THE TRANSMISSION OF NEGATIVE NOMINAL INTEREST RATES IN FINLAND

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Abstract
Despite the implementation of negative nominal interest rates by several advanced economies in the last decade, there is still much we do not know about the effectiveness of this instrument. In this paper, we analyze the pass-through of the European Central Bank's changes in the deposit facility rate to mortgage rates in Finland between 2005 and 2020. We use monthly data and three different empirical methodologies: event studies, high-frequency identification, and exposure-measure regressions. We provide robust evidence that there continues to be pass-through of a cut in the policy rate to mortgage rates even when the policy rate is in negative territory, but that this pass-through is smaller than when the policy rate is in positive territory. (JEL: E44, E52, E58, G21)

1. Introduction

Ever since the Great Financial Crisis of 2008–2009, monetary-policy makers in many advanced economies have frequently brought their main policy interest rate to the vicinity of 0% in order to stimulate economic activity. To confront a perceived zero

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lower bound on the monetary policy rate, central banks expanded their tool set to experiment with unconventional approaches, including negative nominal interest rates, quantitative easing (QE), and forward guidance. Among these unconventional tools, negative policy rates hold a special significance because, if they worked effectively, then the other unconventional policies might not even be necessary under most circumstances.

Despite their implementation in Europe and Japan, questions remain regarding the effectiveness of negative nominal interest rates and their transmission to the financial system and the real economy. While there appears to be some consensus on the transmission of negative rates to bond rates and deposit rates, their transmission to loan rates is much less clear.[1] As discussed in Balloch, Koby, and Ulate (2022), while a slight majority of papers in the negative-rates literature has found that cuts in the policy rate in negative territory still pass through to different types of loan rates, significant disagreement remains.[2] Eggertsson et al. (2024), for instance, argue that cuts in the policy rate in negative territory do not pass through to mortgage rates in Sweden.

In this paper, we contribute to the literature assessing the effectiveness of unconventional monetary policy tools by studying how the pass-through of the policy rate to mortgage rates in Finland changes once the policy rate turns negative. Using three distinct empirical methodologies: event studies, high-frequency identification, and exposure-measure regressions, we provide robust evidence that there continues to be pass-through of a cut in the policy rate to mortgage rates even in the territory where the policy rate is negative (henceforth referred to as "negative territory"). However, we also find that the pass-through in negative territory is smaller than the one in positive territory.

Focusing on a single loan product, home mortgages, for a single euro-zone country, Finland, has some empirical advantages. First, mortgages are more homogeneous to Finnish households than they would be to the whole euro zone, so that the mortgage rates that we study are more directly comparable over time and across banks. Second, all Finnish banks are supervised and regulated by the same authority so that mortgage loan pricing is expected to be more uniform. Third, we can exploit the granular data collected by the Finnish banking regulator under uniform reporting requirements. Finally, being a small country among the 19 economies in the euro zone, Finland's GDP is just about 2% of the euro zone's GDP. Thus, the monetary policy of the European Central Bank (ECB) is unlikely to respond directly to Finnish economic developments alone, mitigating concerns about the endogenity of the policy rate.

Moreover, Finland can also serve as a point of comparison for other countries where the transmission of negative rates to mortgages has been previously studied,

1. The transmission to bond rates has been found to be roughly one-for-one, while the transmission to deposit rates has found to be very limited or nonexistent; see Balloch, Koby, and Ulate (2022).

2. Other useful reviews of the negative-rates literature include Brandao-Marques et al. (2021), Heider, Saidi, and Schepens (2021), Tenreyro (2021), and Ulate (2021a).

such as Sweden (c.f., Eggertsson et al. 2024). Finland is adjacent to Sweden by land and separated from it by the Baltic sea. The two economies are similar in many respects, including their banking market structure and banking products. An important difference is that Finland is in the euro area while Sweden has its own currency and sets its own monetary policy.

Identifying the causal effects of cuts in the policy rate on loan rates in negative territory is not an easy task. Balloch, Koby, and Ulate (2022) enumerate the identification schemes that have been used to answer this question: high-frequency identification, exposure-measure regressions, and cross-country regressions. In this paper, we first use event studies to illustrate how the pass-through of the policy interest rate to mortgage rates might have changed once the policy rate became negative. We further delve into high-frequency and exposure-measure regressions in order to identify the causal effects of negative nominal interest rates. In what follows, we describe these methodologies in detail, together with our results when using each of them.

To begin, we study the relationship between changes in the policy rate and changes in mortgage rates, denoted the "mortgage-rate beta", and assess how this relationship varies between positive and negative territory. The results of these event-study regressions indicate that, in positive territory, a large fraction of the change in the ECB's policy rate was transmitted to Finnish banks' mortgage rates, up to almost 86% over 4 months. When the policy rate was negative, this total pass-through over 4 months was reduced to around 53%, but it remained statistically and economically significant, indicating that monetary policy was still effective at influencing mortgages rates in negative territory.

To identify the causal effects of monetary policy, our second strategy uses high-frequency data to extract unexpected monetary policy shocks from changes in yields at different maturities implied by market data around small windows that bracket monetary policy announcements. We then measure the impact of these high-frequency monetary policy shocks on monthly mortgage rates both before and after the implementation of negative rates. We find that a surprise monetary-policy easing (tightening) leads to a statistically significant decrease (increase) in the mortgage rate, both before and during the negative policy rate period. This transmission is mediated mostly via the policy rate's target factor, while the path factor seems to play a small role.[3] The transmission of monetary policy shocks to mortgage rates is found to be larger in positive territory than in negative territory, but the difference is not statistically significant.

Our third identification strategy leverages an "exposure measure" to negative nominal interest rates. It is important to emphasize that this strategy cannot identify the aggregate effects of negative rates; instead it identifies the effects on banks that are more exposed to the negative-rate environment relative to the effects on banks

3. This evidence is consistent with the notion that we are capturing mainly the effects of negative nominal interest rates as opposed to the effects of QE or forward guidance.

that are less exposed. The identification assumption is that other unobservable factors do not affect the outcomes of interest in the cross section of banks in a manner that is correlated with banks' exposures to the policy rate. The exposure measure we use is the deposit-to-asset ratio (DAR).[4] When the policy rate is non-negative, we find that banks with a higher DAR do not exhibit any differences in the pass-through of monetary policy to mortgage rates compared to banks with a lower DAR. However, when the policy rate is negative, banks relying more on deposit funding pass through a smaller fraction of monetary policy changes to mortgage rates than banks relying on alternative sources of funding.

