Relationship Lending and Monetary Policy Pass-Through*

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October 2023

Abstract

This paper investigates the link between bank-firm lending relationships and monetary policy pass-through, particularly in the context of low interest rates. Using administrative tax and bank supervisory data spanning from 1997 to 2019, we track the entirety of bank-firm relationships in Norway. Our analysis shows that when the Norwegian Interbank Offered Rate (NIBOR) is relatively low, firms that have maintained long-term relationships with banks experience a lower pass-through of further policy rate cuts. We propose a banking model to rationalize these empirical findings, where state-dependent differential pass-through results from the presence of firms' switching costs and banks' leverage constraint. The model highlights that the composition of relationship lengths in the economy matters for aggregate monetary policy pass-through.

JEL Classification: G21, E58, E52, E43, E50

Keywords: Relationship lending; Monetary policy pass-through; Policy rate; Loan rate; Switching cost

*We thank seminar participants at Stanford University, the University of Zurich, and Norges Bank for their very valuable comments. We thank Saskia ter Ellen for her generosity of sharing data with us. This paper should not be reported as representing the views of Norges Bank. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank.

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1 Introduction

In the aftermath of the 2007-2008 financial crisis, the central banks of advanced economies set their policy rates to unprecedented low levels. Amid sluggish recovery, low inflation and further financial distress in Europe following the 2010-2012 sovereign debt crisis, the low interest rate environment persisted throughout the 2010s. For example, the ECB's main refinancing operations rate never rose above 1.5% during this period, even reaching 0% between 2016 and 2019. In the US, the federal funds target rate always remained below 0.5% between 2010 and 2016. Some central banks, such as the Swiss National Bank and the Sveriges Riksbank, even set negative policy rates. In such a setting, monetary policy transmission recently received increased attention due to potentially being impaired at low and negative interest rates.[1] At the beginning of 2020, Janet Yellen, former chairwoman of the Federal Reserve, said: "I worry about low interest rates [...] it has put central banks in a position where they don't have a lot of ammunition. If we have a serious recession, [...] we're probably not going to be able to count on central banks to offer up a significant response."[2]

Most of the research concerning the diminished efficacy of monetary policy under low interest rates has primarily concentrated on the presence of an effective lower bound on deposit rates and its consequences for banks' profitability and their lending behavior. Comparatively little consideration has been given to how the interplay between financial intermediaries and their borrowers is influenced by the prevailing interest rate environment, potentially resulting in reduced transmission of monetary policy to bank loan rates when policy rates are low. In particular, to our knowledge, there is no direct empirical evidence on how the transmission is shaped by the dynamics of bank-borrower relationships, despite a large extant literature on relationship lending.[3] In this paper, we contribute to the intersection of both strands of literature by empirically estimating the heterogeneous pass-through from policy rates to loan rates for firms with different relationship lengths and for environments with different interest

[1](see, e.g., Wang, Whited, Wu, and Xiao, 2022; Heider, Saidi, and Schepens, 2019; Ulate, 2021; Eggertsson, Juelsrud, Summers, and Wold, 2019; Brunnermeier and Koby, 2018)

[2]A conversation with David Malpass and Janet Yellen at event hosted by Bipartisan Policy Center, George Washington University, February 4, 2020. (https://www.worldbank.org/en/news/speech/2020/02/04/transcript-a-conversation-with-david-malpass-and-janet-yellen-at-the-bipartisan-policy-center)

[3]For theoretical studies on the interaction between lending relationships and monetary policy, see, e.g., Hachem (2011); Araujo, Minetti, and Murro (2021); Bethune, Rocheteau, Wong, and Zhang (2021). While relationships can benefit firms and banks by reducing information asymmetries between them (Diamond, 1984), they also create information asymmetries among banks (Sharpe, 1990; Rajan, 1992; von Thadden, 2004; Dell'ariccia and Marquez, 2004) which lead to informational switching costs. Depending on the circumstances, banks can exploit switching costs by holding up their borrowers and extracting rents from them (see, e.g., Petersen and Rajan, 1994; Berlin and Mester, 1999; Schenone, 2010; Bolton, Freixas, Gambacorta, and Mistrulli, 2016; Kysucky and Norden, 2016; Beck, Degryse, De Haas, and van Horen, 2018; Botsch and Vanasco, 2019; Li, Lu, and Srinivasan, 2019; Liaudinskas, 2023).

rate levels. Our results suggest a relationship-based explanation, which we formalize with a model, for the impairment of monetary policy transmission in the low interest rate environment.

Our empirical analyses are based on an advanced economy, Norway, which provides an almost ideal setting for our study as it collects detailed yearly balance sheets and income statements from every firm and bank operating in the country. Moreover, our data include the amounts of paid interest and outstanding loans at yearly frequency between borrowing firms and banks, which allows us to track lending relationships over time and estimate firm-bank specific average loan interest rates. We start by presenting empirical evidence supporting the existence of state-dependent and asymmetric average within-relationship pass-through. Specifically, we find that when the Norwegian Interbank Offered Rate (NIBOR), the central bank's target rate, is one standard deviation below its mean, at approximately 1.1%, banks pass only 9% of a further policy rate cut on to firms' loan rates. In contrast, when the NIBOR is one standard deviation above its mean, at approximately 5.4%, the within-relationship pass-through rate increases to 61% of a rate cut. Our findings are consistent with recent research that has documented a lower monetary policy pass-through at low interest rates. Furthermore, our estimates reveal a significant degree of asymmetry in the pass-through rates. Specifically, banks demonstrate a much greater willingness to pass policy rate increases on to firms' loan rates.

Having evidence of impaired within-relationship monetary policy pass-through at low rates, we investigate the impact of bank-firm relationship length on the pass-through to individual firms. In a linear specification that allows for initial policy rate dependence and asymmetry, we find that when the NIBOR is low, additional years of relationship are associated with reduced pass-through of a policy rate cut. Specifically, at a NIBOR rate of 1.1%, an additional year of relationship is associated with a 2.7 percentage point decrease in the average pass-through of a further rate cut. Conversely, longer relationships are associated with greater pass-through in the event of a monetary policy tightening, with each additional year of relationship being linked to an 8 percentage point increase in pass-through of a rate hike. We test the robustness of these results by allowing for non-linearity in both the initial level of the policy rate and relationship length. Our kernel regressions reveal a threshold effect, with relationship length having no impact on monetary policy pass-through when the NIBOR is above 1.5%. Below this threshold, we observe significant differences in pass-through based on relationship lengths, with the first years of a relationship appearing to create the greatest heterogeneity in pass-through. These findings suggest that, in a low interest rate environment, the length of bank-firm relationships is an important determinant of within-relationship monetary policy pass-through.

To understand whether differential credit supply shifts driven by banks rather than a higher increase in long-relationship firms' demand account for the lower pass-through, we examine the marginal effects of relationship length on loan growth rates following a policy rate cut. Our results suggest that long-relationship firms experience a relatively lower increase in loan volumes, supporting the view that the lower pass-through is driven by the supply side. We further explore the real effects of lower pass-through to long-relationship firms by analyzing changes in firms' tangible capital as a proxy for investment. Our findings indicate that, following a policy rate cut, an investment wedge emerges between long- and short-relationship firms. Specifically, we find that each year of relationship at the time of the shock reduces cumulated tangible capital growth rates by 0.25 percentage points over the four years that follow the shock.

The existing literature has predominantly relied on two primary explanations for why firms become locked in relationships with their bank: information asymmetry between inside and outside banks, and firms' switching costs. To account for our empirical findings using the information asymmetry explanation, we would anticipate that firms engaged in long-term relationships are, on average, of a worse type. Consequently, they would secure relatively high interest rates when switching banks, which, in turn, would enable their existing bank to provide them with reduced pass-through following a rate cut. Conversely, to attribute these results to switching costs, we would anticipate that longer relationships involve higher switching costs. We investigate the extensive margin of relationship lending to discern which of these two explanations is more likely applicable in our dataset. We match firms that switched banks with comparable non-switching firms to estimate the interest rate discounts that the switchers receive when transitioning to a different bank. Subsequently, we conduct a regression analysis on these discounts, considering the switchers' previous relationship durations. Our findings indicate that switchers who had maintained longer relationships with their former bank receive higher discounts at their new bank. This suggests that firms engaged in longer relationships indeed face higher switching costs and only choose to switch when offered relatively substantial discounts. Furthermore, when we match previous short-relationship switchers with previous long-relationship switchers who both arrive at the same new bank, we find that the firms with longer prior relationships receive lower interest rates at the new bank, suggesting they are perceived as a relatively better type. Based on this evidence, we lean towards the explanation of switching costs in developing a model that rationalizes our differential pass-through results.

Our findings regarding differential within-relationship pass-through suggest that the distribution of relationship durations in the economy could impact the aggregate transmission of monetary policy. To elaborate, when longer-lasting relationships exhibit lower pass-through, an increase in their prevalence within the economy can reduce aggregate pass-through due to a compositional effect. This is an important consideration as the proportion of long-term relationships in the Norwegian economy has significantly grown since the financial crisis. For instance, the proportion of relationships lasting longer than 6 years rose from 21% in 2006 to 36% in 2017. The question we ask is how much higher aggregate pass-through in 2017 would have been if the share of long relationships had remained at its 2006 level. It is crucial to note that the pass-through rates specific to different relationship durations might themselves depend on the equilibrium distribution of relationship lengths in the economy. Therefore, in principle, we cannot solely rely on our empirical estimates of within-relationship pass-through to determine how much aggregate pass-through would change with an alternative composition of relationship lengths in the economy. This is because such an approach would neglect potential equilibrium effects resulting from the distribution of relationship lengths on within-relationship pass-through rates. To address this, we introduce a banking model that provides a framework rationalizing our empirical findings. We use this model to calculate counterfactual aggregate pass-through rates under a different relationship length distribution, while considering the equilibrium effects on within-relationship pass-through rates.

The model rests on three key assumptions. First, firms have heterogeneous private switching costs for changing banks. Banks cannot observe their customers' individual switching costs, but they do observe the distributions of these costs by relationship duration. Second, banks face a leverage constraint that limits the amount of loans they can hold on their balance sheets. Third, banks price compete for switching firms. That is, the competitive rate that banks offer to capture switchers is the lowest rate such that no individual bank can undercut it, thereby attracting all switchers, and still satisfy its leverage constraint. In this setting, the policy rate is crucial for banks' net worth. This gives rise to two distinct regimes: In the first regime, when the policy rate is high, banks are far from their leverage constraint, and the competitive rate is driven down to the level of the policy rate by price competition. Banks charge a constant markup above the policy rate and monetary policy pass-through is the same for all firms and equal to one. In the second regime, when the policy rate falls below a cutoff, banks become so close to their leverage constraints that the competitive rate exceeds the policy rate. Banks then charge an increasing markup above the policy rate as the latter decreases. Consequently, the pass-through of monetary policy is impaired and falls below unity. Furthermore, it varies across firms with different relationship lengths and depends on the distribution of switching costs. We lay out the equilibrium condition under which the pass-through to long-relationship firms is smaller, and show it can easily be solved analytically when switching costs are generalized Pareto distributed. Intuitively, banks provide a reduced pass-through of rate cuts to their long-term customers when the distribution of switching costs for these firms exhibits a relatively large mass in the right tail. In this case, a larger proportion of long-term relationships compared to short-term ones are bound to their respective banks because of the substantial switching costs involved. This situation enables banks to maintain a lower pass-through rate for these long-term relationships. We use the model to conduct a counterfactual exercise under some distributional assumption and estimate that aggregate pass-through would have been up to 23% higher in 2017 if the composition of relationship length in the economy had remained as in 2006. The entire change can be attributed to a compositional effect. The within-relationship pass-through rates remain largely unaffected by the shift in the composition of relationship lengths. This has significant implications for policymakers, as it implies that any alterations in the distribution of relationship lengths in the economy will have an impact on the aggregate pass-through of monetary policy. Furthermore, it suggests that reduced-form empirical estimates of within-relationship pass-through rates are sufficient for predicting changes in aggregate monetary policy pass-through following shifts in the composition of relationship lengths within the economy.

Our empirical study belongs to a broader research agenda that investigates the extent to which monetary policy pass-through varies depending on the monetary policy environment. While Altavilla, Burlon, Giannetti, and Holton (2022) find that conventional monetary policy can remain effective below the zero lower bound by means of the pass-through to corporate deposit rates, leading to increased investment by firms, Eisenshmidt and Smets (2019), Ulate (2021), Balloch and Koby (2022), and Balloch, Koby, and Ulate (2022) find that the pass-through to household deposit rates is impaired at low policy rate levels, affecting the lending activities of banks that heavily rely on deposit funding. The majority of previous studies are concerned about a potential zero lower bound on deposit rates and its consequences for monetary transmission when policy rates reach low levels. In this paper, we focus on the bank lending channel and, therefore, the sensitivity of *lending* rates to monetary policy. There is less agreement in the literature on the level of pass-through to lending rates when policy rates are low. For example, Eisenshmidt and Smets (2019) and Ulate (2021) report positive pass-through, while Amzallag, Calza, Georgarakos, and Sousa (2019) and Eggertsson et al. (2019) observe near-zero pass-through. Our research adds to this ongoing debate by providing further empirical evidence that suggests the pass-through to corporate lending rates is significantly diminished in a low-rate environment. Our primary contribution, however, is the evidence of relationship-induced heterogeneity in pass-through to lending rates when policy rates are low. In particular, our results suggest that in such a context, long relationships weaken the bank lending channel.

The model we propose contributes to a limited theoretical literature that seeks to explain the impact of low and negative policy rates on the monetary transmission mechanism. Brunnermeier and Koby (2018) introduce a model that includes a reversal rate, which is the policy rate below which further monetary policy easing becomes contractionary. At low policy rates, banks' margins become thinner, negatively affecting equity and eventually leading to binding capital constraints. As equity issuance is costly, any further reduction in the policy rate must result in decreased lending. Ulate (2021) develops a banking model to investigate the effectiveness of monetary policy in negative territories, mainly through the presence of a zero lower bound on deposit rates that negatively affects bank profitability at low rates. Similarly, Eggertsson et al. (2019) examine the impact of low policy rates in the presence of a lower bound on deposit rates, which disrupts the transmission of rate cuts to the primary source of financing for banks. Wang (2018) also studies the effects of low interest rates on monetary policy transmission, with a focus on the differences between short-term and long-term effects. Similarly to most of these models, our framework also relies on bank net worth being negatively affected by low policy rates, and the presence of a capital constraint.

The rest of the paper proceeds as follows: Section 2 presents the details of the data that are used in our analyses, and the measurements of our key variables. Section 3 contains our empirical analyses. In Section 4, we present a theoretical framework to rationalize our empirical findings and conduct a counterfactual exercise. Section 5 concludes.

2 Data

We draw data mainly from three different sources. The first source is the credit register data provided by the Norwegian Tax Administration.[4] By the end of each year, all banks report all outstanding loan accounts (stock) as well as interest paid on each loan account (flow) to the tax administration for tax purposes. This dataset links each loan account to a unique firm identifier, which allows us to track all bank-firm relationships from 1997 to 2019 at a yearly frequency. We define a firm and a bank to be in a relationship in a given year if either the outstanding loan amount or the interest paid is larger than zero. To construct an unbounded measure of bank-firm relationship length, we drop the existing relationships in the first year of our sample since we do not have information on their starting date. In tracking relationships through time, we account for approximately 50 bank mergers and acquisitions that took place over the 23 years that the dataset covers. Specifically, if bank A absorbs bank B, bank A typically lays hold of the information set on bank B's clients. Moreover, bank B's clients who stay with bank A after the merger do not incur switching costs. We therefore ignore the apparent switches in the data from bank B to bank A by bank B's customers, and treat these cases as continuing relationships. To obtain the average interest rate paid

[4] *Skatteetaten*

by a firm to its bank in year t, we divide the interest amount paid throughout year t by the average of the stocks of loan at the end of years $t-1$ and t. To get rid of clearly erroneous and extreme values of interest rates, we trim the distribution at the 5% and 95% levels. Even though we use firm-bank-account level information in our robustness analysis, the main dataset for our main analysis is at the firm-bank level.

We match this dataset with data from our second source, the firm register data provided by Brønnøysund Register Centre.[5] By the end of each year, all firms operating in Norway are required to register their balance sheets and financial statements at the Register Centre. In our analysis, we drop financial firms and government-owned firms. The third source is the yearly balance sheet reports of all banks operating in Norway – including subsidiaries and branches of foreign-owned banks (mostly Swedish and Danish), between 2000 and 2019 from the financial market statistics (ORBOF).[6] Our final dataset comprises 205 banks and $289,086$ firms for a total of $460,722$ unique bank-firm relationships. A particularity of the Norwegian setting is the very low share of firms that simultaneously maintain multiple bank relationships. Roughly 90% of firms only borrow from one bank at a given point in time.

