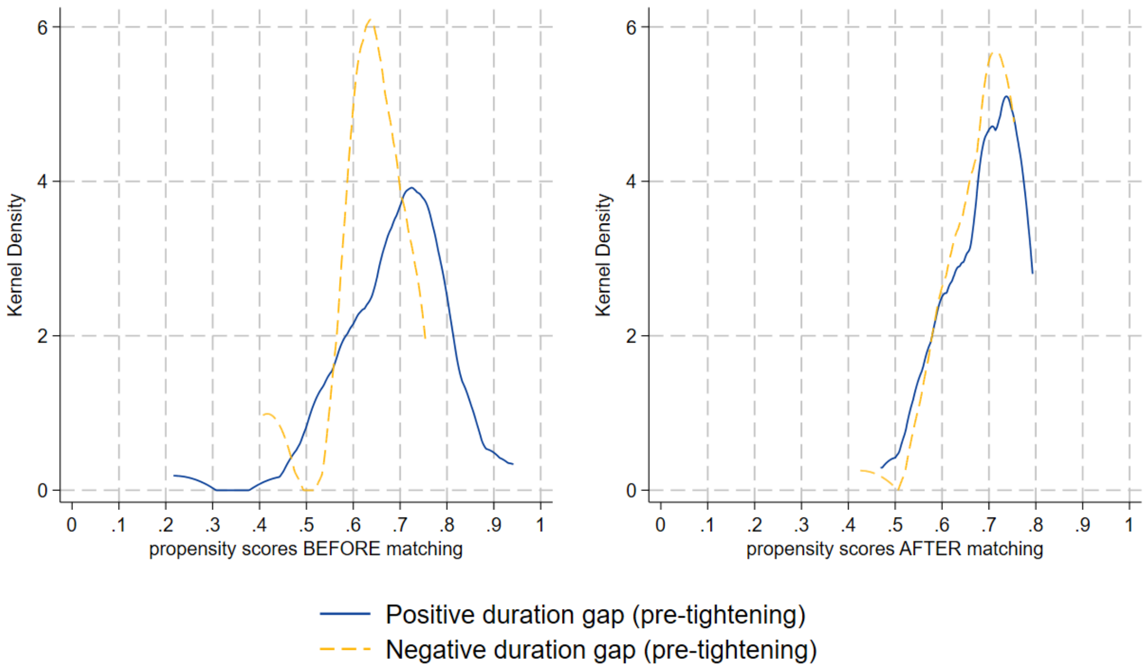


Figure 10: Propensity score distribution for the unmatched and matched sample.

B.4.6 Log of lending

In order to assess the impact of a tightening in monetary policy for banks with a different exposure to duration risk on the *level* of bank-firm lending, we replace the dependent variable in our baseline regression by the log of loans as in Fraisse et al. (2020). As in our baseline results, we find that our coefficient of interest is negative and statistically significant (Table 25). A bank with a duration gap at the 75^{th} percentile reduces its amount lent by 4.1% to 6.8% when interest rates increase compared to a bank with a duration gap at the 25^{th} percentile.

Table 25: Regression with log lending as dependent variable

	Dependent variable: Log (loans)			
	(1)	(2)	(3)	(4)
Duration gap/TA (lag)	0.00149	0.00213***	0.00145	0.00214***
	(1.63)	(3.61)	(1.56)	(3.60)
Duration gap/TA (lag) × Δpolicy rate	-0.220**	-0.133***	-0.220**	-0.134***
	(-2.05)	(-2.87)	(-2.02)	(-2.85)
Income gap/TA (lag)		-0.00367**		-0.00371**
		(-2.10)		(-2.10)
Income gap/TA (lag) × Δpolicy rate		0.283**		0.287**
		(2.01)		(2.01)
Log TA (lag)		0.105***		0.107***
		(8.41)		(8.43)
Log TA (lag) × Δpolicy rate		-0.916		-0.840
		(-1.11)		(-0.98)
Cash/TA (lag)		0.00509*		0.00490*
		(1.83)		(1.75)
Cash/TA (lag)× Δpolicy rate		-0.0886		-0.114
		(-0.29)		(-0.37)
ROA (lag)		-0.00305		-0.00386
		(-0.14)		(-0.17)
ROA (lag) × Δpolicy rate		-8.777**		-9.013***
		(-2.64)		(-2.67)
Debt securities/TA (lag)		0.0147***		0.0145***
		(4.99)		(4.84)
Debt securities/TA (lag) × Δpolicy rate		0.0808		0.0679
		(0.44)		(0.35)
NPL ratio (lag)		0.0222		0.0236
		(1.40)		(1.45)
NPL ratio (lag) × Δpolicy rate		3.737***		3.914***
		(3.84)		(3.94)
Distance to MDA (lag)		0.00566		0.00613
		(0.93)		(0.98)
Distance to MDA (lag) × Δpolicy rate		0.0416		0.0728
		(0.09)		(0.15)
Observations	2028673	2013105	2028661	2013091
Borrower*Time*Interest rate type FE	Yes	Yes	Yes	Yes
Country*Time FE	No	Yes	No	Yes

*Note: ***: 0.01,**: 0.05,*: 0.1. Two-way clustered standard errors at both bank and firm level are reported in parenthesis. For the definitions of the variables, we refer to Table 12.*