Overall, our first two methodologies present evidence that the ECB's policy rate was transmitted to Finnish mortgage rates even when the policy rate fell below zero, providing some validation to the ECB's negative interest rate policy as an effective policy tool. However, they also point to the fact that monetary policy loses some of its effectiveness in negative territory. Our third empirical methodology provides evidence that this efficiency loss can be traced to the zero lower bound on deposit rates. To the extent that commercial banks cannot transmit the fall in the policy rate in negative territory to their depositors, banks' profitability may decline. Ceteris paribus, lower profitability puts pressure on banks' equity, which, in turn, reduces their ability to pass through cuts in the policy rate to their lending rates. This is a combination of the deposit margin channel of bank profitability and the risk bearing (or balance sheet) channel of bank lending discussed in Balloch, Koby, and Ulate (2022).

By now, the empirical literature that discusses the effectiveness of low and negative nominal interest rates has become vast and diverse. As mentioned above, in addition to event studies, these papers have used high-frequency identification, exposure-measure regressions, or cross-country regressions. The papers using high-frequency identification, such as Ampudia and Van den Heuvel (2022), Bats, Giuliodori, and Houben (2023), or Wang (2022), have typically found detrimental effects on bank stock prices from negative rate implementation. Importantly, Bräuning and Wu (2017) show that this can be consistent with a decrease in lending rates like the one we find in this paper.

Papers that use exposure-measure regressions, such as Heider, Saidi, and Schepens (2019), Bottero et al. (2022), Bittner et al. (2022), Basten and Mariathasan (2023), Hong and Kandrac (2022), or Amzallag et al. (2019) typically use the DAR as an exposure measure and find that the profitability of more-exposed banks declines relative to less-exposed banks after a cut in the policy rate in negative territory. The results regarding bank lending are less clear-cut in these exposure-measure papers, presumably due to offsetting channels that may be active. If more-exposed banks suffer a greater fall in profitability due to negative rates, this can prevent them from decreasing their lending rate as much as less-exposed banks through the risk-bearing or balance-sheet channels, but it might also lead them to decrease their lending rate more via

4. This is the exposure measure most commonly used in the literature. Banks with higher DARs are assumed to be more exposed to negative rates, because they obtain a higher share of their funding from deposits whose interest rate is (for the most part) subject to a zero lower bound.

the reaching-for-yield channel.[5] More-exposed banks could also experience a smaller decrease in their funding rate, preventing them from lowering their lending rates as much as less-exposed banks (independently of the impact on profitability). Our results indicate that the reaching-for-yield channel is likely to be dominated by other channels, leading to more-exposed banks passing through a smaller fraction of cuts in the policy rate to mortgage rates in negative territory.

Yet another strategy used in the negative-rates literature is cross-country identification, where many countries with different monetary policy stances are studied. These papers usually include time fixed effects (and bank fixed effects) in their regressions and try to recover the aggregate effects of negative rates. The identifying assumption is that the outcome of interest (lending rates, deposit rates, bank return on equity, etc.) would have behaved similarly across different countries in the absence of differences in the policy rate. Since this paper focuses on Finland, we do not make use of this identification scheme. However, our results complement well with those from the negative-rates cross-country papers with the largest samples, such as Lopez, Rose, and Spiegel (2020) or Ulate (2021b), which find a positive but diminished pass-through to loan rates in negative territory.

Relative to existing literature, our contribution is to simultaneously use several distinct empirical methodologies that complement each other and paint a coherent picture of the transmission of negative policy rates to mortgage rates in Finland. This combination of techniques can help us pinpoint the underlying mechanisms that drive the impacts of negative rates, for example, highlighting the importance of the deposit margin channel and downplaying that of the reaching-for-yield channel for cross-sectional results.

Although this is an empirical paper, our findings are directly related to the theoretical literature that studies the usefulness of low or negative policy rates. Ulate (2021b) proposes two opposing channels through which negative rates impact the economy. On one hand, negative rates lower the opportunity cost of lending for banks with excess reserves, which stimulates the economy. On the other hand, when the deposit margin gets compressed by negative rates, banks may end up with less equity and a reduced lending capacity. In a quantitative implementation, the author finds that between 60% and 90% of the efficiency of monetary policy is preserved in negative territory. Abadi, Brunnermeier, and Koby (2023) study the "reversal rate" (the level of the interest rate where decreasing the policy rate further becomes contractionary for lending) in a model where banks have monopoly power and can accrue capital gains from cuts in the policy rate. In a calibrated model, the reversal rate for the euro area is estimated to be around −1%, indicating that

5. As detailed in Balloch, Koby, and Ulate (2022), the risk-bearing channel refers to the idea that regulatory constraints or risk aversion can limit lending after a fall in bank profitability. Similarly, models with balance sheet constraints imply that low profitability may limit banks' ability to obtain funding, for example, due to moral hazard. In contrast, reaching for yield highlights the notion that decreasing profitability could increase incentives for bank risk-taking, perhaps leading them to lend more or to take on riskier borrowers.

moderately negative rates are still stimulative.[6] Eggertsson et al. (2024) propose a monetary Dynamic Stochastic General Equilibrium (DSGE) model with banks where negative rates do not have stimulative effects, inspired by their Swedish evidence that mortgages rates do not decline with the policy rate in negative territory.

As summarized by Balloch, Koby, and Ulate (2022), with the notable exception of Eggertsson et al. (2024), the majority of the theoretical negative-rates papers with quantitative implementations find that a temporary excursion into negative territory to combat a recession can be effective, with some caveats. The first caveat is that the effectiveness of a cut in the policy rate in negative territory is generally found to be less than the effectiveness of a cut in positive territory. The second caveat is that the effectiveness of negative rates can wane or even reverse as rates become more negative or more time is spent in negative territory. Our results in this paper are consistent with all of these findings.