To analyze the pass-through level of monetary policy, we primarily use average annual changes in the Norwegian Interbank Offered Rate (NIBOR). The latter is the target interest rate used by Norges Bank to conduct monetary policy, and we therefore interchangeably refer to it as the policy rate throughout the rest of the paper. We have daily data on the level of the NIBOR. To construct average annual changes, we follow Gertler and Karadi (2015). For each day of the year, we cumulate the daily changes of the NIBOR on any day during all days of the year. We then average these yearly changes across each day of the year. This procedure ensures that a change in the NIBOR on December 31^{st} of year t will mostly be reflected in year $t+1$ in the series of average annual changes. Figure 1a shows the evolution of the NIBOR over our sample period and figure 1b shows the average annual changes. Changes in the policy rate can obviously be endogenous: The central bank adapts its policy to respond to changes in the state of the economy, which may themselves have confounding effects on the change in loan rates charged by banks to firms. Yet, it is still common in the literature to use changes in the policy rate and attempt to address endogeneity concerns by including different sets of fixed effects, see, for example Greenwald (2019). The use of industry-time fixed effects, for example, controls for the macroeconomic shocks that might have caused the policy rate change, even in the case they have different effects on different sectors. In our specifications, we also use industry-location-size-time fixed effects. As robustness checks, we also re-run our entire analyses using identified monetary policy

[5] *Brønnøysundregistrene*

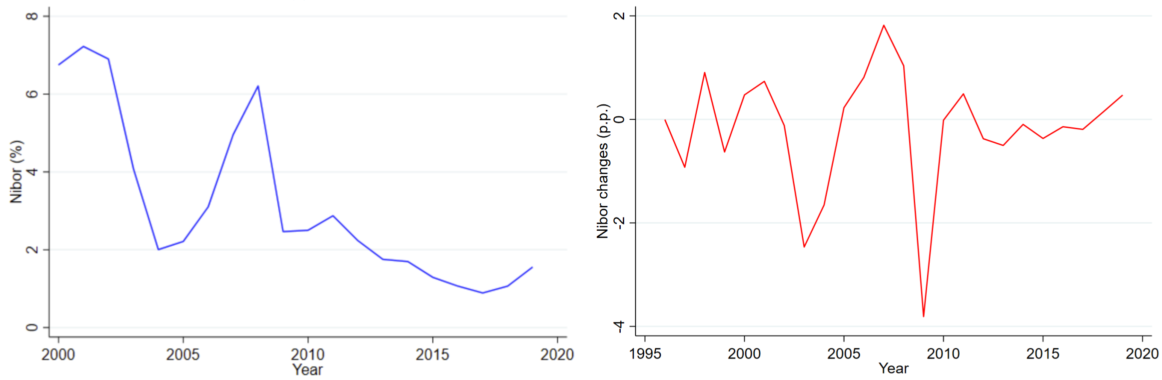
[6] *Offentlig Regnskapsrapportering fra Banker og Finansieringsforetak* (financial reports from banks and financial undertakings)

shocks. We draw these series of exogenous shocks from Brubakk, ter Ellen, Robstad, and Xu (2022), who follow Jarociński and Karadi (2020) and extract monetary policy surprises from one-month rates for a 30-minute window around the central bank, Norges Bank's monetary policy announcements. We then build annual monetary policy shock series following Gertler and Karadi (2015).

Another concern is that relationship length between a given bank and firm is not randomly assigned, and might be correlated with bank and firm characteristics that influence loan interest rates. We try to account for this by controlling for firm-level characteristics and interacting them with the monetary policy shocks, allowing loan rates of firms with different observables to react differently to the same policy rate change. Insofar as selection into a given relationship length is correlated with these characteristics, controlling for them should reduce the endogeneity bias. We also include bank-firm fixed effects, controlling for any time-invariant relationship-level characteristics that influence both loan rates and relationship duration, and bank-time fixed effects.

Table 1 provides some summary statistics of the main variables used in our analyses. Figure 2 shows the five-year moving average of the NIBOR and the evolution of bank switching intensity, defined as the number of firms switching banks divided by the total number of firms in the economy in a given year. The chart shows a positive correlation between the two measures, indicating fewer firms switch when the policy rate is low. Figure 3a again shows bank switching intensity, but broken down by relationship length. It reveals that the overall decline in switching intensity is driven by firms in relationships longer than four years, while the switching intensity of firms in shorter relationships remains stable through time. Figure 3b shows the evolution of the composition of relationships in the economy by duration. It is clear that, consistently with decreasing switching rates, the share of relatively long relationships in the economy drastically increases in the years following the global financial crisis and the introduction of low policy rates. The share of relationships shorter than five years decreased from an average of 60% (pre-crisis), to an average of 48% (post-crisis).

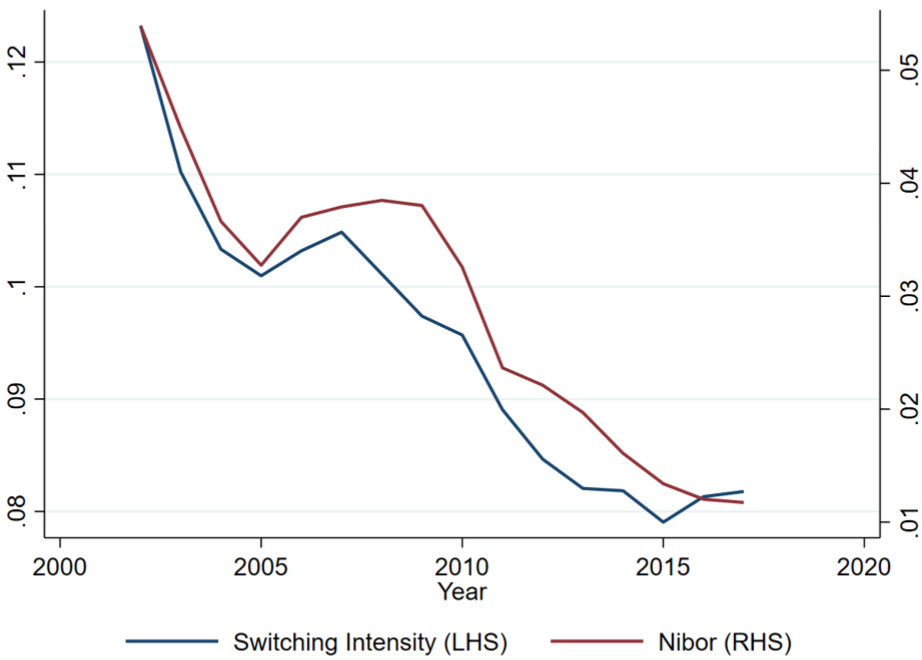
Figure 1



(a) NIBOR: Levels

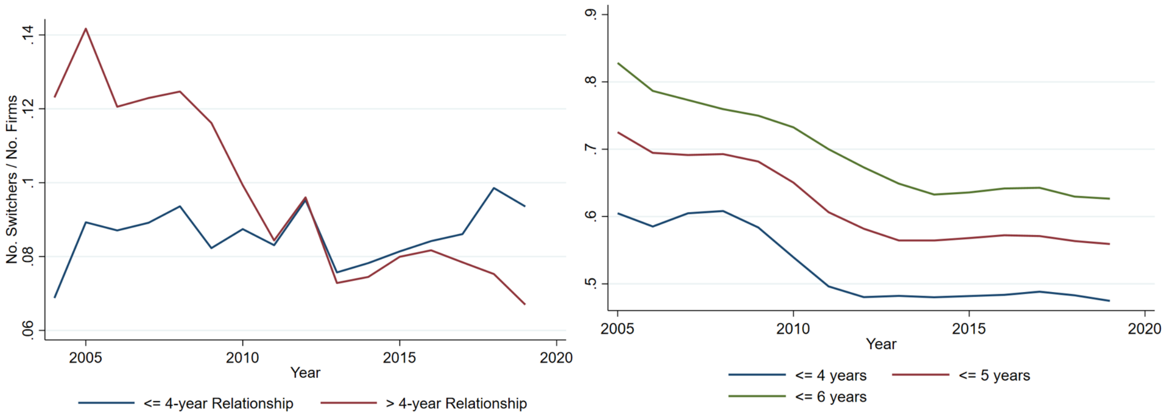
(b) NIBOR: Annual Changes

Figure 2: NIBOR (Five-Year Moving Average) and Bank Switching Intensity



Notes: Switching intensity in a given year is defined as the number of firms starting a new relationship (i.e. borrowing from a new bank) divided by the total number of operating firms in the economy.

Figure 3



(a) Switching Intensity by Relationship Length **(b)** Composition of Relationship Lengths

Notes: The left-hand side chart shows switching intensity by relationship length. Specifically, the blue line shows the number of firms with a current relationship shorter than 5 years starting a new relationship divided by the total number of firms with a current relationship shorter than 5 years. The red line shows the same for firms with relationships longer than 4 years. The right-hand side is a stacked chart showing the evolution of the composition of relationships lengths in the economy.

Table 1: Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min.	Max.
		Macro Variables			
3-month Nibor (%)	20	3.14	2.12	.89	7.23
ΔNibor (p.p.)	20	-.18	1.25	-3.81	1.82
Exogenous MP Shock (p.p.)	20	-.02	.19	-.41	.51
		Relationships			
Length (years)	1,316,117	4.83	3.78	1	22
		Loans			
Interest Received (NOK)	1,316,117	404,077	5,135,723	1	5.23e+09
Loan Amount Outstanding (NOK)	1,316,117	9,636,235	1.47e+08	0	1.52e+11
Interest Rate (%)	1,316,117	7.01	4.45	.12	26.85
ΔInterest Rate (p.p.)	998,702	-.26	2.84	-9.76	8.51
		Firms			
Total Assets (NOK)	1,219,763	90,117.31	3,171,825	0	1.04e+09
Total Debt/Total Assets	1,219,763	.68	.24	0	1
Age (years)	1,219,763	11.61	11.84	1	167
Credit Rating (1-5 ordinal)	1,083,106	3.37	.89	1	5
No. of Creditor Banks	1,219,763	1.14	.44	1	71

3 Empirical Analysis

3.1 Relationship Duration and Policy Rate Pass-Through

We investigate the connection between relationship duration and monetary policy pass-through, and how the initial level of the policy rate matters for this connection. We start by looking at the pass-through to loan rates. Then, in an attempt to distinguish between supply and demand shocks, we investigate the changes in loan volumes following monetary policy shocks. Finally, we show that the identified channel has real effects through investment.

3.1.1 Loan Rates

To evaluate the magnitude and economic significance of any effect that relationship duration may have on monetary policy pass-through, it is useful to first estimate the average pass-through in the economy. We do so by estimating the following regression, in which γ_1 is the coefficient of interest:

$$\Delta r_{ibt} = \alpha_{ib} + MP_{t-1}\gamma_1 + \mathbf{Z}_{i,t-1}\boldsymbol{\delta_1} + \mathbf{W}_{b,t-1}\boldsymbol{\delta_2} + \mathbf{V}_{t-1}\boldsymbol{\delta_3} + \epsilon_{ibt}, \tag{1}$$

where Δr_{ibt} is the change in interest rate paid by firm i to bank b between $t-1$ and t. α_{ib} are firm-bank (i.e. relationship) fixed effects. MP_{t-1} is the monetary policy change in $t-1$. $\mathbf{Z}_{it}$ are firm-level controls including age, size, leverage, and credit rating. $\mathbf{W}_{bt}$ are bank-level controls including size measured by the logarithm of total assets, interbank borrowing to total liabilities ratio, deposits to total liabilities ratio, loans to deposits ratio, equity to total assets ratio, liquid assets to total assets ratio, and financial securities to total assets ratio. $\mathbf{V}_t$ are macroeconomic controls including GDP growth, inflation, a measure of market volatility (VIX index), oil prices, the NOK/USD exchange rate, and the slope of the yield curve measured as the difference between the yields on 10y-NIBOR and 3m-NIBOR. Column 2 of Table 2 shows that a 1 p.p. increase in the NIBOR is associated with a 0.483 p.p. increase in loan rates on average.

We then allow for asymmetric pass-through, depending on whether monetary policy is tightening or loosening.

$$\Delta r_{ibt} = \alpha_{ib} + MP_{t-1}[\gamma_1 + tight_{t-1}\gamma_2] + tight_{t-1}\gamma_3 + \mathbf{Z}_{i,t-1}\boldsymbol{\delta_1} + \mathbf{W}_{b,t-1}\boldsymbol{\delta_2} + \mathbf{V}_{t-1}\boldsymbol{\delta_3} + \epsilon_{ibt}, \tag{2}$$

where the dummy variable $tight_t$ equals one when the policy rate increases. Column 4 of Table 2 shows that pass-through displays strong asymmetry with only 26% of a policy rate cut transmitted to firms, while banks increase rates by 143% of a policy rate hike on average.

Finally, we add an interaction term with the initial level of the NIBOR, allowing pass-through to depend on the initial stance of monetary policy.

(3)
$$\Delta r_{ibt} = \alpha_{ib} + MP_{t-1}[\gamma_1 + tight_{t-1}\gamma_2 + Nibor_{t-1}(\gamma_3 + tight_{t-1}\gamma_4)] + tight_{t-1}\gamma_5 + Nibor_{t-1}\gamma_6 + tight_{t-1} \times Nibor_{t-1}\gamma_7 + \mathbf{Z}_{i,t-1}\boldsymbol{\delta_1} + \mathbf{W}_{b,t-1}\boldsymbol{\delta_2} + \mathbf{V}_{t-1}\boldsymbol{\delta_3} + \epsilon_{ibt},$$

where $Nibor_{t-1}$ is the level of the NIBOR at time $t-1$. Column 6 of Table 2 shows that as the policy rate decreases, any further cut is transmitted to a lesser extent. Symmetrically, as the policy rate increases, smaller shares of further hikes are passed on to firms. Table 3 summarizes this by calculating the average monetary policy pass-through in the case of a monetary expansion/contraction in a low/high initial policy rate environment. It is constructed using the coefficient estimates of regression (3). When the NIBOR is one standard deviation below its mean, *only* 9% *of a further rate cut is passed on to firms.* This contrasts with the 61% that are transmitted when the initial policy rate is one standard deviation above the mean.

Having shown that the average pass-through following a policy rate cut is decreasing in the initial level of said policy rate, we next investigate the role of bank-firm relationship duration. We run similar regressions to those estimating the average pass-through, but now include interaction terms between relationship duration and monetary policy shocks. Since we are interested in the marginal effect of a bank-firm-time level variable (i.e. relationship length) on pass-through, we can now include time fixed effects, which was not possible for the estimation of the average monetary policy pass-through. We run the following set of regressions and report the estimated coefficients of interest in Table 4.

(4)
$$\Delta r_{ibt} = \alpha_{ib} + length_{ib,t-1}\mathbf{X}_{t-1}\beta + \epsilon_{ibt}$$

(5)
$$\Delta r_{ibt} = \alpha_{ib} + \alpha_{bt} + length_{ib,t-1}\mathbf{X}_{t-1}\beta + \epsilon_{ibt}$$

(6)
$$\Delta r_{ibt} = \alpha_{ib} + \alpha_{bt} + \alpha_{jlst} + length_{ib,t-1}\mathbf{X}_{t-1}\beta + \epsilon_{ibt}$$

Table 2: Within-Relationship Pass-Through

	(1)	(2)	(3)	(4)	(5)	(6)
ϵ^m_{t-1}	0.143***	0.483***	0.022	0.263***	-0.640***	-0.042
	(0.012)	(0.031)	(0.011)	(0.017)	(0.031)	(0.065)
$tight_{t-1} \times \epsilon^m_{t-1}$			0.286***	1.167***	4.324***	3.160***
			(0.045)	(0.045)	(0.135)	(0.155)
$\epsilon^m_{t-1} \times i_{t-1}$					0.252***	0.121***
					(0.012)	(0.021)
$tight_{t-1} \times \epsilon^m_{t-1} \times i_{t-1}$					-0.761***	-0.388***
					(0.037)	(0.025)
N	937476	763122	937476	763122	937476	763122
Macro Controls	No	Yes	No	Yes	No	Yes
Firm Controls	No	Yes	No	Yes	No	Yes
Bank Controls	No	Yes	No	Yes	No	Yes
Industry-Time FE	No	No	No	No	No	No
ILS-Time FE	No	No	No	No	No	No
Bank-Time FE	No	No	No	No	No	No
Bank-Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: Columns (1)-(2) report the estimated coefficients of interest from regression (1). Columns (3)-(4) report the estimated coefficients of interest from regression (2). Columns (5)-(6) report the estimated coefficients of interest from regression (3). Macroeconomic controls **V** include GDP growth, inflation, market volatility (VIX index), oil prices, the NOK/USD exchange rate, and the slope of the yield curve (difference between the yields on 10y-NIBOR and 3m-NIBOR). Firm controls **Z** include age, size, leverage, and credit rating. Bank controls **W** include size measured by the logarithm of total assets, interbank borrowing to total liabilities ratio, deposits to total liabilities ratio, loans to deposits ratio, equity to total assets ratio, liquid assets to total assets ratio, and financial securities to total assets ratio.

$$\Delta r_{ibt} = \alpha_{ib} + \alpha_{jt} + \alpha_{bt} + length_{ib,t-1}\mathbf{X}_{t-1}\beta + \mathbf{Z}_{i,t-1}\mathbf{U}_{i,t-1}\delta + \epsilon_{ibt}, \tag{7}$$

where $length_{ib,t-1}$ is the relationship length between firm i and bank b at time $t-1$,

$$\mathbf{X}'_{t-1} = \begin{pmatrix} 1 \\ MP_t \\ Nibor_t \\ tight_t \\ MP_t \times Nibor_t \\ MP_t \times tight_t \\ tight_t \times Nibor_t \\ MP_t \times tight_t \times Nibor_t \end{pmatrix},$$

Table 3: Within-Relationship Pass-Through: Marginal Effects

	Easing ($tight_{t-1} = 0$)	Tightening ($tight_{t-1} = 1$)
Low Nibor	0.090^{*}	2.827^{***}
($i_{t-1} = 1.09\%$)	(0.044)	(0.129)
High Nibor	0.610^{***}	1.685^{***}
($i_{t-1} = 5.37\%$)	(0.056)	(0.099)

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table shows the marginal effects of MP (change in NIBOR) on Δr (change in loan rates) when monetary policy is loosening/tightening and when the initial level of the NIBOR is one standard deviation below/above its mean. Marginal effects are calculated from specification (3) and the estimated coefficients of column (6) in table 2.

and

$$\mathbf{U}'_{t-1} = \begin{pmatrix} \mathbf{X'}_{t-1} & \ldots & \mathbf{X'}_{t-1} \end{pmatrix}$$

with the column dimension of $\mathbf{U}'_{t-1}$ being equal to the number of firm-level controls in $\mathbf{Z}_{i,t-1}$.