The rest of the paper is organized as follows: Section 2 briefly describes the Finnish economy and banking system as well as the data used. In Section 3, we examine the extent to which changes in the policy rate were transmitted to newly originated mortgage rates in Finland before and during the negative-rate period using event studies. To identify the causal effects of monetary policy, Section 4 employs a high-frequency identification strategy to examine policy transmission. To further explore the effects of negative rates on the transmission across differentially exposed banks, Section 5 exploits banks' cross-sectional differences in funding sources. Finally, Section 6 concludes.

2. Background about Finland and Summary Statistics

Finland is a small open economy, which has been part of the European Union since 1995 and of the euro area since its establishment in 1999. In 2019, Finnish GDP was 242 billion euros (269 billion USD), which was about 2% of the euro area's GDP. The banking sector in Finland is dominated by a handful of large banking organizations. Monetary conditions in Finland are set by the monetary policy of the ECB. The ECB's main policy instrument is the deposit facility rate (DFR), which is the interest rate banks receive for their deposits held at the ECB.[7] In June 2014, the ECB lowered the DFR to negative territory. Figure 1 shows the DFR, along with the euro area overnight interest rate (EONIA), the 6-month Euribor, as well as 2- and 10-year Finnish government bond yields. Historically, short-term euro area rates, as well as government

6. Additionally, de Groot and Haas (2023) study the signaling channel, another mechanism through which negative rates can stimulate the economy even if current deposit rates are stuck at zero; Onofri, Peersman, and Smets (2023) emphasize that the effects of negative rates might be more stimulative if households save in bonds or if banks have access to wholesale funding; Balloch and Koby (2023) study the long run impacts of persistently low interest rates using evidence from Japan.

7. As can be downloaded, for example, from FRED (2024).

FIGURE 1. DFR and market rates. The figure displays the ECB's DFR along with the euro overnight rate (EONIA), the 6-month Euribor rate, as well as the 2- and 10-year Finnish government bond yields. The vertical black dashed line denotes the start of NIRP. The frequency is daily between January 1, 2005 and December 31, 2021. Source: Bloomberg (2022) and authors' calculations.

bond yields, have followed the DFR somewhat closely. During the negative interest rate policy (NIRP) period, when the DFR was negative, short-term rates converged with the DFR, whereas the 2-year government yield turned even more negative than the DFR.

For our analysis, we employ a monthly panel dataset with information on the balance sheets of Finnish credit institutions from January 2005 to October 2020 at the bank-group level. The dataset contains amounts and interest rates on new home mortgage loans to Finnish residents originated by ten bank groups.[8,9,10] Together, the ten bank groups in the sample account for 95% of all new mortgage origination in Finland as of December 2020. We also collect data on each sample bank-group's balance sheet ratios such as the DAR.[11] Our main data source is Bank of Finland

8. "New home mortgage loans" refers to euro-denominated newly issued home mortgage loan contracts (in contrast to new draw-downs). Bank-group specific interest rates on new mortgages are the volume-weighted average of contractually agreed total interest rates. See Appendix A for more details.

9. As elaborated upon in Appendix A, the original data contains the 12 biggest bank groups in Finland. Of these groups, 10 have been consistently granting mortgages and we select these groups into our main sample. However, we keep all 12 bank groups when constructing aggregate series. Keeping only the 10 consistent bank groups when constructing aggregate series would have minuscule impacts on our results.

10. For all codes used to process data and do our empirical analysis, please see the Supplementary Material. Since most of the data we use is confidential and cannot be shared, the replication code shared generates proxy data to go along with the analysis.

11. "Deposit-to-asset ratio" refers to the ratio of customer deposits (i.e., excluding deposits by banks) to total assets. See Appendix A for more details.

FIGURE 2. Interest rates and amounts of new mortgage loans. The frequency of the data is monthly. "New mortgage loans" refers to newly-originated mortgage loan contracts. The top panel displays the volume-weighted average mortgage rate over the sample banks (solid line) as well as the ECB's DFR (dashed line). The bottom panel displays the total amount of new mortgages over the sample banks. The black vertical dashed line denotes the start of NIRP in June 2014. Source: Bank of Finland and authors' calculations.

(2022), which contains information on the "Balance Sheet Items and Interest Rate Statistics of Finnish Monetary Financial Institutions".[12] We complement this with bank-group level balance-sheet information from S&P Global Market Intelligence (2021).

Figure 2 displays new mortgage loan amounts in the bottom panel with the corresponding average interest rate (aggregated over bank groups) in the top panel. The DFR is also included in the top panel of the figure for comparison. We can see that

12. The Bank of Finland, among other national central banks in the Eurosystem, collects statistical data on credit institutions. The data are collected as part of Monetary Financial Institution data collection; see the Bank of Finland's website at https://www.suomenpankki.fi/en/Statistics/reporting-instructions/mfi-data-collection/ for more information. Data for the analysis are sourced internally at the Bank of Finland.

interest rates on new mortgage loans have fallen in tandem with the DFR. The bottom panel shows that the amount of new mortgage loans plummeted following the 2008–2009 Great Financial Crisis, and has not yet returned to the pre-crisis level. During the negative interest rate period, new mortgage originations have been trending up.

In terms of the composition of bank loans, the share of mortgages as a percent of total outstanding bank loans in Finland at the end of 2022 was roughly 42% (about 103 billion euros), which is in line with the average in the euro area. Finnish banks typically hold mortgage loans on their balance sheets (i.e., little securitization takes place). Furthermore, banks may acquire market-based funding by issuing bonds collateralized by pools of mortgage loans, or so-called covered bonds. Covered bonds, which have high credit ratings, have been a source of relatively inexpensive funding for Finnish banks.[13] Yet, deposits from the public are still the single-most important funding source (Putkuri 2020). The fact that Finnish banks mostly keep mortgages on their balance sheets makes our setting different from that in the United States, where many banks use the "originate-to-distribute" model so that they do not keep mortgages on their balance sheet. Moreover, banks in other European countries, particularly the Nordic countries (including Sweden) have business models that are much closer to the Finnish one than to the U.S. one.

In terms of the rate-fixing structure of mortgages in Finland, the vast majority of them have a semi-variable rate with a fixing period of 1 year or less.[14] It is worth noting that the share of mortgages with a rate-fixing term of 1 year or less is greater in Finland (which has a sample average of 97% between 2010 and 2020) than in other countries where the pass-through to mortgage rates has been studied (73% in Sweden and 53% in Italy). This could explain some of the differences in the results that we obtain compared to papers such as Eggertsson et al. (2024, studying Sweden) or Amzallag et al. (2019, studying Italy), both of which find a lower pass-through of negative rates to mortgages rates than we do. Given that a higher share of variable-rate mortgages is expected to increase the pass-through of the policy rate to mortgages rates, as documented in Amzallag et al. (2019), these differences in findings are in line with expectations.

Table 1 shows descriptive statistics for new mortgage interest rates (MR) and quantities (MA), DFR, as well as the DAR. The average interest rate on new mortgages

13. As detailed in Appendix A.4, negative rates might tilt the incentives of banks to start funding more of their operations with covered bonds. If the only way that banks can issue covered bonds is by having enough mortgages and if the mortgage constraint is binding, then tilting the funding mix also implies tilting the asset mix more toward mortgages. This incentivizes banks to lower the rates on mortgages more than usual, so the transmission of the policy rate to mortgage rates might be stronger. From the information that we could gather from the public financial reports of the largest banking groups, it seems that most Finnish banks were not against the "mortgage constraint" during most of our sample. Therefore, we conclude that this channel is unlikely to substantially alter transmission.

14. As an example, take a mortgage with one-year fixing that starts on January 1, 2024, and has a rate of the 1-year Euribor plus 1%. For all of 2024, this mortgage would have an interest rate of what the 1-year Euribor was on January 1, 2024 plus 1%. Then, for all of 2025, the rate would be whatever the 1-year Euribor will be in January 2025 plus 1%, and so on. The reference rate, in this case 1-year Euribor, resets yearly. That is why the mortgage rate is denoted as a semi-variable rate with a fixing period of 1 year.

TABLE 1. Descriptive statistics for monthly panel data.

	Mean	SD	Obser-vations	Mini-mum	5p	25p	50p	75p	95p	Maxi-mum
MR	215	129	1,808	–	63	106	196	271	490	–
$\Delta MR_{t-1,t}$	−1	15	1,798	−118	−20	−5	−1	4	16	88
$\Delta MR_{t-1,t+1}$	−3	25	1,780	−235	−29	−8	−2	6	25	84
MA	178	230	1,808	–	6	28	68	242	710	–
DFR	48	111	190	−50	−50	−40	0	100	300	325
$\Delta DFR_{t-1,t}$	−1	13	189	−100	−10	0	0	0	25	25
DAR	49%	24%	10	25%	26%	30%	42%	67%	82%	83%

Notes: This table presents descriptive statistics for the monthly panel data. The sample spans from January 2005 to October 2020. The variables are the new mortgage loans interest rate in levels (MR, in basis points) as well as 1-month and 2-month changes, the amount of new mortgage loans (MA, in million EUR), the level and the 1-month change in the DFR (in basis points), as well as bank-group specific DARs. The left panel displays the mean, standard deviation, and the number of observations for each variable. The right panel displays the minimum and maximum values as well as selected percentiles for the variable's distribution. The statistics for mortgage loans are calculated over time and bank groups, whereas the statistics for the DFR are calculated over time. For the DAR, we first calculate the time-series averages for each bank group over the year 2013 and the statistics are then calculated from these averages. There are ten bank groups in the sample. The minimum and maximum values of new mortgage amounts and interest rate levels are omitted for confidentiality. Source: S&P Market Intelligence, Bank of Finland, and authors' calculations.

in our sample is 215 basis points with a standard deviation of 129 basis points. On average, monthly changes in mortgage rates have been negative, with the largest monthly decline (−118 basis points) observed during the Great Financial Crisis. The largest 2-month decline is −235 basis points. The amount of monthly new mortgages varies quite extensively over bank groups and periods, with the largest (95th percentile) monthly originations being over 700 million euros and the smallest (5th percentile) being just about 6 million euros. There is also a lot of variation in the DAR across bank groups, from a low of 25% to a high of 83%.

Figure 3 shows the average interest rate on new mortgages, between 2014 and 2016, separately for each of the ten bank groups in our sample. The bank-level mortgage rate tends to fall around cuts in the DFR, especially for the first, second, and third cuts in negative territory. In the following section, we take a more systematic look at this relationship by regressing bank-group mortgage rates on bank fixed effects and changes in the policy rate both before and after the negative-rates period.

3. Mortgage-Rate Betas

In this section, we investigate the extent to which changes in the policy rate pass onto the rates on newly originated mortgages. We will denote this pass-through of the policy rate to the mortgage rate as the "mortgage-rate beta". This concept is similar to the deposit-rate beta in Drechsler, Savov, and Schnabl (2017) and Drechsler, Savov, and Schnabl (2021), but for a product on the asset side of the bank balance sheet (mortgages) instead of one on the liability side.

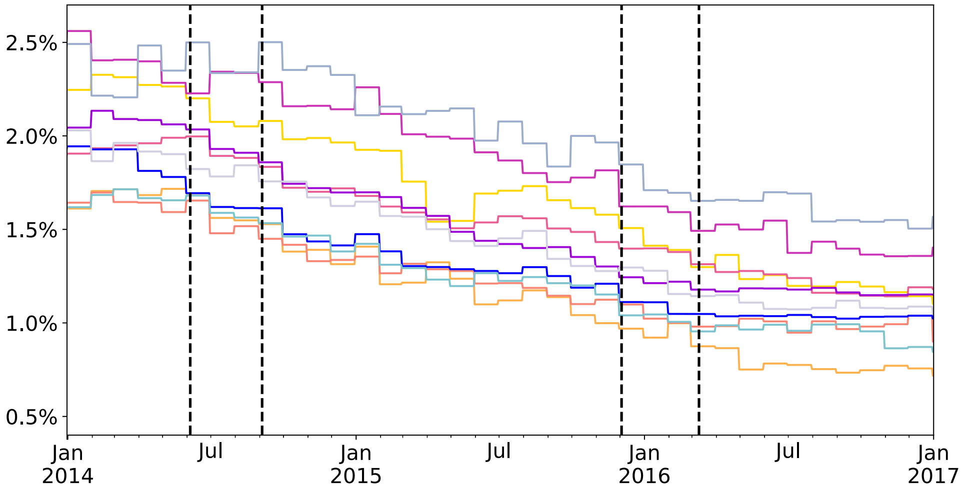

FIGURE 3. Interest rate on new mortgage loans by bank group. The figure displays the average interest rate on new mortgage loans by bank group between 2014 and 2016. The series are at daily frequency (up-sampled from monthly observations using forward fill). The vertical dashed lines denote the dates of cuts in the ECB's DFR (a 10 basis points cut in all four cases). Source: Bank of Finland and authors' calculations.