In regression (4), we do not control for anything beyond bank-firm fixed effects (α_{ib}). In regression (5), we add bank-time fixed effects (α_{bt}). Identification within bank-time takes care of the concern that relationship duration may be correlated with bank balance sheet items (such as deposit ratios), which also affect pass-through. To control for the demand side and identify supply shocks, the literature typically relies on the inclusion of firm-time fixed effects. Under the assumption that firms have the same demand for credit across banks at one point in time, identification within firm-time ensures that any estimated effect does not come from changes in firm demand. However, the structure of bank-firm relationships in Norway prevents us from relying on firm-time fixed effects. Indeed, approximately 90% of the firms in our dataset only borrow from a single bank at one point in time. In regression (6), we try to circumvent this issue by following Degryse, De Jonghe, Jakovljević, Mulier, and Schepens (2019) and add firm industry-location-size-time fixed effects (α_{jlst}). Under the assumption that firms within the same cell have the same demand for credit across banks, these fixed effects allow to identify supply shocks. In regression (7), we only include firm industry-time fixed effects (α_{jt}) and control for a set of firm characteristics (age, size, leverage, credit rating). We also interact these firm characteristics with the monetary policy shocks, allowing the former to matter for the extent of monetary policy pass-through.

Table 4 shows that the estimates are similar across specifications. In particular, regressions (6) and (7), which both attempt to control for demand, yield quantitatively close estimates in the case of a monetary policy expansion. The negative coefficient on the interaction between length and monetary policy shock, along with the positive coefficient on the interaction between length, monetary policy shock, and NIBOR indicate that, after a policy rate cut, the pass-through is decreasing in relationship length when the NIBOR is low. Table 5 shows the marginal effects (calculated from the estimates of regression (7)) of relationship length on pass-through in the case of a monetary policy expansion/contraction in a low/high initial policy rate environment. It shows that when the NIBOR is one standard deviation below its mean, each additional year of relationship at the moment of the shock *reduces* the pass-through of a policy rate cut by 2.7 percentage points. This effect represents roughly one-third of the average pass-through from Table 3. On the other hand, each additional year of relationship *increases* the pass-through of a policy rate hike by 8 percentage points. It appears that at low policy rates, banks take advantage of their long-relationship customers in both directions of a policy rate change. In contrast, when the NIBOR is one standard deviation above its mean, the pass-through following a policy rate cut is larger for firms in long relationships.

Table 4: Pass-Through and Relationship Length

	(1)	(2)	(3)	(4)
$length_{ibt} \times \epsilon^m_{t-1}$	-0.062***	-0.053***	-0.057***	-0.054***
	(0.010)	(0.012)	(0.012)	(0.012)
$length_{ibt} \times \epsilon^m_{t-1} \times i_{t-1}$	0.030***	0.024***	0.026***	0.026***
	(0.004)	(0.005)	(0.005)	(0.005)
$tight_{t-1} \times length_{ibt} \times \epsilon^m_{t-1}$	0.056*	0.085*	0.073**	0.149***
	(0.028)	(0.034)	(0.028)	(0.034)
$tight_{t-1} \times length_{ibt} \times \epsilon^m_{t-1} \times i_{t-1}$	0.004	-0.027**	-0.025***	-0.040***
	(0.007)	(0.009)	(0.007)	(0.008)
N	937476	937449	703029	865407
Macro Controls	No	No	No	No
Firm Controls	No	No	No	Yes
Bank Controls	No	No	No	No
Industry-Time FE	No	No	No	Yes
ILS-Time FE	No	No	Yes	No
Bank-Time FE	No	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: Columns (1)-(4) report the estimated coefficients of interest from regressions (4)-(7) respectively. Firm controls **Z** include age, size, leverage, and credit rating.

Table 5: Pass-Through and Relationship Length: Marginal Effects

	Easing ($tight_{t-1} = 0$)	Tightening ($tight_{t-1} = 1$)
Low Nibor	-0.027***	0.080*
($i_{t-1} = 1.09\%$)	(0.007)	(0.033)
High Nibor	0.083***	0.020
($i_{t-1} = 5.37\%$)	(0.014)	(0.186)

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

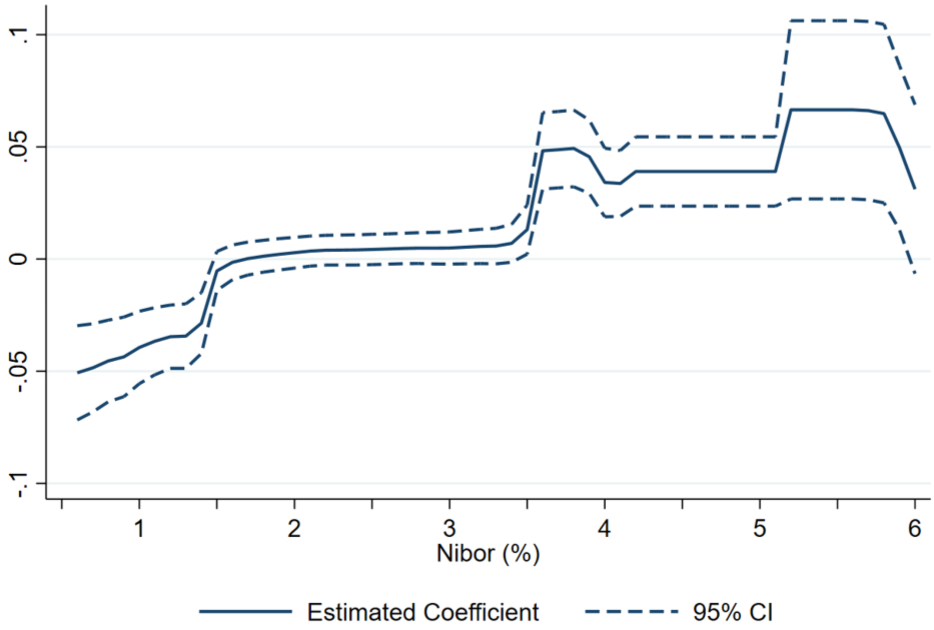
Notes: This table shows the marginal effects of *length* (relationship length) on the marginal effect of MP (change in NIBOR) on Δr (change in loan rates) when monetary policy is loosening/tightening and when the initial level of the NIBOR is one standard deviation below/above its mean. In other words, the table shows $\frac{\partial^2 \Delta r_t}{\partial MP_{t-1} \partial length_{t-1}}$. Marginal effects are calculated from specification (7) and the estimated coefficients of column (4) in table 4.

Regressions (4) to (7) assume that marginal effects are linear in the initial level of the NIBOR. To address potential non-linearity concerns, especially when interest rates are low, we run the following Kernel regressions at different initial levels of the policy rate. We weight data points using Epanechnikov's kernel centered at 0.1 increments of the NIBOR and a Silverman bandwidth. Since the regressions are now centered around a specific initial NIBOR level, we remove the dummy $tight_{t-1}$ from the specifications. In the data, a specific NIBOR level is either associated with a rate hike or a rate cut, making it impossible to identify any asymmetry. However, note that the observations of low NIBOR are associated with policy rate cuts. The results we get in this region are therefore to be interpreted in the context of a monetary policy expansion.

$$(8) \quad \Delta r_{ibt} = \alpha_{ib} + \alpha_{jt} + \alpha_{bt} + length_{ib,t-1}(\beta_0 + \beta_1 MP_{t-1}) + \mathbf{Z}_{i,t-1}(\gamma_{\mathbf{1}} + \gamma_{\mathbf{2}} MP_{t-1}) + \epsilon_{ibt}$$

Figure 4 plots the estimated coefficients β_1 against the initial level of the NIBOR. It shows the marginal effect of relationship length on pass-through displays non-linearity with three apparent regimes. When the NIBOR is above 3.5%, firms in longer relationships seem to get more pass-through. However, confidence intervals are relatively large as we have few observations of high policy rates. When the NIBOR is in an intermediate range, between 1.5% and 3.5%, relationship length is irrelevant for monetary policy pass-through. Finally, when the NIBOR is below 1.5%, firms in long relationships get relatively less pass-through. Quantitatively, the estimated effects for this last regime are even larger than those estimated in Table 5. When the initial level of the NIBOR is 1.1%, each additional year of relationship reduces pass-through by x percentage points.

Figure 4: Pass-Through and Relationship Length: Allowing for Non-linearity in NIBOR



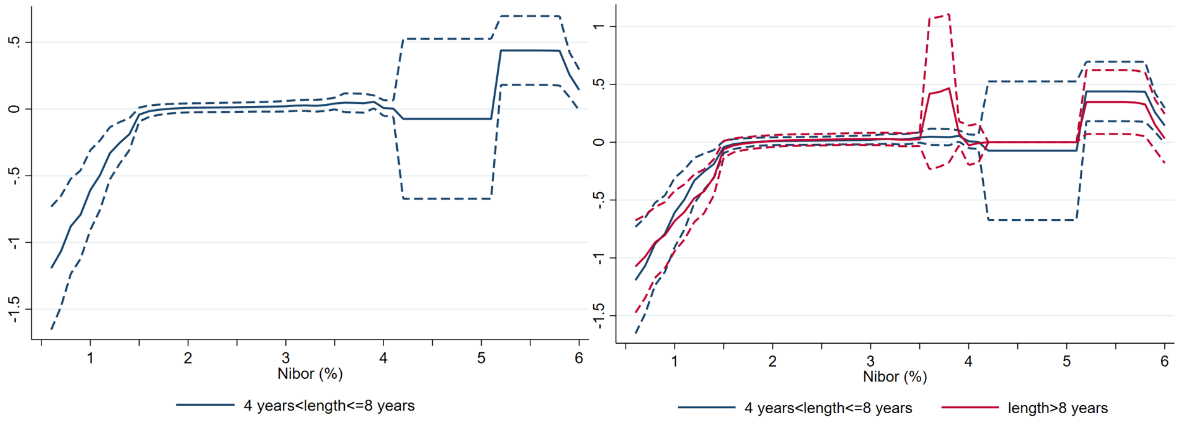
Notes: The figure plots coefficient β_1 from kernel regressions (8), where points are weighted using Epanechnikov's kernel centered at 0.1 increments on the x-axis and a Silverman bandwidth (here = 1.07). Coefficient β_1 is the marginal effect of *length* (relationship length) on the marginal effect of MP (change in NIBOR) on Δr (change in loan rates). I.e. $\beta_1 = \frac{\partial^2 \Delta r_t}{\partial MP_{t-1} \partial length_{t-1}}$.

Next, we also allow for non-linearity in relationship length by using dummies instead of the continuous variable $length_{ib,t-1}$. We run the following kernel regressions, using the same kernel and bandwidth as in equation (4):

$$(9) \quad \Delta r_{ibt} = \alpha_{ib} + \alpha_{It} + \alpha_{bt} + \sum_{s=1}^{2} \mathcal{I}_{sib,t-1}(\beta_{0,s} + \beta_{1,s} MP_{t-1}) + \mathbf{Z}_{i,t-1}(\gamma_{\mathbf{1}} + \gamma_{\mathbf{2}} MP_{t-1}) + \epsilon_{ibt},$$

where $\mathcal{I}_{1ib,t-1}$ is a dummy variable equal to 1 if relationship length between bank b and firm i at time $t-1$ is between 5 and 8 years. $\mathcal{I}_{2ib,t-1}$ equals 1 if relationship length is longer than 8 years. The left-hand side of Figure 5 plots the estimated coefficients $\beta_{1,1}$ against the initial level of the NIBOR, and the right-hand side adds the estimated coefficients $\beta_{1,2}$. These regressions reveal substantial non-linearity in relationship length. When the NIBOR is at 1.1%, firms whose relationships are between 5 and 8 years get approximately 50 percentage points less pass-through than firms with a relationship shorter than 5 years. The difference in pass-through between firms in a relationship shorter than 5 years and firms with a relationship longer than 8 years is of similar magnitude. This suggests it is the variation in relationship duration during the first 8 years of relationship that matters for differential pass-through. In other words, the marginal effect of relationship length on pass-through is itself decreasing in relationship length. This explains why its estimate was of much smaller magnitude in our previous fully linear specifications (4) to (7). Finally, allowing for non-linearity in relationship length seems to indicate the presence of only two regimes with a cutoff around 1.5% for the NIBOR. I.e., we do not get the previous results of larger pass-through to long-relationship firms at high NIBOR levels anymore.

Figure 5: Pass-Through and Relationship Length: Allowing Non-Linearity in NIBOR and Relationship Length



Notes: The left-hand side figure plots coefficient $\beta_{1,1}$ from kernel regressions (9), where points are weighted using Epanechnikov's kernel centered at 0.1 increments on the x-axis and a Silverman bandwidth (here = 1.07). Coefficient $\beta_{1,1}$ is the additional effect of having a relationship aged between 5 and 8 years compared to the reference group (relationships shorter than 5 years) on the marginal effect of MP (change in NIBOR) on Δr (change in loan rates). The right-hand side figure adds coefficient $\beta_{1,2}$ from kernel regressions (9). Coefficient $\beta_{1,2}$ is the additional effect of having a relationship longer than 8 years compared to the reference group (relationships shorter than 5 years) on the marginal effect of MP (change in NIBOR) on Δr (change in loan rates).

3.1.2 Volumes

In our previous analysis, we regress a change in equilibrium prices (loan rates) on the change in banks' marginal cost of funds (the policy rate) in an attempt to uncover the relevance of relationship length for monetary policy pass-through. The main concern for identification is that firms' loan demand may be shifting at the same time than monetary policy and correlated with relationship length. For example, we may worry that long-relationship firms increase their loan demand relatively more after a monetary policy expansion. The resulting higher increase in equilibrium loan volumes could therefore explain why these firms get relatively less pass-through. From a monetary policy standpoint though, we really are interested in understanding whether our differential pass-through results stem from bank credit supply.

Our previous analysis already attempts to control for firm credit demand in two ways. In a first specification, we include industry-time fixed effects and control for the most important firm-level characteristics. In a second specification, we include industry-location-size-time fixed effects. Under the assumption that firms in a same cell have the same homogeneous credit demand across banks, these fixed effects allow us to identify differential pass-through originating from credit supply. To further rule out that our results could be entirely driven by firms' demand side, we run the same regressions as in (4)-(7), but using loan growth rates from $t-1$ to t as outcome variable. Table 6 shows the results. The estimated coefficients on the interaction between relationship length and monetary policy shocks (first row) are either insignificant or positive. This means that when the NIBOR is at 0%, additional years of relationship have a non-negative effect on the marginal effect of a policy rate cut on loan growth rates. In other words, long-relationship firms *do not* have a higher loan growth rate than short-relationship firms following the policy change. If anything, their loan growth rate is lower. This rules out the possibility that our differential pass-through results from Section 3.1.1 may be driven by firms' demand side only. Banks' credit supply must have increased relatively more for short-relationship firms.

Table 6: Credit Growth and Relationship Length

	(1)	(2)	(3)	(4)
$length_{ibt} \times MP_{t-1}$	0.000	0.004*	0.007***	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
$length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	0.001	-0.001	-0.002**	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$tight_{t-1} \times length_{ibt} \times MP_{t-1}$	-0.003	-0.044***	-0.051***	-0.011*
	(0.007)	(0.004)	(0.004)	(0.004)
$tight_{t-1} \times length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	0.003*	0.011***	0.013***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)
N	968586	968564	703932	873884
Macro Controls	No	No	No	No
Firm Controls	No	No	No	Yes
Bank Controls	No	No	No	No
Industry-Time FE	No	No	No	Yes
ILS-Time FE	No	No	Yes	No
Bank-Time FE	No	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: Columns (1)-(4) report the estimated coefficients of interest from regressions (4)-(7), but using loan growth rates $\frac{L_{ibt}-L_{ib,t-1}}{L_{ib,t-1}}$ as the outcome variable, where L_{ibt} is the loan volume between bank b and firm i at time t. Firm controls $\mathbf{Z}$ include age, size, leverage, and credit rating.

3.1.3 Real Effects

We investigate whether lower pass-through to long-relationship firms after a policy rate cut at initial low rate has real effects. To do so, we regress tangible capital growth rates – a proxy for firm investment – at yearly horizons $h \in \{0, \ldots, 8\}$ on the same variables as in regression (7). We use the coefficients on the interaction terms between relationship length and monetary policy shocks to calculate the wedges in cumulated tangible capital growth h years after the monetary policy shock, which are due to the length of the relationship at the moment of the shock.

We run the following regressions for $h \in \{0, \ldots, 8\}$:

$$\frac{k_{i,t+h} - k_{i,t-1}}{k_{i,t-1}} = \alpha_{ib} + \alpha_{jt} + \alpha_{bt} + length_{ib,t-1}\mathbf{X}_{t-1}\beta_h + \mathbf{Z}_{i,t-1}\mathbf{U}_{i,t-1}\delta_h + \epsilon_{ibt}, \tag{10}$$

where k_{it} is the tangible capital of firm i at time t,

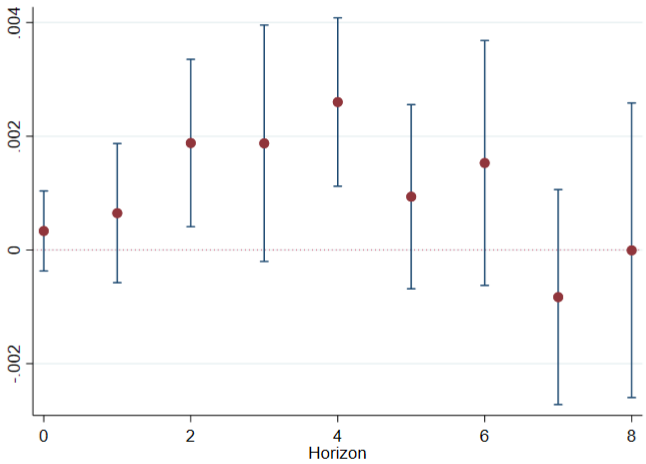
$$\mathbf{X}'_{t-1} = \begin{pmatrix} 1 \\ MP_t \\ Nibor_t \\ tight_t \\ MP_t \times Nibor_t \\ MP_t \times tight_t \\ tight_t \times Nibor_t \\ MP_t \times tight_t \times Nibor_t \end{pmatrix},$$

and

$$\mathbf{U}'_{t-1} = \begin{pmatrix} \mathbf{X}'_{t-1} & \ldots & \mathbf{X}'_{t-1} \end{pmatrix}.$$

Figure 6 plots the marginal effects of relationship length on monetary policy pass-through to capital growth rates at horizons $h \in \{0, \ldots, 8\}$ for a monetary expansion when the NIBOR is at 1.1%. The positive estimates mean that additional years of relationship at the moment of the shock reduce tangible capital growth following a policy rate cut. The figure shows an inverted u-shaped wedge path. Initially, investment in tangible capital reacts independently from the length of the relationship firms maintain with their banks. A wedge then builds over time and peaks four years after the monetary policy shock before disappearing. Each year of existing relationship at the moment of the policy rate cut reduces cumulated tangible capital growth over the next four years by 0.25 percentage points.

Figure 6: Relationship Length and Capital Growth



Notes: The figure shows the marginal effects of relationship length on the marginal effect of MP (change in NIBOR) on tangible capital growth rates $\frac{\partial^2 g_{k,t+h}}{\partial MP_{t-1} \partial lengtht-1}$ at horizons $h \in \{0, \ldots, 8\}$ for a monetary policy easing when the initial NIBOR is 1.1%. Marginal effects are calculated from the coefficient estimates of regression (10).

3.2 Robustness Analysis

In this section, we conduct further robustness checks to ensure that our results are robust to different measurements of monetary policy shocks as well as more detailed, account-level information.

3.2.1 Exogenous Monetary Policy Shocks

To address the endogeneity of movements in the NIBOR beyond using different sets of fixed effects, we re-run our entire analyses using identified monetary policy shocks instead. These shocks are identifies in a 30-minute window around monetary policy announcements and can be thought of as the unexpected component of a change in policy rate. They are therefore arguably uncorrelated with any unobservables potentially affecting bank-firm loan interest rates. Section 6.1 of the Appendix contains the tables showing our results using these shocks. Our qualitative conclusions remain unchanged.

3.2.2 Using Account-Level Information

Bank-firm-level loan rates are subject to measurement error due to the lack of loan-level information. We only have access to end-of-year account-level information, which includes the stock of outstanding loans and interest paid for each account. Consequently, we cannot observe the composition of loans by time since origination, which may result in variation in the loan rates we measure due to differences in loan age and associated interest rates. Although most loans in Norway come with adjustable rates, non-linear interest rate paths for certain loan contracts could still affect our pass-through analysis. To address this potential issue, we use the account-level information in our dataset and recalculate average yearly loan rates based only on newly issued accounts within the year. By focusing on newly issued accounts, which are associated with new loans, we ensure that our interest rate measure is based on loans with the same age. Although this method does not control for loan maturity, which is not observed in our data, it allows us to construct a measure of interest rates that is less affected by potential variations in loan ages. In Section 6.2 of the Appendix, we present the results of our empirical analysis using this newly constructed measure of loan rates. Our analysis shows that our main qualitative conclusions remain robust even when we account for potential variations in loan ages.

3.3 Extensive Margin Analysis

Our empirical analysis shows that firms that have maintained a relatively long relationship with their bank get a lower pass-through of a monetary policy rate cut at initial low rate. The literature on relationship lending has identified two main reasons that can lead firms to be locked in a relationship with their bank. On the one hand, inside banks can exploit the informational advantage they have about their customers over outside banks, allowing them to charge higher rates than those that would prevail under perfect information. On the other hand, costs associated with switching banks can lead banks to charge relatively high rates and firms still being locked in the relationship. In this section, we investigate the extensive margin of relationship lending to understand which of these two alternative explanations is most likely driving our intensive margin results on pass-through. Following the methodology in Ioannidou and Ongena (2010), we look at switching firms and compare the discounts and rates they get at their new bank depending on the length of their previous relationship. To account for our empirical findings on pass-through using the information asymmetry explanation, we would anticipate that firms engaged in long-term relationships are, on average, of a worse type. Consequently, they would secure relatively high interest rates when switching banks, which, in turn, would enable their existing bank to provide them with reduced pass-through following a rate cut. Conversely, to attribute these results to switching costs, we would anticipate that longer relationships involve higher switching costs.

We start by matching switching firms with non-switching firms. Suppose firm i borrows from bank b until year $t-1$ and switches to bank b' in year t, where it pays the interest rate $r_{ib't}$. We find a comparable non-switching firm j, which borrows from bank b in both $t-1$ and t. We interpret the rate r_{jbt} paid by firm j to bank b in t

as the counterfactual rate firm i would have paid in t if it had stayed with bank b. The discount $s_{ibb't}$ firm i obtains by switching from bank b to bank b' in t is therefore estimated to be:

$$s_{ibb't} = r_{jbt} - r_{ib't}$$

We match switching firms with non-switching firms on year, origin bank, industry, size, age, leverage, credit rating, whether the firms borrow from a single or several banks, and length of relationship with the origin bank. Our dataset contains $21'000$ matched pairs.
Next, we regress the estimated discounts on a dummy indicating whether the switcher's previous relationship was long or short, controlling for the variables we used for matching:

$$s_{ib't} = \sum_{k=2000}^{2019} \mathcal{I}_k(\beta_k d_{ib't} + \mathbf{Z}_{ib't}\gamma_k) + \epsilon_{ib't}$$

where $s_{ib't}$ is the discount obtained by firm i when switching to b' in t, $\mathbf{Z}_{ib't}$ are the firm controls used for matching (industry, size, age, leverage, credit rating), and:

$$\begin{aligned} \mathcal{I}_k &= 1 \quad \text{if} \quad k = t \\ d_{ib't} &= 1 \quad \text{if previous relationship of switching firm } i \text{ was long (e.g. } \geq 4 \text{ years)} \end{aligned}$$

Figure 7 plots the estimated coefficients β_k. They show the difference in discounts obtained by switching firms, which is due to having a previous long relationship. Our results indicate that firms with a previous long relationship consistently obtain a larger discount than firms with a previous short relationship when switching banks, with the point estimates ranging from 50 to 100 basis points for most years.

To investigate further the role that previous relationship length plays for loan rates when switching banks, we then match switching firms among themselves. We split switchers into two groups: firms with a previous long relationship and firms with a previous short relationship. We create pairs of switching firms, matching on year, new bank, and firm characteristics (industry, size, age, leverage, credit rating). With this procedure, we obtain the spread s_{ijt} between the loan rates of two similar firms i and j arriving at the same bank in year t, where the main difference between the firms is that firm i has a previous short relationship whereas firm j has a previous long relationship. Next, we regress the spreads on year dummies:

$$s_{ijt} = \sum_{k=2000}^{2019} \mathcal{I}_k \beta_k + \epsilon_{ijt}$$

Figure 7

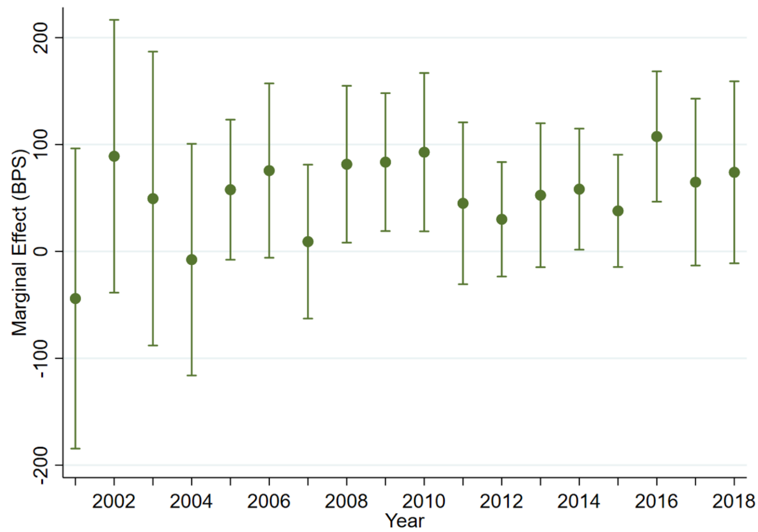
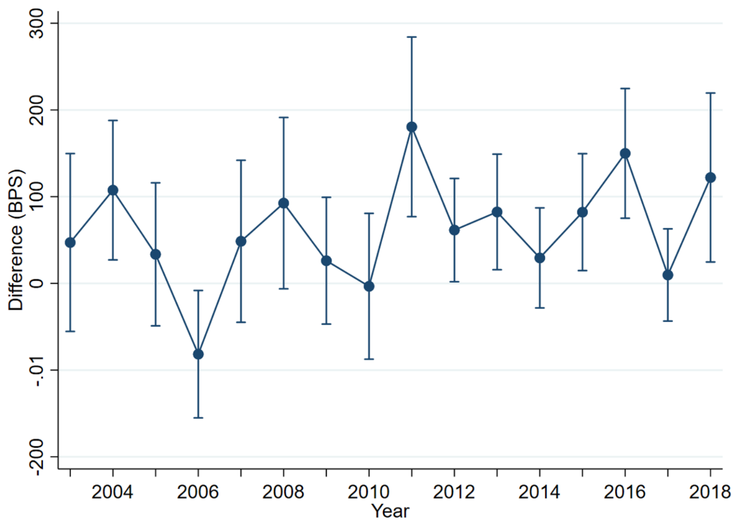


Figure 8



where $s_{ijt} = r_{it} - r_{jt}$ and $\mathcal{I}_k = 1$ if $k = t$. Figure 8 plots the estimated coefficients β_k. The results indicate that in most years, switching firms with a previous long relationship obtain a lower loan rate than similar firms with a previous short relationship at their new bank.

Overall, our findings indicate that switchers who had maintained longer relationships with their former bank receive higher discounts at their new bank. This suggests that firms engaged in longer relationships indeed face higher switching costs and only choose to switch when offered relatively substantial discounts. Furthermore, when we match previous short-relationship switchers with previous long-relationship switchers who both arrive at the same new bank, we find that the firms with longer prior relationships receive lower interest rates at the new bank, suggesting they are perceived as a relatively better type. Based on this evidence, we lean towards the explanation of switching costs in developing a model that rationalizes our differential pass-through results.

4 Theoretical Framework

Our empirical results on differential pass-through suggest that the composition of relationship lengths in the economy may play a role in aggregate monetary policy transmission. Specifically, if pass-through to long-relationship firms is relatively small, an increasing share of long relationships could impair aggregate pass-through. This is an important consideration in view of the evolution of the composition of relationship lengths over the past 20 years in the Norwegian economy. As depicted in figure (3b), the share of long-relationship firms has dramatically increased after the financial crisis, in a period where the central bank considerably lowered its policy rate. The question arises whether monetary easing would have been better transmitted to loan rates, if the relationship length profile of the economy had remained stable. To answer this question, we cannot simply rely, à priori, on our empirical estimates. The reason is that the estimated difference in pass-through between short and long relationships, as well as the pass-through levels themselves, may depend on the observed composition of relationship length in the economy. Our empirical estimates might therefore not be appropriate to calculate a counterfactual aggregate pass-through under an alternative distribution of relationship length. For example, it may be that in an economy with a $50\% - 50\%$ share of short and long relationships, banks are able to give relatively more pass-through to their short-term customers because they have a pool of long-term customers to whom they can pass relatively less of a policy rate cut. In an economy with short relationships only, and for the same profitability target, banks would need to give their short-term customers less pass-through than in the initial economy, leaving the aggregate pass-through unchanged. To answer questions about counterfactual aggregate pass-through, we therefore need a model allowing the composition of relationship length to affect the relationship-length dependent individual pass-through.

We construct a static partial equilibrium banking model, which rationalizes our empirical findings, and allows us to answer counterfactual questions. We consider an economy that extends to two periods. Agents (firms and banks) make decisions in period 1 taking the policy rate i as given. Payoffs are realized in period 2. In what follows, we outline the model setup and characterize the equilibrium conditions. The comparative statics exercise shows how equilibrium prices (i.e. interest rates) would react to an unexpected shock to i at the beginning of the first period. We provide a condition under which lower pass-through of a policy rate cut to long-relationship firms obtains when the initial policy rate is low, and study how it relates to the composition of relationship lengths in the economy.

4.1 Firms

There is a continuum of firms of mass 1. In period 1, each firm inelastically demands 1 unit of lending to be paid back with interest in period 2. Note this means aggregate lending $\mathbf{L}$ is fixed and equal to one (partial equilibrium). Each firm has a non-negative private cost of switching bank $c_j \geq 0$. Banks cannot observe their clients' individual switching costs, but know the duration of the relationship.

At the beginning of period 1, all firms are matched with a bank and either are in a *short* or *long* relationship. Although this is a static model, a short relationship between firm j and bank b at the beginning of period 1 can be thought of firm j having switched to bank b in the previous period. A long relationship at the beginning of period 1 can be thought of the relationship being short in the previous period. In this two-period setting, the initial shares of short vs. long relationships is exogenous. The switching costs distribution of firms in short relationships is characterized by a density function $f_s(c)$. That of long relationships by $f_l(c)$.

At the beginning of period 1, a firm is offered a rate r_s or r_l (depending on whether it has a short or long relationship) by the bank it is currently matched with, and an outside option r_{out} by competing banks. A firm decides to switch to an outside bank if the discount it gets covers its private switching costs: $r_k - r_{out} > c_j$, where $k \in \{s, l\}$.

4.2 Banks

There is a continuum of banks of mass 1. We look for a symmetric equilibrium and therefore consider a representative bank. The bank takes the policy rate i and the rate offered by other competing banks r_{out} as given. The bank doesn't know its clients' private switching costs, but it knows the distributions $f_s(c)$ and $f_l(c)$.

The asset side of the bank balance sheet is made of loans given out to short and long relationship clients, as well as to firms that switch away from their current bank. Given the firms' switching behavior, the loan demands by short-relationship firms $L_s(r_s)$ and long-relationship firms $L_l(r_l)$ faced by the bank are:

$$L_s(r_s) = [1 - F_s(r_s - r_{out})]p_s\mathbf{L}, \tag{11}$$

$$L_l(r_l) = [1 - F_l(r_l - r_{out})]p_l\mathbf{L}, \tag{12}$$

where F_s and F_l respectively are the cumulative density functions of the short- and long-relationship firms' switching costs, p_s and p_l are the shares of short and long relationships in the economy at the beginning of period 1 with $p_s + p_l = 1$, and $\mathbf{L}$ is the amount of aggregate lending.