To assess the mortgage-rate beta, including the possibility of lags in transmission and differences between normal and negative territory, we specify the following panel regression with bank fixed effects:

$$\Delta y_{b,t} = \alpha_b + \sum_{k=0}^{K} \beta_k \Delta i_{t-k} + Post_t \cdot \sum_{k=0}^{K} \mu_k \Delta i_{t-k} + \varepsilon_{b,t}. \quad (1)$$

In equation (1), b is a given bank, t is the time period, Δ is the difference operator, $y_{b,t}$ is the interest rate on new mortgages charged by bank b at time t, α_b is a bank fixed effect, i_t is the policy rate (DFR) in period t, Post_t is a dummy variable equal to 1 if t is on or after June 2014 (the first implementation of negative rates by the ECB), $\varepsilon_{b,t}$ is an error term for bank b at time t, and K indicates the maximum number of lags in transmission being considered in the regression.

The second term in equation (1) measures how much of the change in the policy rate was transmitted to the mortgage rate on average across bank groups, both contemporaneously and with lags, during the period when the policy rate was non-negative. If banks changed their mortgage rates by exactly the same amount as the change in the policy rate instantly and permanently, the contemporaneous coefficient, β_0, would be equal to 1 and all lagged coefficients would be equal to 0. When some of the transmission takes place with a lag, the coefficient β_0 is less than 1, and the lagged coefficient β_k measures how much of the mortgage rate change in month t is a result of the change in the policy rate in month $t - k$. The sum $\sum_{k=0}^{K} \beta_k$ measures the total

TABLE 2. Results from correlational analysis.

Change in the mortgage rate (pp)				
β_0	β_1	β_2	β_3	$\sum_{k=0}^{3} \beta_k$
0.689***	0.237***	0.055	−0.122***	0.859***
(0.052)	(0.050)	(0.030)	(0.033)	(0.034)
μ_0	μ_1	μ_2	μ_3	$\sum_{k=0}^{3} \mu_k$
−0.358***	−0.170**	0.079	0.125	−0.324***
(0.090)	(0.064)	(0.057)	(0.074)	(0.052)
$\beta_0 + \mu_0$	$\beta_1 + \mu_1$	$\beta_2 + \mu_2$	$\beta_3 + \mu_3$	$\sum_{k=0}^{3} \beta_k + \mu_k$
0.332***	0.067	0.133***	0.003	0.535***
(0.102)	(0.061)	(0.037)	(0.073)	(0.056)
Number of observations			1774	
Adjusted R^2			0.43	
Bank-group fixed effects			Yes	

Notes: This table presents selected coefficients and standard errors (in brackets) estimated from the regression in equation (1) with $K = 3$ and the dependent variable being the one-month difference in the rate on new mortgage loans in percentage points. The change in the policy rate is also measured in percentage points. The sample period is January 2005 to October 2020. Standard errors are clustered at the bank-group level. Asterisks denote statistical significance: $* = 10\%$, $** = 5\%$, $*** = 1\%$.

transmission of the policy rate to the mortgage rate over $K + 1$ months (the cumulative mortgage-rate beta in positive territory).

The third term in equation (1) measures the additional transmission of the policy rate to mortgage rates when the policy rate was negative, on average across bank groups. If there was no change in the transmission of the policy rate to the mortgage rate when the policy rate became negative, all the μ coefficients would be zero. The sum of the μ coefficients ($\sum_{k=0}^{K} \mu_k$) measures the total change in transmission during the negative-rates period, and the sum of all the β and μ coefficients ($\sum_{k=0}^{K} \beta_k + \sum_{k=0}^{K} \mu_k$) measures the total transmission during the negative-rates period (the cumulative mortgage-rate beta in negative territory).

The estimates from the regression in equation (1) with $K = 3$ are shown in Table 2.[15] The top panel provides estimates of the β coefficients measuring the transmission of the policy rate to mortgage rates when the policy rate is greater than zero. These estimates provide evidence that the change in the policy rate by the ECB was transmitted to Finnish banks' mortgage rates, both contemporaneously and with lags. At 69%, the contemporaneous transmission of the policy rate to the mortgage rate is significantly positive and economically large. Although the bulk of the transmission of the policy rate to the mortgage rate took place contemporaneously, the significant

15. Adding more lags or fitting the regression using weighted (instead of ordinary) least squares provides very similar results. For the weighted regression results, see Table B.1 in the Appendix.

coefficients on the lags point to some of the transmission occurring with a delay. The last column of the top panel in Table 2 shows the sum of β's, which measures the total transmission of the policy rate to the mortgage rate over 4 months, estimated to be roughly 86%. The result suggests a large fraction of the change in the ECB's policy rate was eventually transmitted to Finnish banks' mortgage rates while the policy rate was positive.

The middle panel of Table 2 displays the additional transmission during the negative-rates period from June 2014 to October 2020. During this period, the contemporaneous transmission is found to be significantly smaller, as evidenced by the significantly negative μ_0. The last column in the middle panel displays the sum of the μ's, which is significantly negative at -32%. This suggests that the effectiveness of monetary policy decreased when the policy rate was below zero.

Overall, the estimates in Table 2 indicate that the total pass-through from the policy rate to the mortgage rate was reduced by 38% (from 0.859 to 0.535) during the negative-rates period. Despite this sizable reduction, the net pass-through from the policy rate to mortgage rates was still 53% when the policy rate was below zero (last column of the bottom panel). This evidence suggests that monetary policy remained operational through the interest rate channel during the negative-rates period. To identify the causal effects of monetary policy more precisely, in the next section, we employ a high-frequency identification strategy to examine the policy transmission of negative nominal interest rates.

While the results in Table 2 use the DFR as a measure of the ECB's policy rate, the actual policy rate that matters the most for the operations between commercial banks and the ECB has varied over time. In particular, the effective policy rate before the Great Financial Crisis was mostly the rate on main refinancing operations (MRO), while during the crisis, this relevant policy rate became the DFR. In order to capture the fact that the relevant policy rate switched from the MRO to the DFR over the second half of 2008, we compute a concatenated policy rate that smoothly transitions between the MRO and the DFR during the second half of 2008.[16] Appendix Table B.2 presents the results of the regression in equation (1) but using this concatenated policy rate instead of just the DFR. The main takeaways are the same as in Table 2, but the reduction in effectiveness during the negative rates period gets reduced roughly by half (strengthening the result that rate cuts continue to be effective in negative territory).

4. High Frequency Identification

As mentioned in the introduction, using high-frequency data allows the econometrician to identify monetary surprises from short event-windows surrounding monetary policy announcements. The idea is to take the difference between several measures of

16. Specifically, the concatenated policy rate is given as follows: Up to July of 2008, it is just the MRO, in August of 2008, it is 80% MRO + 20% DFR, in September, it is 60% MRO + 40% DFR, in October, it is 40% MRO + 60% DFR, in November, it is 20% MRO + 80% DFR, and from December of 2008 onward, it is just DFR. The MRO is obtained from ECB (2024).

yields before the monetary policy announcement and those same measures after the announcement has occurred. If the window around the monetary policy announcement is short enough, the change in asset prices is likely driven solely by the new information embedded in the announcement. This method arguably provides a "clean" measure of unexpected monetary policy shocks, to the extent that the expected component of the monetary policy announcement has already been incorporated into the pre-announcement asset prices in an efficient market.

To operationalize this identification scheme in our particular context, we need data on asset prices around monetary policy announcements. We follow Altavilla et al. (2019b), utilizing their Euro Area Monetary Policy Event-Study Database (EA-MPD, Altavilla et al. 2019a).[17] This dataset contains, among other things, what the authors call the changes in the "Monetary Event Window". These are changes between the median quote of a given asset price in the 10-minute window before the ECB's press release of its monetary policy decision (from 13:25 CET to 13:35 CET) and the median quote for that same asset price in the 10-minute window after the ECB's press conference that accompanies its monetary policy decision (from 15:40 CET to 15:50 CET).

The derivation of our monetary policy surprises follows a procedure similar to the one described in Gurkaynak, Sack, and Swanson (2005) in the case of the United States. First, we select seven bond yields from EA-MPD data (the same ones as in Altavilla et al. 2019b) that describe the euro area's yield curve from 1 month to 10 years. Next, we extract the first two principal components of the (normalized) bond yield series. We rotate the resulting components such that the first component, S^T, captures the "target" factor (corresponding to the surprise change in the short-term policy rate) and the second component, S^P, captures the "path" factor (corresponding to expected future changes in policy rates, which are independent from changes in the current policy rate).

The rotated factors do not naturally have an interpretable direction or scale. We re-scale the factors such that S^T moves the first asset price (the 1 month Overnight Index Swap, OIS, yield) by exactly 1 unit. This way we can interpret a shock to the target factor (S^T) as if it were a 1% shock to the short-term rate. Further, the re-scaling is such that it forces S^T and S^P to have the same effect on the 1-year yield (12-month OIS yield). This allows us to interpret S^P as a longer run (path) factor that moves the 1-year yield as much (and in the same direction) as S^T. Finally, to use the shocks in regressions, we aggregate the shock series to monthly frequency by summing the shocks from all the monetary policy decisions taking place during the same month.[18] We plot the resulting monetary policy surprise series in Figure C.1 of Appendix B.

17. The data version used in this paper is from January 30, 2022. The most up-to-date dataset is available at https://www.ecb.europa.eu/pub/pdf/annex/Dataset_EA-MPD.xlsx.

18. We exclude from the sample the monetary policy decision dates on November 6, 2008 and December 4, 2008. These dates, occurring during the height of the Great Financial Crisis, have a particularly large difference between the asset price changes in the monetary event window and the changes in the daily window, indicating that financial market participants may have required a longer interval to fully "process" the information contained in the actions of the ECB due to the huge uncertainty of the period.

After identifying the monetary policy shocks using high frequency data, we test the causal effects of monetary policy on mortgage rates by running the following regression:

$$y_{t+1} - y_{t-1} = \alpha + \gamma \text{Post}_t + \beta^T S_t^T + \beta^P S_t^P + \mu^T S_t^T \text{Post}_t + \mu^P S_t^P \text{Post}_t + \varepsilon_t, \quad (2)$$

where y_t is the interest rate on new mortgages aggregated across banks at time t, S_t^i is the i identified monetary policy shock at time t (S^T being the target shock and S^P the path shock), and Post_t is the dummy indicating whether t is in the negative interest rate period. The results from the regression in equation (2) are shown in the top panel of Table 3.[19] The bottom panel of Table 3 presents similar results but when there is a single extracted shock instead of two orthogonal ones.

We gather several important lessons from the results in Table 3. First, a surprise tightening in monetary policy, as measured by an increase in the target factor S^T, leads to a statistically significant increase in the mortgage rate, both before and during the negative-rates period. Second, the difference between the pre-NIRP and the NIRP coefficients for S^T is negative but not significant, meaning that perhaps the transmission of target shocks to mortgages rates weakened during the negative-rates period, but that this cannot be asserted at the standard levels of statistical significance. Third, for the path factor, S^P, the pre-NIRP and the NIRP coefficients are similar, in both cases not statistically significant. This indicates that the effects of shocks to the path factor do not seem to be an important part in the transmission of the ECB's monetary policy to Finnish mortgages rates. The significance of S^T combined with the insignificance of S^P suggests that, during the unconventional monetary policy period, we are capturing mostly the effect of negative rates (which would be reflected in the target factor) as opposed to the effect of QE or forward guidance (which are likely to be reflected in the path factor).[20]

The reduction in effectiveness (even if not statistically significant) that we find between the positive policy rate period and the negative policy rate period using our high-frequency identification strategy is of around 50% (for either S^T or the single shock in the bottom panel of Table 3). This magnitude is similar to the decrease in effectiveness of around 40% that we found in Section 3. It is also comparable to the 30% decrease in effectiveness found in Ulate (2021b).[21] Overall, the results suggest

19. In equation 2, we use a 2-month change in the mortgage rate as the left-hand side variable. The results would be similar if we used a 1-month change.