The total number of switching firms in the economy and the outside rate r_{out} are taken as given by the bank. If the bank sets $r_{sw} > r_{out}$, it does not attract any switching firm. On the other hand, if the bank sets $r_{sw} < r_{out}$, it can extend as many loans to switchers as its leverage constraint allows. If the bank sets $r_{sw} = r_{out}$, switchers are evenly split across all banks in the economy. In this latter case, denote $\bar{L}_{sw}$ the amount of switchers each bank gets. Note that in our representative bank setting, $\bar{L}_{sw}$ is actually the total number of switchers in the economy. That is, the bank absorbs all switchers by setting $r_{sw} = r_{out}$. The loan demand from switchers the representative bank faces can therefore be written as:

$$L_{sw}(r_{sw}) = \begin{cases} > \bar{L}_{sw} & \text{if } r_{sw} < r_{out} \\ \bar{L}_{sw} & \text{if } r_{sw} = r_{out} \\ 0 & \text{if } r_{sw} > r_{out} \end{cases} \tag{13}$$

In a symmetric equilibrium, the representative bank sets $r_{sw} = r_{out}$ and attracts $\bar{L}_{sw}$, which is the total number of switchers in the economy.

The bank can also invest in some financial assets S at the policy rate i. Since financial assets will always be positive, the policy rate represents the marginal cost of issuing an extra unit of loan. The liability side of the balance sheet consist of equity E and deposits D. Equity E is exogenous and deposits D stem from a constant elasticity deposit supply function, which we take from the literature without explicitly modelling a household side.

$$D(r_d) = \left(\frac{1+r_d}{1+\bar{r}_d}\right)^{-\epsilon^d} \mathbf{D}, \tag{14}$$

where $\bar{r}_d$ is the average deposit rate and $\epsilon^d < -1$ means that banks that pay higher deposit rates attract more deposits.
Aggregate lending $\mathbf{L}$ and deposits $\mathbf{D}$ are fixed. In a symmetric equilibrium, all banks (i.e. the representative bank) set the same loan and deposit rates and hold the aggregate quantities $\mathbf{L}$ of loans and $\mathbf{D}$ of deposits on their balance sheet.

The bank's problem is to choose the rates it offers to short-relationship firms r_s, long-relationship firms r_l, switching firms r_{sw}, depositors r_d, and the amount of financial securities S to maximize its period-two net worth, subject to its balance sheet constraint and a net worth constraint.

The bank's problem can therefore be written:

$$\max_{r_{sw}, r_s, r_l, r_d, S} \quad N = (1+r_{sw})L_{sw}(r_{sw}) + (1+r_s)L_s(r_s) + (1+r_l)L_l(r_l) + (1+i)S - (1+r_d)D(r_d)$$

s.t.

$$
\begin{aligned}
L_{sw}(r_{sw}) &= \begin{cases} > \bar{L}_{sw} & \text{if } r_{sw} < r_{out} \\ \bar{L}_{sw} & \text{if } r_{sw} = r_{out} \\ 0 & \text{if } r_{sw} > r_{out} \end{cases} \\
L_s(r_s) &= [1 - F_s(r_s - r_{out})]p_s\mathbf{L} \\
L_l(r_l) &= [1 - F_l(r_l - r_{out})](1 - p_s)\mathbf{L} \\
D(r_d) &= \left(\frac{1 + r_d}{1 + \bar{r}_d}\right)^{-\epsilon^d} \mathbf{D} \\
L_{sw} + L_s + L_l + S &= E + D \qquad \text{(Balance sheet)} \\
\lambda(L_{sw} + L_s + L_l) &\leq N \qquad \text{(Net worth constraint)}
\end{aligned}
$$

where $1/\lambda$ is the maximum leverage a bank can take.

The first order conditions for r_s, r_l and r_d yield the bank's optimal pricing rule.

Lemma 1. *The optimal loan and deposit rates r_s^*, r_l^*, and r_d^* are implicitly defined by:*

$$r_s^* - i = \frac{1 - F_s(r_s^* - r_{out})}{f_s(r_s^* - r_{out})} + \lambda \frac{\xi}{1 + \xi}, \tag{15}$$

$$r_l^* - i = \frac{1 - F_l(r_l^* - r_{out})}{f_l(r_l^* - r_{out})} + \lambda \frac{\xi}{1 + \xi}, \tag{16}$$

$$1 + r_d^* = \frac{\epsilon^d}{\epsilon^d - 1}(1 + i), \tag{17}$$

where ξ is the Lagrange multiplier on the leverage constraint.

Proof. See Appendix 6.3. □

From (15) and (16), we clearly see that the switching costs distributions play a crucial role for optimal rate setting. The bank chooses a markup above the policy rate, which equals the ratio between the survival function and the density function evaluated at the markup above the outside rate. This also means that the spread between the policy rate and the outside rate matters for the optimal markups.

4.3 Equilibrium and Comparative Statics

Before we can study the effects of the policy rate i on equilibrium prices, we still need to characterize the equilibrium outside rate r_{out}. We assume that banks compete for switchers à la Bertrand. That is, taking r_{out} as given, an atomistic bank will consider setting its own rate for switchers r_{sw} slightly below r_{out} to attract more switchers than competing banks. To understand until which level r_{out} will be driven down throughout this process, the bank's leverage constraint is crucial. When an atomistic bank sets $r_{sw} = r_{out} - \epsilon$, it attracts all switchers and can potentially replace all of its financial securities S paying rate i by loans to switchers paying the higher rate r_{sw}. If the bank's net worth is high enough such that it can do so without violating its constraint, all banks will proceed the same way (by symmetry), meaning that the original outside rate r_{out} we started with is too high. When banks' net worth is high enough, this process will therefore drive r_{out} down to the policy rate i, where it is not worth for any bank to go lower (i being the marginal cost of issuing an extra unit of loan). However, when banks' net worth is low, r_{out} will be competed down to a level *above* the policy rate i. The reason being that at some level $r_{out} > i$, banks will not be able to set $r_{sw} = r_{out} - \epsilon$ and take on more switchers on their balance sheet without violating the leverage constraint.

Under the assumption that $\mathbf{E} < \mathbf{L} < \mathbf{D}$, the bank's net worth N is increasing in the policy rate since the latter is the rate of return on on securities $S > 0$.[7] Therefore, there exists a threshold interest rate $\tilde{i}$ above which net worth N is high enough to drive r_{out} down to i, and below which r_{out} is larger than i. In other words, the equilibrium outside rate is a function of the policy rate:

$$r_{out}(i) = \begin{cases} i & \text{if } i \geq \tilde{i} \\ g(i) > i & \text{if } i < \tilde{i} \end{cases} \tag{18}$$

where $g(i)$ is a continuous function with $g(\tilde{i}) = i$ and $0 < g'(i) < 1$. $g(i)$ can be determined numerically. It is the highest rate for r_{out} that no individual bank could undercut, thereby substituting additional loans to switchers L_{sw} for financial securities S, without violating its constraint. In other words, $g(i)$ is the highest rate above the policy rate such that the bank's net worth constraint exactly binds.

We are now in a position to study how the representative bank's optimal rates r_s and r_l respond to a change in the policy rate i. That is, we provide an analytical expression for monetary policy pass-through by applying the implicit function theorem on the first order conditions (15) and (16).

Lemma 2. *The monetary policy pass-through to short- and long-relationship firms' loan rates is given by:*

$$\frac{dr_s^*}{di} = \frac{1 + \frac{\partial r_{out}}{\partial i}[1 + (r_s^* - i)\frac{f_s'(r_s^* - g(i))}{f_s(r_s^* - g(i))}]}{1 + [1 + (r_s^* - i)\frac{f_s'(r_s^* - g(i))}{f_s(r_s^* - g(i))}]}, \tag{19}$$

$$\frac{dr_l^*}{di} = \frac{1 + \frac{\partial r_{out}}{\partial i}[1 + (r_l^* - i)\frac{f_l'(r_l^* - g(i))}{f_l(r_l^* - g(i))}]}{1 + [1 + (r_l^* - i)\frac{f_l'(r_l^* - g(i))}{f_l(r_l^* - g(i))}]}. \tag{20}$$

Proof. See Appendix 6.3. □

[7]By the envelope theorem, one can easily see that $\frac{dN}{di} = S(1 + \xi) > 0$.

The interest rate threshold $\tilde{i}$ defines two distinct regimes. When $i > \tilde{i}$ and $\frac{\partial r_{out}}{\partial i} = 1$, it is easy to see that:

$$\frac{dr_s^*}{di} = \frac{dr_l^*}{di} = 1. \tag{21}$$

In words, when the policy rate is high enough, the outside rate r_{out} is driven down to i and banks charge a constant markup for both long- and short-relationship firms, implying full pass-through.

When $i < \tilde{i}$, $\frac{\partial r_{out}}{\partial i} = g'(i) < 1$. In this case, we have $\frac{dr_s^*}{di} < 1$, $\frac{dr_l^*}{di} < 1$ and $\frac{dr_s^*}{di} \neq \frac{dr_l^*}{di}$. In words, when the policy rate falls below the threshold $\tilde{i}$, the pass-through to both short- and long-relationship firms is not complete anymore, and is not the same for both types. We can derive the following proposition.

Proposition 1. *Let $i < \tilde{i}$ so that $\frac{\partial r_{out}}{\partial i} = g'(i) < 1$. The pass-through of a change in i is smaller for long-relationship firms than for short-relationship firms, i.e. $\frac{dr_l^*}{di} < \frac{dr_s^*}{di}$ if:*

$$\frac{r_s^* - i}{r_s^* - g(i)} \epsilon_{f_s}|_{r_s^* - g(i)} < \frac{r_l^* - i}{r_l^* - g(i)} \epsilon_{f_l}|_{r_l^* - g(i)},$$

where $\epsilon_f|_{x^*} = \frac{f'(x^*)}{f(x^*)} x^*$ is the elasticity of the density function $f(x)$ at $x = x^*$.

Proof. See Appendix 6.3. □

Proposition 1 provides a condition that ensures a lower pass-through rate to long-relationship firms if it holds in equilibrium. This condition stipulates that the weighted elasticity of the switching cost density for long-relationship firms f_l must be larger than that of short-relationship firms f_s, at the optimal markups. The weights are defined by the ratios between the optimal markup above the policy rate and the optimal markup above the outside rate. To provide more intuition, consider the case where these elasticities are negative, i.e. $f'(x^*) < 0$. The condition for a lower pass-through to long relationships requires the weighted elasticity of their switching cost density to be smaller than that of short relationships in absolute value at the optimum. Roughly speaking, this means there must be a larger mass to the right of the optimal markup of long relationships than that of short relationships. When this is the case and the policy rate goes down, banks give less pass-through (i.e. decrease the markup relatively less) to long relationships because a high share of these customers is locked in the relationship due to relatively high switching costs. Lowering the markup therefore decreases revenue on this high share of locked in customers and only earns a small amount of firms, which decide not to switch because of the lower markup. The reasoning for the pass-through to short relationships is the opposite. When the mass to the right of the optimal markup is small, decreasing the markup only modestly affects revenue on locked in customers, while it can earn a large mass of firms by preventing them from switching. In section 4.4, we provide more intuition on the condition outlined in proposition 1 by assuming a specific functional form for the switching cost distributions.

From lemma 2 and proposition 1, it is clear that the pass-through ($\frac{dr_s^*}{di}$ and $\frac{dr_l^*}{di}$), and whether there is less pass-through to long relationships ($\frac{dr_l^*}{di} < \frac{dr_s^*}{di}$) depend on the outside rate ($r_{out} = g(i)$) and its derivative ($g'(i)$). The latter are determined in equilibrium by the binding bank's constraint, which itself depends on the shares of short and long relationships in the economy (p_s and p_l). Thus, for a given level of the policy rate i, changing the shares p_s and p_l will alter the individual pass-through. That is, when modifying the shares p_s and p_l, the change in aggregate pass-through may not only come from a composition effect, but also from the fact that the individual pass-through themselves are changing. This consideration highlights why we cannot, à priori, just use our empirical estimates to calculate a counterfactual aggregate pass-through under an alternative composition of relationship length. In the next section, we make an assumption about the functional form of the switching cost distributions, which allows us to assess the importance of this general equilibrium effect.

4.4 Special Case

For general distributions, there is no closed-form solution for the bank's optimal choices and equilibrium outside rate, and the model must be solved numerically. In this section, we look at the special case where switching costs follow a generalized Pareto distribution (GPD). In this case, we can derive analytical solutions for the optimal rates and pass-through. This allows to get a better intuition for Proposition 1, and explicitly calculate counterfactual aggregate pass-through under an alternative distribution of relationship length in the economy.

Lemma 3. *Recall that the pdf and cdf of a random variable following a generalized Pareto distribution with location parameter μ, scale parameter σ, and shape parameter ξ are respectively given by:*

$$\begin{aligned} f(x) &= \frac{1}{\sigma}\left(1+\xi\frac{x-\mu}{\sigma}\right)^{-\left(\frac{1}{\xi}+1\right)} \\ F(x) &= 1-\left(1+\xi\frac{x-\mu}{\sigma}\right)^{-\frac{1}{\xi}} \end{aligned}$$

Let $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ and $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. The optimal loan rates r_s^* and r_l^*

are given by:

$$r_s^* = \frac{i + \sigma_s - \xi_s(r_{out} + \mu_s)}{1 - \xi_s}, \tag{22}$$

$$r_l^* = \frac{i + \sigma_l - \xi_l(r_{out} + \mu_l)}{1 - \xi_l}. \tag{23}$$

Proof. See Appendix 6.3. □

Next, we can explicitly derive the policy rate cutoff $\bar{i}$, below which the bank's constraint becomes binding, the outside rate is above the policy rate, and pass-through for short and long relationships differ.

Lemma 4. *Let $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ and $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. The threshold $\bar{i}$ below which the bank's net worth constraint binds and $\frac{\partial r_{out}}{\partial i} < 1$ is given by:*

$$\bar{i} = \frac{\lambda L - E - \tau_s - \tau_l}{1 + S}, \tag{24}$$

where:

$$\tau_s = p_s \left(\frac{\sigma_s - \xi_s \mu_s}{1 - \xi_s} \right) \left(1 + \frac{\xi_s}{1 - \xi_s} \frac{\sigma_s - \mu_s}{\sigma_s} \right)^{-\frac{1}{\xi_s}}, \tag{25}$$

$$\tau_l = p_l \left(\frac{\sigma_l - \xi_l \mu_l}{1 - \xi_l} \right) \left(1 + \frac{\xi_l}{1 - \xi_l} \frac{\sigma_l - \mu_l}{\sigma_l} \right)^{-\frac{1}{\xi_l}}. \tag{26}$$

Proof. See Appendix 6.3. □

Note that the threshold $\bar{i}$ increases with the capital requirement λ and decreases with equity E and securities S. The composition of relationship length also affect the threshold through τ_s and τ_l.

The GPD assumption also allows to solve explicitly for the derivative of the outside rate with respect to the policy rate.

Lemma 5. *Let $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ and $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. The monetary policy pass-through to the outside rate r_{out} when $i < \bar{i}$ is given by:*

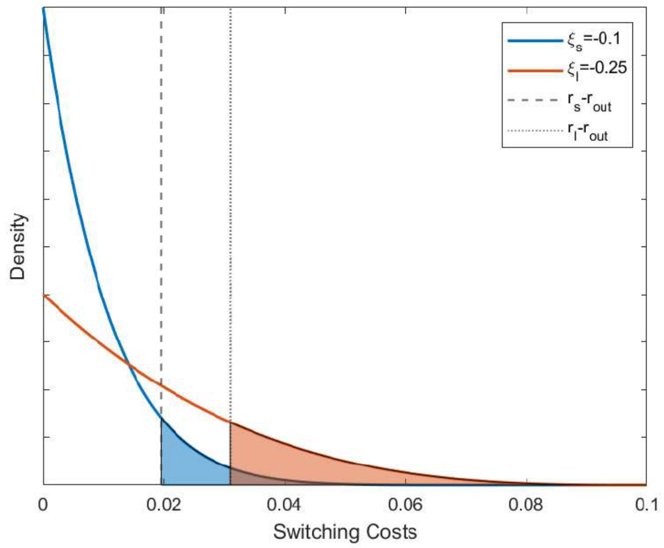
$$\frac{\partial r_{out}}{\partial i} = 1 - \frac{L + S}{L \left(1 - (r_{out} - i) \left[\frac{p_s}{\sigma_s} \kappa_s^{-\frac{1}{\xi_s} - 1} + \frac{p_l}{\sigma_l} \kappa_l^{-\frac{1}{\xi_l} - 1} \right] \right)}, \tag{27}$$

where:

$$\kappa_s = 1 + \frac{\xi_s}{\sigma_s(1 - \xi_s)} (\sigma_s - \mu_s - (r_{out} - i)), \tag{28}$$

$$\kappa_l = 1 + \frac{\xi_l}{\sigma_l(1 - \xi_l)} (\sigma_l - \mu_l - (r_{out} - i)). \tag{29}$$

Figure 9: Generalized Pareto Distribution - Stylized Example



Proof. See Appendix 6.3. □

The result from lemma 4 can then be used to obtain the pass-through to long and short relationships.

Lemma 6. *Let* $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ *and* $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. *The monetary policy pass-through to short- and long-relationship firms' loan rates is given by:*

$$\frac{dr_s^*}{di} = \frac{1 - \xi_s \frac{\partial r_{out}}{\partial i}}{1 - \xi_s}, \tag{30}$$

$$\frac{dr_l^*}{di} = \frac{1 - \xi_l \frac{\partial r_{out}}{\partial i}}{1 - \xi_l}. \tag{31}$$

Proof. See Appendix 6.3. □

Finally, we easily obtain the equivalent of proposition 1 in the case of generalized Pareto distributed switching costs.

Proposition 2. *Let* $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ *and* $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. *Let* $i < \tilde{i}$ *so that* $\frac{\partial r_{out}}{\partial i} = g'(i) < 1$. *The pass-through of a change in* i *is smaller for long-relationship firms than for short-relationship firms, i.e.* $\frac{dr_l^*}{di} < \frac{dr_s^*}{di}$ *if:*

$$\xi_s > \xi_l. \tag{32}$$

Proof. See Appendix 6.3. □

Proposition 2 states that in the case switching costs are generalized Pareto distributed, whether long relationships get less pass-through than short relationships only depends on the shape parameters of the distributions. For illustration, figure 9 shows the densities of two generalized Pareto distributed random variables with the associated optimal markups chosen by the bank for an arbitrary level of the policy rate i and outside rate r_{out}. The scale parameters have been chosen so that the supports of the two densities are the same. The density with the higher shape parameter (the short relationships) has a smaller mass in the tail to the right of the optimal markup than the density with the lower shape parameter (the long relationships). Recall that the mass to the right of the optimal markup chooses to stay with the bank since switching costs are high. The mass to the left of the optimal markup switches since the discount thus obtained more than covers the switching costs. When the policy rate decreases and the constrained bank decreases the markup it charges its customers, two opposite effects take place. On the one hand, decreasing the markup decreases the amount of switchers. The bank thus serves a larger mass of customers, which increases revenue. On the other hand, decreasing the markup lowers the revenue earned on all customers. The bank will decrease markups up to the point where the two effects cancel out and the FOCs from lemma 3 are satisfied at the new policy rate. On figure 9, one can see that it is optimal to decrease the markup by relatively less (i.e. give less pass-through) for long relationships. Indeed, since there is more mass in the tail to the right of the optimal markup, decreasing the markup to the same extent as for the short relationships would not prevent as many customers from switching, and it would lower the revenues earned from the relatively high share of locked in customers.

We end this section by noting that in this special case, proposition 2 tells us the composition of relationship length in the economy is irrelevant to whether long relationships get less pass-through than short relationships or not. However, it is clear from lemma 6 that this composition still matters for the levels of the pass-through through the equilibrium object $g'(i)$. Calculating a counterfactual aggregate pass-through under an alternative distribution of relationship length requires taking this general equilibrium effect into account. We tackle this task in the next section.

4.5 Counterfactual Exercise

In sections 4.3 and 4.4, we highlighted how within-relationship pass-through depends on the composition of relationship length in the economy. In this section, we use the results of the special case from section 4.4 to calculate a counterfactual aggregate pass-through, taking this equilibrium effect into account. More specifically, we ask how much higher would aggregate pass-through of a policy rate cut have been with a higher share of short relationships, at a time when the policy rate was low. Figure (3b) shows the share of relationships that are shorter than 7 years declined from 79% in 2006 to 64% in 2017. In 2017, the policy rate was 0.89%, which is below our estimated threshold $\bar{i}$ for differential pass-through (cf. figure (4)). We use our model to get the actual aggregate pass-through in 2017 and estimate the counterfactual aggregate pass-through that would have prevailed if the share of short relationships had remained stable at its 2006 level. We compute the aggregate pass-through as the weighted sum of the within-relationship pass-throughs for short and long relationships, and the pass-through for switchers (dr_{out}/di), where the weights are given by the respective shares of short/long relationships and switchers.

Our main assumption is that the switching cost distributions have remained constant over the entire period of our sample. In other words, we assume that the decline in the share of short relationships observed after the financial crisis is not due to any change in the switching cost distributions. It is rather explained by factors that are exogenous to our model and unrelated to switching costs, like a decline in firm entry during the crisis for example. We then use moments from our data and the equations of the model to back out the implied parameters of the switching cost distributions. With these parameters at hand, we solve the model using a counterfactual share of short relationships. We thus obtain within-relationship pass-throughs, which take equilibrium effects into account and allow us to calculate a counterfactual aggregate pass-through.

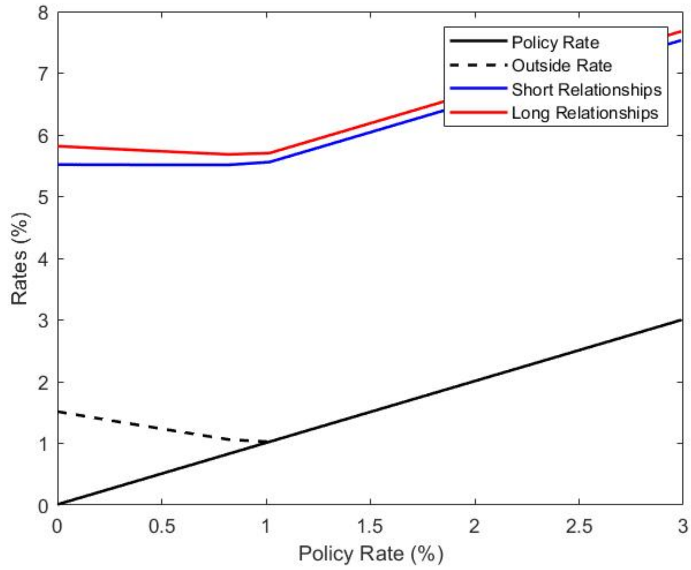
We use 7 equations for 7 unknowns. 6 of these equations involve data moments from 2017: the optimal markup equations (23)-(23), the pass-through equations (31)-(31), the binding net worth constraint from the bank's problem, and the share of switching firms at the optimum. The seventh equation targets the spread between the interest rates paid by short and long relationships when the policy rate is above the threshold $\bar{i}$. Panels A and B of table 7 show the data input used in these equations. Panel A shows the targeted moments from the data, which are endogenous in the model. Panel B shows the exogenous parameters of the model. All the parameters come from the data, except for the deposit supply elasticity (taken from the literature) and the capital requirement parameter. The latter is set to a slightly higher level than Basel requirements to ensure the constraint binds at low policy rates. This is necessary in our framework, since with fixed aggregate quantities, the decline in the policy rate only brings the bank closer to the constraint through its earnings on securities S and not through an increase in aggregate loans L. The 7 unknowns are the 3 parameters of the generalized Pareto distribution for short and long relationships, and the outside rate in 2017. Panel C of table 7 shows the estimates. Section 6.4 of the appendix gives more details on the calibration procedure, especially how the markups and pass-throughs are estimated from the data.

Table 7

A. Targeted Moments		
Short Relationship Markup (2017)	$r_s^* - i$	4.66%
Long Relationship Markup (2017)	$r_l^* - i$	4.84%
Short Relationship Pass-Through (2017)	dr_s^*/di	0.22
Long Relationship Pass-Through (2017)	dr_l^*/di	0.1
Proportion of Switchers (2017)	L_{sw}/L	0.1
Interest Rate Spread (2012-2015)	$r_l^* - r_s^*$	0.12%
B. Exogenous Parameters		
Policy Rate (2017)	i	0.89%
Share of Short Relationships (2017)	p_s	0.64
Share of Long Relationships (2017)	p_l	0.36
Bank Equity/Total Assets (2000-2019)	$E/(L+S)$	8.22%
Bank Securities/Total Assets (2000-2019)	$S/(L+S)$	15.5%
Capital Requirements	λ	0.15
Deposit Supply Elasticity	ϵ	-10
C. Estimates		
Short Relationship Sw. Cost Distribution - Location	μ_s	0.04
Short Relationship Sw. Cost Distribution - Scale	σ_s	0.05
Short Relationship Sw. Cost Distribution - Shape	ξ_s	-1.85
Long Relationship Sw. Cost Distribution - Location	μ_l	0.02
Long Relationship Sw. Cost Distribution - Scale	σ_l	0.13
Long Relationship Sw. Cost Distribution - Shape	ξ_l	-3
Outside rate (2017)	r_{out}	1.11%

We use these estimates to solve the model for any share of short/long relationships in the economy. Figure 10 shows the optimal rates and equilibrium outside rates for the shares that were prevailing in 2017. We calculate the aggregate pass-through to be 0.146. We then re-solve the model using the short/long relationships shares from 2006. We calculate a counterfactual pass-through of 0.179, that is 23% higher. All of the change is coming from a composition effect. Indeed, the equilibrium effect on the within-relationship pass-throughs going through the outside rate is negligible. The within-relationship pass-throughs remain almost unchanged for a different composition of short and long relationships in the economy.

Figure 10



5 Conclusion

In this paper, we investigate how bank-firm lending relationships shape the monetary policy pass-through to banks' loan rates, particularly on how low monetary policy rates modify such a channel. Using Norwegian administrative tax and bank supervisory data spanning over two decades, we are able to track the universe of bank-firm relationships in the economy. Our analysis shows that when the monetary policy rate is relatively low, firms that have maintained long-term relationships with banks experience a lower pass-through of further cuts in policy rates. We then propose a static partial equilibrium banking model to rationalize these findings, where state-dependent differential pass-through results from the presence of firms' switching costs and banks' leverage constraint. Both our empirical results and theoretical model highlight that the composition of relationship lengths in an economy matters for aggregate monetary policy pass-through. We leave further quantitative analysis of this novel transmission channel in a general equilibrium framework to future research.

References

Altavilla, C., L. Burlon, M. Giannetti, and S. Holton (2022): "Is there a zero lower bound? The effects of negative policy rates on banks and firms," *Journal of Financial Economics*, 144, 885–907.

Amzallag, A., A. Calza, D. Georgarakos, and J. Sousa (2019): "Monetary policy transmission to mortgages in a negative interest rate environment," Working paper no. 2243, European Central Bank.

Araujo, L., R. Minetti, and P. Murro (2021): "Relationship finance, informed liquidity, and monetary policy," *Journal of Economic Theory*, 193, 105210.

Balloch, C. M. and Y. Koby (2022): "Low Rates and Bank Loan Supply: Theory and Evidence from Japan," Working paper, London School of Economics and Political Science.

Balloch, C. M., Y. Koby, and M. Ulate (2022): "Making sense of negative rates," Working paper no. 2022-12, Federal Reserve Bank of San Francisco.

Beck, T., H. Degryse, R. De Haas, and N. van Horen (2018): "When arm's length is too far: Relationship banking over the credit cycle," *Journal of Financial Economics*, 127, 174–196.

Berlin, M. and L. Mester (1999): "Deposits and Relationship Lending," *The Review of Financial Studies*, 12, 579–607.

Bethune, Z., G. Rocheteau, T.-N. Wong, and C. Zhang (2021): "Lending Relationships and Optimal Monetary Policy," *The Review of Economic Studies*, 89, 1833–1872.

Bolton, P., X. Freixas, L. Gambacorta, and P. E. Mistrulli (2016): "Relationship and transaction lending in a crisis," *Review of Financial Studies*, 29, 2643–2676.

Botsch, M. and V. Vanasco (2019): "Learning by lending," *Journal of Financial Intermediation*, 37, 1–14.

Brubakk, L., S. ter Ellen, Ø. Robstad, and H. Xu (2022): "The macroeconomic effects of forward communication," *Journal of International Money and Finance*, 120, 102536.

Brunnermeier, M. K. and Y. Koby (2018): "The reversal interest rate," Working Paper 25406, National Bureau of Economic Research.

Degryse, H., O. De Jonghe, S. Jakovljević, K. Mulier, and G. Schepens (2019): "Identifying credit supply shocks with bank-firm data: Methods and applications," *Journal of Financial Intermediation*, 40, 100813.

Dell'ariccia, G. and R. Marquez (2004): "Information and bank credit allocation," *Journal of Financial Economics*, 72, 185–214.

Diamond, D. W. (1984): "Financial intermediation and delegated monitoring," *Review of Economic Studies*, 51, 393–414.

Eggertsson, G. B., R. E. Juelsrud, L. H. Summers, and E. G. Wold (2019): "Negative nominal interest rates and the bank lending channel," Working Paper 25416, National Bureau of Economic Research.

Eisenshmidt, J. and F. Smets (2019): "Negative interest rates: Lessons from the euro area," *Series on Central Banking Analysis and Economic Policies no. 26.*

Gertler, M. and P. Karadi (2015): "Monetary policy surprises, credit costs, and economic activity," *American Economic Journal: Macroeconomics*, 7, 44–76.

Greenwald, D. (2019): "Firm debt covenants and the macroeconomy: The interest coverage channel," Working paper, MIT Sloan School of Management.

Hachem, K. (2011): "Relationship lending and the transmission of monetary policy," *Journal of Monetary Economics*, 58, 590–600.

Heider, F., F. Saidi, and G. Schepens (2019): "Life below zero: Bank lending under negative policy rates," *Review of Financial Studies*, 32, 3728–3761.

Ioannidou, V. and S. Ongena (2010): ""Time for a change": loan conditions and bank behavior when firms switch banks," *The Journal of Finance*, 65, 1847–1877.

Jarociński, M. and P. Karadi (2020): "Deconstructing monetary policy surprises – The role of information shocks," *American Economic Journal: Macroeconomics*, 12, 1–43.

Kysucky, V. and L. Norden (2016): "The Benefits of Relationship Lending in a Cross-Country Context: A Meta-Analysis," *Management Science*, 62, 90–110.

Li, Y., R. Lu, and A. Srinivasan (2019): "Relationship Bank Behavior during Borrower Distress," *Journal of Financial and Quantitative Analysis*, 54, 1231–1262.

Liaudinskas, K. (2023): "How forced switches reveal switching costs: evidence from the loan market," *Working paper.*

Petersen, M. A. and R. G. Rajan (1994): "The Benefits of Lending Relationships: Evidence from Small Business Data," *The Journal of Finance*, 49, 3–37.

Rajan, R. G. (1992): "Insiders and outsiders: The choice between informed and arm's-length debt," *Journal of Finance*, 47, 1367–1400.

Schenone, C. (2010): "Lending relationships and information rents: Do banks exploit their information advantages?" *Review of Financial Studies*, 23, 1149–1199.

Sharpe, S. A. (1990): "Asymmetric information, bank lending and implicit contracts: A stylized model of customer relationships," *Journal of Finance*, 45, 1069–1087.

Ulate, M. (2021): "Going Negative at the Zero Lower Bound: The Effects of Negative Nominal Interest Rates," *American Economic Review*, 111, 1–40.

von Thadden, E.-L. (2004): "Asymmetric information, bank lending and implicit contracts: the winner's curse," *Finance Research Letters*, 1, 11–23.

Wang, O. (2018): "Banks, low interest rates, and monetary policy transmission," *NYU Stern School of Business*.

Wang, Y., T. M. Whited, Y. Wu, and K. Xiao (2022): "Bank Market Power and Monetary Policy Transmission: Evidence from a Structural Estimation," *The Journal of Finance*, 77, 2093–2141.

6 Appendix

6.1 Exogenous Monetary Policy Shocks

This section presents the same regression tables as our main empirical analyses from section (3), but using identified monetary policy shocks instead of changes in the NIBOR. The notes below each table indicate the equivalent table in the main text.

Table 8: Average Pass-Through: Identified MP Shocks

	(1)	(2)	(3)	(4)	(5)	(6)
MP_{t-1}	0.111	0.889***	1.653***	4.197***	-3.707***	-0.356
	(0.098)	(0.197)	(0.124)	(0.210)	(0.212)	(0.412)
$tight_{t-1} \times MP_{t-1}$			-3.565***	-7.568***	0.398	14.452***
			(0.175)	(0.475)	(0.374)	(2.653)
$MP_{t-1} \times Nibor_{t-1}$					2.222***	0.969***
					(0.096)	(0.200)
$tight_{t-1} \times MP_{t-1} \times Nibor_{t-1}$					-1.889***	-3.400***
					(0.065)	(0.231)
N	937476	763122	937476	763122	937476	763122
Macro Controls	No	Yes	No	Yes	No	Yes
Firm Controls	No	Yes	No	Yes	No	Yes
Bank Controls	No	Yes	No	Yes	No	Yes
Industry-Time FE	No	No	No	No	No	No
ILS-Time FE	No	No	No	No	No	No
Bank-Time FE	No	No	No	No	No	No
Bank-Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 2 in the main text.