20. The fact that an overwhelming majority of mortgages in Finland are effectively variable-rate is likely a contributing element in explaining why the target factor matters more than the path factor. However, it is not enough to explain the significance of the target factor. For example, even if 100% of mortgages were variable rate, if banks get all their funding from deposits that are subject to the deposit zero lower bound, when the DFR becomes more negative, their funding rate would not react and they would be unable to decrease their mortgage rates, so the target factor would have no effect on the rate (neither would the path factor).

21. The decrease in effectiveness in Ulate (2021b) is for welfare and not just for loan rate pass-through. Given that there are other channels through which negative rates can stimulate the economy that do not rely on the banking sector, it seems reasonable for the welfare results to show a lower fall in effectiveness compared to the loan pass-through results.

TABLE 3. Results from high-frequency analysis.

	Change in the mortgage rate (bps)
Target Shock (S^T)	
S^T pre-NIRP (β^T)	6.57**
	(2.68)
S^T NIRP ($\beta^T + \mu^T$)	3.16***
	(0.86)
S^T difference (μ^T)	– 3.41
	(2.83)
Path Shock (S^P)	
S^P pre-NIRP (β^P)	1.01
	(1.73)
S^P NIRP ($\beta^P + \mu^P$)	0.87
	(0.81)
S^P difference (μ^P)	– 0.14
	(1.91)
Number of observations	185
Adjusted R^2	0.06
Single Shock	
pre-NIRP (β)	6.09**
	(2.99)
NIRP ($\beta + \mu$)	2.80*
	(1.67)
difference (μ)	– 3.29
	(3.43)
Number of observations	185
Adjusted R^2	0.05

Notes: The top part of the table presents the coefficients and standard errors (in brackets) estimated from the regression in equation (2) with the dependent variable being the 2-month difference (from $t-1$ to $t+1$) in the mortgage rate in basis points. The two independent variables are the monetary policy shocks derived using the extraction method described in the main text. The bottom part of the table presents the results of a regression similar to that in equation (2) but where there is a single extracted shock that is the first principal component of the asset prices described in the text, normalized to move the short rate one-for-one. Standard errors are Heteroskedasticity and Auto-Correlation (HAC) robust with a maximum of one lag. Asterisks denote statistical significance: $* = 10\%$, $** = 5\%$, $*** = 1\%$.

that monetary policy surprises have kept passing through to mortgage rates in the negative-rates period but that pass-through has likely diminished.[22,23]

22. We have also employed an alternative method to extract the monetary policy shocks, following Bräuning and Wu (2017), who identify monetary policy shocks from asset price changes on days bracketing the monetary policy announcements. Those results are well in line with the baseline results shown here and are available upon request.

23. Appendix Section B presents the results of estimating equation (2) but including one lag of the shocks, the main conclusions are unchanged.

5. Exposure Measure Regressions

Finally, our third empirical method uses banks' exposure to negative interest rates to identify the effects of negative rates on more-exposed banks vis-a-vis less-exposed banks. This type of identification is somewhat common in the literature (see, e.g., Heider, Saidi, and Schepens 2019; Bittner et al. 2022) and requires taking a stance on what constitutes being "more exposed" to negative rates. Here, as the measure of exposure, we use the DAR, which is the most commonly used exposure measure as described in Balloch, Koby, and Ulate (2022).

Banks with higher DARs are assumed to be more exposed to negative rates, because they obtain a higher share of their funding from deposits, for which the interest rate is likely to be floored at 0%. When the policy rate is in positive territory, and the rates on different sources of funding co-move strongly, the degree of exposure to deposit funding is not expected to affect the pass-through. In contrast, when the policy rate is in negative territory, the rates on non-deposit funding respond more strongly to changes in the policy rate (see Figure 1) than deposit rates. Consequently, banks relying more on deposit funding (indicated by a higher DAR), ceteris paribus, are expected to pass through less of the change in the policy rate to mortgage rates.

To test whether banks with more exposure to deposit funding pass through less of the changes in the policy rate to their mortgage rates in negative territory, we run the following regression:

$$\Delta y_{b,t} = \alpha_b + \delta_t + \beta \cdot \mathrm{DAR}_b \cdot \Delta i_t + \mu \cdot \mathrm{Post}_t \cdot \mathrm{DAR}_b \cdot \Delta i_t + \varepsilon_{b,t}, \tag{3}$$

where $\Delta y_{b,t}$ is the change in the rate on new mortgage loans issued by bank b between time $t-1$ and t, α_b denotes a set of bank fixed effects, δ_t denotes a set of time fixed effects, and DAR_b is the average DAR of bank b in 2013. Post_t continues to be the dummy for the negative-rate period as in equations (1) and (2). We note that this regression is run using only those periods where there is a change in the policy rate (i.e., periods where $\Delta i_t \neq 0$).

In equation (3), the coefficient β measures how much more-exposed banks cut their mortgage rates after a cut in the policy rate compared to less-exposed banks when the policy rate is in positive territory. The sum of the coefficients $(\beta + \mu)$ measures this same relative difference when the policy rate is in negative territory. Therefore, the coefficient μ measures how much the transmission of more-exposed banks is hindered in negative territory compared to positive territory. As explained above, we expect μ to be negative.

The results of estimating equation (3) by Ordinary Least Squares (OLS) are presented in Table 4. As expected, the β coefficient is not significantly different from zero, indicating that when the policy rate is positive, banks with a higher DAR do not exhibit a differential pass-through of monetary policy to mortgage rates compared to banks with a lower DAR. In contrast, μ is negative and significant at the 10% level, indicating that banks with a higher DAR pass through a smaller fraction of monetary

TABLE 4. Results from exposure-measure analysis.