Table 9: Pass-Through and Relationship Length: Identified MP Shocks

	(1)	(2)	(3)	(4)
$length_{ibt} \times MP_{t-1}$	-0.963***	-0.395***	-0.426***	-0.473***
	(0.073)	(0.113)	(0.101)	(0.118)
$length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	0.482***	0.185***	0.195***	0.207***
	(0.030)	(0.041)	(0.036)	(0.041)
$tight_{t-1} \times length_{ibt} \times MP_{t-1}$	0.513***	0.652***	0.596***	0.673***
	(0.141)	(0.135)	(0.117)	(0.120)
$tight_{t-1} \times length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	-0.383***	-0.244***	-0.231***	-0.241***
	(0.041)	(0.046)	(0.039)	(0.043)
N	937476	937449	703029	865407
Macro Controls	No	No	No	No
Firm Controls	No	No	No	Yes
Bank Controls	No	No	No	No
Industry-Time FE	No	No	No	Yes
ILS-Time FE	No	No	Yes	No
Bank-Time FE	No	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 4 in the main text.

Table 10: Credit Growth and Relationship Length: Identified MP Shocks

	(1)	(2)	(3)	(4)
$length_{ibt} \times MP_{t-1}$	0.057**	0.009	0.033**	-0.004
	(0.021)	(0.010)	(0.010)	(0.009)
$length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	-0.012	-0.000	-0.011*	0.003
	(0.011)	(0.006)	(0.005)	(0.005)
$tight_{t-1} \times length_{ibt} \times MP_{t-1}$	-0.010	-0.130***	-0.138***	-0.081***
	(0.027)	(0.012)	(0.013)	(0.014)
$tight_{t-1} \times length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	0.011	0.023***	0.033***	0.013*
	(0.013)	(0.006)	(0.006)	(0.006)
N	968586	968564	703932	873884
Macro Controls	No	No	No	No
Firm Controls	No	No	No	Yes
Bank Controls	No	No	No	No
Industry-Time FE	No	No	No	Yes
ILS-Time FE	No	No	Yes	No
Bank-Time FE	No	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 6 in the main text.

6.2 Using Account-Level Information

This section presents the same regression tables as our main empirical analyses from section (3), but using newly issued accounts only. The title of each table indicates whether the regressions were run using changes in the NIBOR or identified monetary policy shocks. The notes below each table indicate the equivalent table in the main text.

Table 11: Average Pass-Through: Changes in NIBOR

	(1)	(2)	(3)	(4)	(5)	(6)
MP_{t-1}	0.117***	0.478***	-0.055**	0.257***	-0.505***	-0.126
	(0.018)	(0.033)	(0.021)	(0.032)	(0.090)	(0.093)
$tight_{t-1} \times MP_{t-1}$			0.578***	1.357***	4.515***	2.962***
			(0.041)	(0.072)	(0.320)	(0.230)
$MP_{t-1} \times Nibor_{t-1}$					0.185***	0.151***
					(0.029)	(0.027)
$tight_{t-1} \times MP_{t-1} \times Nibor_{t-1}$					-0.730***	-0.277***
					(0.098)	(0.053)
N	93304	79592	93304	79592	93304	79592
Macro Controls	No	Yes	No	Yes	No	Yes
Firm Controls	No	Yes	No	Yes	No	Yes
Bank Controls	No	Yes	No	Yes	No	Yes
Industry-Time FE	No	No	No	No	No	No
ILS-Time FE	No	No	No	No	No	No
Bank-Time FE	No	No	No	No	No	No
Bank-Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 2 in the main text.

Table 12: Pass-Through and Relationship Length: Changes in NIBOR

	(1)	(2)	(3)	(4)
$length_{ibt} \times MP_{t-1}$	-0.068*	-0.062	-0.069	-0.097*
	(0.028)	(0.032)	(0.052)	(0.043)
$length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	0.035**	0.033**	0.033	0.047**
	(0.010)	(0.012)	(0.020)	(0.016)
$tight_{t-1} \times length_{ibt} \times MP_{t-1}$	0.084	0.105	0.061	0.258**
	(0.051)	(0.074)	(0.088)	(0.087)
$tight_{t-1} \times length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	-0.007	-0.034	-0.024	-0.075**
	(0.012)	(0.020)	(0.026)	(0.024)
N	93304	92940	42052	87576
Macro Controls	No	No	No	No
Firm Controls	No	No	No	Yes
Bank Controls	No	No	No	No
Industry-Time FE	No	No	No	Yes
ILS-Time FE	No	No	Yes	No
Bank-Time FE	No	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 4 in the main text.

Table 13: Average Pass-Through: Identified MP Shocks

	(1)	(2)	(3)	(4)	(5)	(6)
MP_{t-1}	-0.138	0.694***	1.242***	4.069***	-2.618***	0.459
	(0.093)	(0.203)	(0.195)	(0.307)	(0.433)	(0.688)
$tight_{t-1} \times MP_{t-1}$			-2.560***	-7.098***	0.249	17.927***
			(0.324)	(0.661)	(0.609)	(3.001)
$MP_{t-1} \times Nibor_{t-1}$					1.673***	0.557
					(0.132)	(0.308)
$tight_{t-1} \times MP_{t-1} \times Nibor_{t-1}$					-1.470***	-3.616***
					(0.171)	(0.353)
N	93304	79592	93304	79592	93304	79592
Macro Controls	No	Yes	No	Yes	No	Yes
Firm Controls	No	Yes	No	Yes	No	Yes
Bank Controls	No	Yes	No	Yes	No	Yes
Industry-Time FE	No	No	No	No	No	No
ILS-Time FE	No	No	No	No	No	No
Bank-Time FE	No	No	No	No	No	No
Bank-Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 2 in the main text.

Table 14: Pass-Through and Relationship Length: Identified MP Shocks

	(1)	(2)	(3)	(4)
$length_{ibt} \times MP_{t-1}$	-1.219***	-0.693***	-0.799***	-0.982***
	(0.140)	(0.167)	(0.235)	(0.199)
$length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	0.617***	0.325***	0.348**	0.432***
	(0.060)	(0.067)	(0.114)	(0.080)
$tight_{t-1} \times length_{ibt} \times MP_{t-1}$	0.430*	0.782***	0.737**	1.040***
	(0.178)	(0.192)	(0.278)	(0.228)
$tight_{t-1} \times length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	-0.494***	-0.360***	-0.325*	-0.431***
	(0.075)	(0.075)	(0.141)	(0.081)
N	93304	92940	42052	87576
Macro Controls	No	No	No	No
Firm Controls	No	No	No	Yes
Bank Controls	No	No	No	No
Industry-Time FE	No	No	No	Yes
ILS-Time FE	No	No	Yes	No
Bank-Time FE	No	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 4 in the main text.

Table 15: Credit Growth and Relationship Length: Changes in NIBOR

	(1)	(2)	(3)	(4)
$length_{ibt} \times MP_{t-1}$	0.006	0.001	0.002	-0.008
	(0.004)	(0.005)	(0.013)	(0.006)
$length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	-0.001	0.001	-0.000	0.004
	(0.002)	(0.002)	(0.005)	(0.002)
$tight_{t-1} \times length_{ibt} \times MP_{t-1}$	-0.130***	-0.177***	-0.184***	-0.100***
	(0.012)	(0.013)	(0.030)	(0.013)
$tight_{t-1} \times length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	0.030***	0.040***	0.042***	0.024***
	(0.003)	(0.003)	(0.007)	(0.003)
N	58475	57979	23988	55255
Macro Controls	No	No	No	No
Firm Controls	No	No	No	Yes
Bank Controls	No	No	No	No
Industry-Time FE	No	No	No	Yes
ILS-Time FE	No	No	Yes	No
Bank-Time FE	No	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 6 in the main text.

Table 16: Credit Growth and Relationship Length: Identified MP Shocks

	(1)	(2)	(3)	(4)
$length_{ibt} \times MP_{t-1}$	0.022	0.059	0.149	-0.017
	(0.034)	(0.043)	(0.082)	(0.038)
$length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	-0.009	-0.026	-0.080*	-0.000
	(0.014)	(0.018)	(0.039)	(0.015)
$tight_{t-1} \times length_{ibt} \times MP_{t-1}$	0.074	-0.034	-0.204*	0.035
	(0.051)	(0.049)	(0.079)	(0.043)
$tight_{t-1} \times length_{ibt} \times MP_{t-1} \times Nibor_{t-1}$	0.000	0.033	0.123***	0.009
	(0.017)	(0.019)	(0.035)	(0.017)
N	58475	57979	23988	55255
Macro Controls	No	No	No	No
Firm Controls	No	No	No	Yes
Bank Controls	No	No	No	No
Industry-Time FE	No	No	No	Yes
ILS-Time FE	No	No	Yes	No
Bank-Time FE	No	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes

Dually clustered (bank and firm levels) standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table is the equivalent of table 6 in the main text.

6.3 Proofs

Proof of Lemma 1

The bank's problem is:

$$\max_{r_{sw},r_s,r_l,r_d,S} \quad N = (1+r_{sw})L_{sw}(r_{sw})+(1+r_s)L_s(r_s)+(1+r_l)L_l(r_l)+(1+i)S-(1+r_d)D(r_d)$$

s.t.

$$\begin{aligned}
L_{sw}(r_{sw}) &= \begin{cases} > \bar{L}_{sw} & \text{if } r_{sw} < r_{out} \\ \bar{L}_{sw} & \text{if } r_{sw} = r_{out} \\ 0 & \text{if } r_{sw} > r_{out} \end{cases} \\
L_s(r_s) &= [1 - F_s(r_s - r_{out})]p_s\mathbf{L} \\
L_l(r_l) &= [1 - F_l(r_l - r_{out})](1 - p_s)\mathbf{L} \\
D(r_d) &= \left(\frac{1+r_d}{1+\bar{r}_d}\right)^{-\epsilon^d}\mathbf{D} \\
L_{sw} + L_s + L_l + S &= E + D \qquad \text{(Balance sheet)} \\
\lambda(L_{sw} + L_s + L_l) &\leq N \qquad \text{(Net worth constraint)}
\end{aligned}$$

Substituting the balance sheet constraint in the objective function, we can rewrite the maximization problem as:

$$\max_{r_{sw},r_s,r_l,r_d} \quad N = (r_{sw}-i)L_{sw}(r_{sw})+(r_s-i)L_s(r_s)+(r_l-i)L_l(r_l)+(1+i)E+(i-r_d)D(r_d)$$

s.t.

$$\begin{aligned}
L_{sw}(r_{sw}) &= \begin{cases} > \bar{L}_{sw} & \text{if } r_{sw} < r_{out} \\ \bar{L}_{sw} & \text{if } r_{sw} = r_{out} \\ 0 & \text{if } r_{sw} > r_{out} \end{cases} \\
L_s(r_s) &= [1 - F_s(r_s - r_{out})]p_s\mathbf{L} \\
L_l(r_l) &= [1 - F_l(r_l - r_{out})](1 - p_s)\mathbf{L} \\
D(r_d) &= \left(\frac{1+r_d}{1+\bar{r}_d}\right)^{-\epsilon^d}\mathbf{D} \\
\lambda(L_{sw} + L_s + L_l) &\leq N
\end{aligned}$$

The associated Lagrangian is:

$$
\begin{aligned}
\mathcal{L} &= (r_{sw}-i)L_{sw}(r_{sw}) + (r_s-i)[1-F_s(r_s-r_{out})]p_s\mathbf{L} + (r_l-i)[1-F_l(r_l-r_{out})](1-p_s)\mathbf{L} \\
&+ (1+i)E + (i-r_d)\left(\frac{1+r_d}{1+\bar{r}_d}\right)^{-\epsilon^d}\mathbf{D} \\
&- \xi\Bigg((\lambda-(r_{sw}-i))L_{sw}(r_{sw}) + (\lambda-(r_s-i))[1-F_s(r_s-r_{out})]p_s\mathbf{L} \\
&+ (\lambda-(r_l-i))[1-F_l(r_l-r_{out})]p_l\mathbf{L} - (1+i)E - (i-r_d)\left(\frac{1+r_d}{1+\bar{r}_d}\right)^{-\epsilon^d}\mathbf{D}\Bigg)
\end{aligned}
$$

, where ξ is the Lagrange multiplier on the leverage constraint.
The F.O.C. with respect to r_s, $\frac{\partial\mathcal{L}}{\partial r_s}=0$ yields:

$$
\begin{aligned}
&[1-F_s(r_s-r_{out})]\,p_s\mathbf{L} - (r_s-i)f_s(r_s-r_{out})p_s\mathbf{L} \\
&-\xi(-(1-F_s(r_s-r_{out}))p_s\mathbf{L}) - (\lambda-(r_s-i))f_s(r_s-r_{out}))]p_s\mathbf{L}) = 0
\end{aligned}
$$

Solving for $r_s - i$ yields:

$$
r_s - i = \frac{1-F_s(r_s-r_{out})}{f_s(r_s-r_{out})} + \lambda\frac{\xi}{1+\xi}
$$

Analog for the F.O.C. with respect to r_l, $\frac{\partial\mathcal{L}}{\partial r_l}=0$.

The F.O.C. with respect to r_d, $\frac{\partial\mathcal{L}}{\partial r_d}=0$ yields:

$$
(1+\xi)\left(-\left(\frac{1+r_d}{1+\bar{r}_d}\right)^{-\epsilon^d}\mathbf{D} - (i-r_d)\epsilon^d\left(\frac{1+r_d}{1+\bar{r}_d}\right)^{-\epsilon^d-1}\mathbf{D}\frac{1}{1+\bar{r}_d}\right) = 0
$$

Solving for r_d yields $1+r_d^* = \frac{\epsilon^d}{\epsilon^d-1}(1+i)$.

Proof of Lemma 2

Apply the implicit function theorem on FOCs (15) and (16) to get how the optimal rates r_s^* and r_l^* react to a change in the policy rate i. We show this explicitly for r_s.

Define the function $G(r_s, i)$ from FOC (15) and consider the case where the leverage constraint does not bind s.t. $\xi = 0$:

$$G(r_s, i) = r_s - i - \frac{1 - F(r_s - r_{out}(i))}{f(r_s - r_{out}(i))} = 0$$

We have:

$$\begin{aligned}
\frac{\partial G}{\partial r_s} &= 1 - \left(\frac{-f(r_s - r_{out}(i))^2 - (1 - F(r_s - r_{out}(i)))f'(r_s - r_{out}(i))}{f(r_s - r_{out}(i))^2} \right) \\
&= 2 + \frac{(1 - F(r_s - r_{out}(i)))f'(r_s - r_{out}(i))}{f(r_s - r_{out}(i))^2}
\end{aligned}$$

and:

$$\begin{aligned}
\frac{\partial G}{\partial i} &= -1 - \left(\frac{f(r_s - r_{out})^2 r'_{out}(i) + (1 - F(r_s - r_{out}(i)))f'(r_s - r_{out}(i))r'_{out}(i)}{f(r_s - r_{out}(i))^2} \right) \\
&= -1 - r'_{out}(i) - \frac{(1 - F(r_s - r_{out}(i)))f'(r_s - r_{out}(i))r'_{out}(i)}{f(r_s - r_{out}(i))^2}
\end{aligned}$$

By the implicit function theorem, it therefore follows:

$$\frac{dr_s^*}{di} = -\frac{\partial G}{\partial i} / \frac{\partial G}{\partial r_s} = \frac{1 + r'_{out}(i) \left(1 + \frac{(1-F(r_s - r_{out}(i)))f'(r_s - r_{out}(i))}{f(r_s - r_{out}(i))^2} \right)}{1 + \left(1 + \frac{(1-F(r_s - r_{out}(i)))f'(r_s - r_{out}(i))}{f(r_s - r_{out}(i))^2} \right)}$$

Using the FOC (15), this can be rewritten:

$$\frac{dr_s^*}{di} = \frac{1 + r'_{out}(i) \left(1 + (r_s^* - i) \frac{f'(r_s - r_{out}(i))}{f(r_s - r_{out}(i))} \right)}{1 + \left(1 + (r_s^* - i) \frac{f'(r_s - r_{out}(i))}{f(r_s - r_{out}(i))} \right)}$$

Analog derivation for $\frac{dr_l^*}{di}$.

Proof of Proposition 1

Let $i < \tilde{i}$ so that $\frac{\partial r_{out}}{\partial i} = g'(i) < 1$. Rewrite $\frac{dr_s^*}{di}$:

$$\frac{dr_s^*}{di} = \frac{1 + g'(i)x_s}{1 + x_s},$$

where $x_s := 1 + (r_s^* - i)\frac{f'(r_s - r_{out}(i))}{f(r_s - r_{out}(i))}$.

Similarly, rewrite $\frac{dr_l^*}{di}$:

$$\frac{dr_l^*}{di} = \frac{1+g'(i)x_l}{1+x_l},$$

where $x_l := 1 + (r_l^* - i)\frac{f'(r_l - r_{out}(i))}{f(r_l - r_{out}(i))}$.

The function $f(z) = \frac{1+g'(i)z}{1+z}$ is decreasing in z. It follows that $\frac{dr_s^*}{di} > \frac{dr_l^*}{di}$ if $x_s < x_l$:

$$1 + (r_s^* - i)\frac{f'(r_s - r_{out}(i))}{f(r_s - r_{out}(i))} < 1 + (r_l^* - i)\frac{f'(r_l - r_{out}(i))}{f(r_l - r_{out}(i))} \tag{33}$$

using the definition of the elasticity of the density function $f(x)$ at x^*:

$$\epsilon_f|_{x^*} = \frac{f'(x^*)}{f(x^*)}x^*$$

, we can rewrite condition (33) as:

$$\frac{r_s^* - i}{r_s^* - g(i)}\epsilon_{f_s|_{r_s^* - g(i)}} < \frac{r_l^* - i}{r_l^* - g(i)}\epsilon_{f_l|_{r_l^* - g(i)}},$$

Proof of Lemma 3

Let $f_k \sim GPD(\mu_k, \sigma_k, \xi_k)$, where $k \in \{s, l\}$. Plugging in the associated probability density functions and cumulative density functions in the first order conditions derived in lemma 1 yields:

$$r_k - i = \frac{\left(1 + \xi_k \frac{(r_k - r_{out} - \mu_k)}{\sigma_k}\right)^{-\frac{1}{\xi_k}}}{\frac{1}{\sigma_k}\left(1 + \xi_k \frac{(r_k - r_{out} - \mu_k)}{\sigma_k}\right)^{-\frac{1}{\xi_k} - 1}}$$

Solving for r_k yields the result.

Proof of Lemma 4

Let $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ and $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. The threshold $\bar{i}$ is implicitly defined as the highest policy rate i at which the bank's net worth constraint exactly binds (i.e. with the multiplier equal to zero). The binding net worth constraint is given by:

$$\lambda L = L_{sw}(r_{sw} - i) + L_s(r_s - i) + L_l(r_l - i) + E(1 + i) + D(i - r_d)$$

The threshold $\bar{i}$ is the highest policy rate i such that this equality holds. We use the facts that $r_{sw} = r_{out}$ in equilibrium and $r_k - i = \sigma_k + \xi_k(r_k - r_{out} - \mu_k)$ for $k \in \{s, l\}$ from lemma 3. Furthermore, since we are looking at the highest rate i such that the constraint exactly binds, it holds $r_{out} = i$ and again from lemma 3: $r_k - i = \frac{\sigma_k - \xi_k \mu_k}{1 - \sigma_k}$.

Plugging this in the binding constraint yields:

$$\lambda L = L_s \left(\frac{\sigma_s - \xi_s \mu_s}{1 - \xi_s} \right) + L_l \left(\frac{\sigma_l - \xi_l \mu_l}{1 - \xi_l} \right) + E(1+i) + D * \max(i - \frac{1 + i\epsilon}{\epsilon - 1}, i)$$

We then use the expressions for loan demands with $r_{out} = i$:

$$L_k = [1 - F_k(r_k - i)] p_k$$

where $k \in \{s, l\}$ Replacing F_k with the GPD cumulative distribution function and using $r_k - i = \frac{\sigma_k - \xi_k \mu_k}{1 - \sigma_k}$, loan demands simplify to:

$$L_k = \left(1 + \frac{\xi_k}{1 - \xi_k} \frac{\sigma_k - \mu_k}{\sigma_k} \right)^{-\frac{1}{\xi_k}} p_k$$

Substituting this expression back into the binding net worth constraint yields:

$$\begin{aligned} \lambda L &= \left(1 + \frac{\xi_s}{1 - \xi_s} \frac{\sigma_s - \mu_s}{\sigma_s} \right)^{-\frac{1}{\xi_s}} p_s \left(\frac{\sigma_s - \xi_s \mu_s}{1 - \xi_s} \right) \\ &+ \left(1 + \frac{\xi_l}{1 - \xi_l} \frac{\sigma_l - \mu_l}{\sigma_l} \right)^{-\frac{1}{\xi_l}} p_l \left(\frac{\sigma_l - \xi_l \mu_l}{1 - \xi_l} \right) \\ &+ E(1+i) + D * \max(i - \frac{1 + i\epsilon}{\epsilon - 1}, i) \end{aligned}$$

Defining:

$$\begin{aligned} \tau_s &= \left(1 + \frac{\xi_s}{1 - \xi_s} \frac{\sigma_s - \mu_s}{\sigma_s} \right)^{-\frac{1}{\xi_s}} p_s \left(\frac{\sigma_s - \xi_s \mu_s}{1 - \xi_s} \right) \\ \tau_l &= \left(1 + \frac{\xi_l}{1 - \xi_l} \frac{\sigma_l - \mu_l}{\sigma_l} \right)^{-\frac{1}{\xi_l}} p_l \left(\frac{\sigma_l - \xi_l \mu_l}{1 - \xi_l} \right) \end{aligned}$$

and assuming the zero lower bound constraint on the deposit rate binds, one can rewrite the binding net worth constraint as:

$$\lambda L = \tau_s + \tau_l + E(1+i) + Di$$

Finally, using the balance sheet identity $D + E = L + S$ and solving for i yields $\bar{i}$:

$$\bar{i} = \frac{\lambda L - \tau_s - \tau_l - E}{1 + S}$$

Proof of Lemma 5

Let $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ and $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. We are seeking the monetary policy pass-through to the outside rate $r_{out} = g(i)$ when $i < \bar{i}$.

In the region $i < \bar{i}$, the outside rate is implicitly defined by the binding bank's net worth constraint:

$$\lambda L = N$$

The first step of the proof consists of rewriting the binding constraint as a function of i and $g(i)$ to apply the implicit function theorem. That is, our goal is to rewrite the constraint under the form:

$$N - \lambda L = h(i, g(i)) = 0$$

We have:

$$h(i, g(i)) = L_{sw}(g(i) - i) + L_s(r_s - i) + L_l(r_l - i) + D(i - r_d) + E(1 + i) - \lambda L$$

We use the FOC from lemma 3, which establishes $r_k - i = \frac{\sigma_k - \xi_k(g(i) + \mu_k - i)}{1 - \xi_k}$ for $k \in \{s, l\}$ and rewrite:

$$\begin{aligned} h(i, g(i)) &= L_{sw}(g(i) - i) + L_s\left(\frac{\sigma_s - \xi_s(g(i) + \mu_s - i)}{1 - \xi_s}\right) + L_l\left(\frac{\sigma_l - \xi_l(g(i) + \mu_l - i)}{1 - \xi_l}\right) \\ &+ D * \min(\frac{1 + i}{1 - \epsilon}, i) + E(1 + i) - \lambda L \end{aligned}$$

We then rewrite the optimal quantities L_s and L_l in terms of i and $g(i)$.

$$\begin{aligned} L_s &= [1 - F_s(r_s - g(i))]p_s L \\ &= \left(1 + \xi_s \frac{r_s - g(i) - \mu_s}{\sigma_s}\right)^{-\frac{1}{\xi_s}} p_s L \end{aligned}$$

and again using the FOC from lemma 3 for $r_s - g(i)$:

$$L_s = \left(1 + \frac{\xi_s}{\sigma_s} \frac{(\sigma_s + i - g(i) - \mu_s)}{1 - \xi_s}\right)^{-\frac{1}{\xi_s}} p_s L$$

By symmetry, the same holds for L_l. Using $L_{sw} = L - L_s - L_l$, one can rewrite:

$$\begin{aligned} h(i, g(i)) &= L(g(i) - i) \\ &+ \left(1 + \frac{\xi_s}{\sigma_s} \frac{(\sigma_s + i - g(i) - \mu_s)}{1 - \xi_s}\right)^{-\frac{1}{\xi_s}} p_s L \left(\frac{\sigma_s - \xi_s(g(i) + \mu_s - i)}{1 - \xi_s} - (g(i) - i)\right) \\ &+ \left(1 + \frac{\xi_l}{\sigma_l} \frac{(\sigma_l + i - g(i) - \mu_l)}{1 - \xi_l}\right)^{-\frac{1}{\xi_l}} p_l L \left(\frac{\sigma_l - \xi_l(g(i) + \mu_l - i)}{1 - \xi_l} - (g(i) - i)\right) \\ &+ D * \min(\frac{1 + i}{1 - \epsilon}, i) + E(1 + i) - \lambda L \end{aligned}$$

Simplifying further yields:

$$
\begin{aligned}
h(i,g(i)) &= L(g(i)-i) \\
&+ \left(1+\frac{\xi_s}{\sigma_s}\frac{(\sigma_s+i-g(i)-\mu_s)}{1-\xi_s}\right)^{-\frac{1}{\xi_s}} p_s L\left(\frac{\sigma_s+i-g(i)-\xi_s\mu_s}{1-\xi_s}\right) \\
&+ \left(1+\frac{\xi_l}{\sigma_l}\frac{(\sigma_l+i-g(i)-\mu_l)}{1-\xi_l}\right)^{-\frac{1}{\xi_l}} p_l L\left(\frac{\sigma_l+i-g(i)-\xi_l\mu_l}{1-\xi_l}\right) \\
&+ D*\min(\frac{1+i}{1-\epsilon},i)+E(1+i)-\lambda L \\
&= 0
\end{aligned}
$$

We can now get the partial derivatives $\frac{\partial h(i,g(i))}{\partial g(i)}$ and $\frac{\partial h(i,g(i))}{\partial i}$ and apply the implicit function theorem.

$$
\begin{aligned}
\frac{\partial h(i,g(i))}{\partial g(i)} &= L(1+p_s\left(1+\frac{\xi_s}{\sigma_s}\frac{(\sigma_s+i-g(i)-\mu_s)}{1-\xi_s}\right)^{-\frac{1}{\xi_s}-1}\frac{i-g(i)}{\sigma_s(1-\xi_s)} \\
&+ p_l\left(1+\frac{\xi_l}{\sigma_l}\frac{(\sigma_l+i-g(i)-\mu_l)}{1-\xi_l}\right)^{-\frac{1}{\xi_l}-1}\frac{i-g(i)}{\sigma_l(1-\xi_l)})
\end{aligned}
$$

and

$$
\begin{aligned}
\frac{\partial h(i,g(i))}{\partial i} &= -L(1+p_s\left(1+\frac{\xi_s}{\sigma_s}\frac{(\sigma_s+i-g(i)-\mu_s)}{1-\xi_s}\right)^{-\frac{1}{\xi_s}-1}\frac{i-g(i)}{\sigma_s(1-\xi_s)} \\
&+ p_l\left(1+\frac{\xi_l}{\sigma_l}\frac{(\sigma_l+i-g(i)-\mu_l)}{1-\xi_l}\right)^{-\frac{1}{\xi_l}-1}\frac{i-g(i)}{\sigma_l(1-\xi_l)})+D+E
\end{aligned}
$$

Finally, since $\frac{dg(i)}{di} = -\frac{\partial h/\partial i}{\partial h/\partial g(i)}$:

$$
\begin{aligned}
\frac{dg(i)}{di} &= -\frac{-L\left(1+p_s\kappa_s^{-\frac{1}{\xi_s}-1}\frac{i-g(i)}{\sigma_s(1-\xi_s)}+p_l\kappa_l^{-\frac{1}{\xi_l}-1}\frac{i-g(i)}{\sigma_l(1-\xi_l)}\right)+D+E}{L\left(1+p_s\kappa_s^{-\frac{1}{\xi_s}-1}\frac{i-g(i)}{\sigma_s(1-\xi_s)}+p_l\kappa_l^{-\frac{1}{\xi_l}-1}\frac{i-g(i)}{\sigma_l(1-\xi_l)}\right)} \\
&= 1-\frac{D+E}{L\left(1+p_s\kappa_s^{-\frac{1}{\xi_s}-1}\frac{i-g(i)}{\sigma_s(1-\xi_s)}+p_l\kappa_l^{-\frac{1}{\xi_l}-1}\frac{i-g(i)}{\sigma_l(1-\xi_l)}\right)} \\
&= 1-\frac{L+S}{L\left(1-(g(i)-i)\left[\frac{p_s}{\sigma_s(1-\xi_s)}\kappa_s^{-\frac{1}{\xi_s}-1}+\frac{p_l}{\sigma_l(1-\xi_l)}\kappa_l^{-\frac{1}{\xi_l}-1}\right]\right)}
\end{aligned}
$$

where we used the balance sheet identity: $D + E = L + S$ and

$$\begin{aligned}\kappa_s &= \left(1 + \frac{\xi_s}{\sigma_s}\frac{(\sigma_s + i - g(i) - \mu_s)}{1-\xi_s}\right)\\ \kappa_l &= \left(1 + \frac{\xi_l}{\sigma_l}\frac{(\sigma_l + i - g(i) - \mu_l)}{1-\xi_l}\right).\end{aligned}$$

Proof of Lemma 6

Let $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ and $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. Using the general expression for pass-through derived in lemma 2, the GPD probability density function and its derivative

$$\begin{aligned}f(x) &= \frac{1}{\sigma}\left(1 + \xi\left(\frac{x-\mu}{\sigma}\right)\right)^{-(\frac{1}{\xi}+1)}\\ f'(x) &= -\frac{\xi}{\sigma^2}\left(\frac{1}{\xi}+1\right)\left(1 + \xi\frac{x-\mu}{\sigma}\right)^{-\frac{1}{\xi}-2}\end{aligned}$$

yields:

$$\frac{dr_k}{di} = \frac{1 + g'(i)\left(1 - (r_k - i)\frac{1+\xi_k}{\sigma_k + \xi_k(r_k - g(i) - \mu_k)}\right)}{1 + \left(1 - (r_k - i)\frac{1+\xi_k}{\sigma_k + \xi_k(r_k - g(i) - \mu_k)}\right)}$$

for $k \in \{s, l\}$.

Further substituting $r_k - i$ with $\sigma_k + \xi_k(r_k - g(i) - \mu_k)$ from the FOC derived in lemma 3 yields the result

$$\frac{dr_k}{di} = \frac{1 - g'(i)\xi_k}{1 - \xi_k}$$

for $k \in \{s, l\}$.

Proof of Proposition 2

Let $f_s \sim GPD(\mu_s, \sigma_s, \xi_s)$ and $f_l \sim GPD(\mu_l, \sigma_l, \xi_l)$. Let $i < \bar{i}$ so that $\frac{\partial r_{out}}{\partial i} = g'(i) < 1$. Using the pass-through result from lemma 6, it is clear that $\frac{dr_l}{di} < \frac{dr_s}{di}$ if and only if $\xi_s > \xi_l$:

$$\frac{1 - g'(i)\xi_l}{1 - \xi_l} < \frac{1 - g'(i)\xi_s}{1 - \xi_s} \iff \xi_s > \xi_l$$

6.4 Details on Calibration

6.5 Relationship Duration and Interest Rate Levels

We document the evolution of interest rates that banks charge their borrowers as the lengths of their relationships grow. We run the following regression:

$$r_{ibt} = \alpha_{ib} + \alpha_{jt} + \alpha_{bt} + \mathbf{Z}_{it}\gamma + \sum_{l=2}^{22} \beta_l \mathcal{I}_{l,ibt} + \epsilon_{ibt}, \tag{34}$$

where r_{ibt} is the loan rate paid by firm i to bank b in year t. α_{ib} are firm-bank (i.e. relationship) fixed effects. α_{jt} are industry-time fixed effects. α_{bt} are bank-time fixed effects. $\mathbf{Z}_{it}$ are firm-level controls including the firm's age, size by total assets, leverage ratio, and credit rating. $\mathcal{I}_{l,ibt}$ are a set of dummies taking the value of 1 if the relationship duration between firm i and bank b at time t is l years.

With the base category being 1 year of relationship, the coefficients β_l tell us the additional effect of being in a l-year relationship on the interest rate. The inclusion of bank-time fixed effects controls for all bank balance sheet items and ensures that the identification of the β coefficients is not contaminated by bank characteristics such as liquidity and capital ratios. On the firm side, we control for the most important characteristics that usually explain the level of loan rates. As previously mentioned, approximately 80% of the firms in our dataset borrow from one bank only and we therefore will lose most of the observations if we include firm-time fixed effects. We nevertheless include firm-time fixed effects in a robustness check later. The inclusion of bank-firm fixed effects allows for identification within relationship and therefore controls for all relationship-specific characteristics, such as macroeconomic conditions at the time when the relationship started.

Figure 11 plots the β coefficients. It shows that, after the first year, the interest rate drops by 0.9 percentage point on average. This could indicate that banks learn about the credit quality of their borrowers during the first year of the relationship, retaining only good firms and decreasing the rate charged in the second year to reflect lower credit risk. Banks then ratchet the rates up by approximately 0.1 percentage point per year until the fifth year of the relationship, after which they seem to reach a plateau.

Figure 11: Interest Rate Path