	Change in the mortgage rate (bps)
β	-0.197
	(0.131)
μ	-1.084^{*}
	(0.533)
Number of observations	219
Adjusted R^2	0.87
Bank group fixed effects	Yes
Period fixed effects	Yes

Notes: This table presents selected coefficients and standard errors (in brackets) estimated from regression equation (3) with the dependent variable being the one-month difference in the mortgage rate in basis points. The change in the policy rate is also measured in basis points and the DAR is measured as a number between 0 and 1. Standard errors are clustered at the bank-group level. Asterisks denote statistical significance: $* = 10\%$, $** = 5\%$, $*** = 1\%$.

policy changes to mortgage rates when the policy rate is negative compared to banks with a lower DAR.[24]

As noted earlier, the mechanism can be as follows. Banks with a higher DAR rely more heavily on deposits for their funding. In negative territory, the deposit rate essentially stops co-moving with the policy rate, while interest rates on other sources of funding continue to co-move with the policy rate. Therefore, banks with a higher DAR face a smaller reduction in their funding costs compared to banks with a lower DAR when the ECB cuts the DFR in negative territory. As a consequence, banks with a higher DAR pass through less of the reduction in the policy rate to the mortgage rate, ceteris paribus.[25]

To gauge the economic significance of the exposure to deposits, we multiply the estimated coefficient μ by the difference in DAR between the 25th and the 75th percentile of the DAR in our sample (37%). The result indicates that a bank at the 75th percentile of the DAR distribution transmits roughly 40% less of the fall in the DFR to mortgage rates than a bank at the 25th percentile of the DAR distribution during the negative-rates period. This difference is relevant and economically significant. It is also in line with the magnitude of the reduction in transmission during the negative-rates period that we found in Sections 3 and 4, indicating that the deposit margin channel can be an important contributor to the decrease in the aggregate transmission.

Note that these exposure-measure regressions do not identify the aggregate response of mortgage rates to changes in the policy rate in negative territory (these aggregate effects would be absorbed by the time fixed effects in the regression). They

24. Appendix Table B.3 gives the results of the regression in equation (3) but using the concatenated policy rate described at the end of Section 3. The main takeaways are unaffected by this change.

25. If banks do not have monopoly power, then a smaller reduction in their funding rate implies that they cannot reduce their lending rates (including the mortgage rate) as much. If banks have monopoly power, still a smaller reduction in their funding rate means that their deposit spread gets reduced by more, decreasing their profitability and eventually their equity and their ability to decrease their lending rates.

merely identify the response of more-exposed banks relative to the response of less-exposed banks. From these regressions alone, we would not be able to tell whether aggregate mortgage rates increased or decreased with the advent of negative rates. However, given our results in the event studies and the high-frequency identification, it is safe to interpret that mortgage rates indeed fall with the policy rate even in negative territory, but that this occurs less for more-exposed banks.

6. Conclusion

The transmission mechanisms and effectiveness of unconventional monetary policy tools, in general, and of negative nominal policy interest rates in particular, have received a lot of attention from economists and policy makers. This paper contributes to this growing literature by studying the transmission of the ECB's policy rate to Finnish mortgage rates before and during the negative policy rate period. We find evidence that the ECB's policy rate was transmitted to Finnish mortgage rates even when the policy rate fell below zero, supporting the ECB's negative interest rate policy as an effective policy tool.

We employ three empirical strategies to study the monetary policy pass-through in Finland. First, event studies show that, in positive territory, a large fraction of the change in the ECB's policy rate was transmitted to Finnish banks' mortgage rates both contemporaneously and with lags, up to 86% over 4 months. When the policy rate was negative, the total pass-through was reduced significantly. Nevertheless, the total pass-through from the policy rate to the mortgage rate was estimated to be 53% during the negative interest rate period, suggesting that the interest rate channel of monetary policy remained operational.

Our second empirical strategy pins down the causal effects of monetary policy more precisely. In this strategy, we first identify monetary policy shocks over a short window around monetary policy announcements, providing estimates of the monetary policy shock's target factor and the future policy rate path factor. These monetary policy shocks are then used to explain the changes in the mortgage rate. Our results show that a surprise easing (tightening) in monetary policy leads to a statistically significant decrease (increase) in the mortgage rate, both before and during the negative policy rate period. While the monetary policy shock's target factor is found to be significant, the future-rate path factor is not, suggesting that we are capturing the effects of negative nominal interest rates and not those of QE or forward guidance. Additionally, the transmission in the negative-rates period is smaller than that in the positive policy rate period (although this difference is not statistically significant). This evidence further confirms the effectiveness of negative policy rates via the interest rate channel.

Our third empirical strategy exploits differences in Finnish banks' reliance on deposits as a funding source to identify the differential effects of negative policy rates among more- versus less-exposed banks. To the extent that bank deposit rates are likely constrained by the zero lower bound while market-based funding rates are not, banks relying more on deposit funding are expected to have a smaller pass-through to mortgage rates during the negative policy rate period. Our results show that when the policy rate was non-negative, banks with a higher DAR did not exhibit any differences in the pass-through of monetary policy to mortgage rates compared to banks with a lower DAR. However, when the policy rate was negative, banks relying more on deposit funding passed through a smaller fraction of monetary policy changes to mortgage rates than banks with a lower DAR.

Taken together, the results in this paper show that the effectiveness of monetary policy during the negative policy rate period was likely diminished, but did not disappear. They lend credence to the usage of negative nominal interest rate policies by central banks. Although the negative rate policy lasted for years, the policy rate did not become very negative during our sampling period (the lowest DFR was -0.5%). While the limits of negative interest rate policies are beyond the scope of this paper, these are interesting questions for future research that have important policy implications.

Appendix A: Further Details about the Data

A.1 Interest Rates and Amounts of New Mortgages

The series on amounts and interest rates of new home mortgages come from our main data sources: the Balance Sheet Items and Interest Rate Statistics of Finnish Monetary Financial Institutions (MFIs). These statistical datasets are collected by the Bank of Finland via the MFI data collection; see: https://www.suomenpankki.fi/en/statistics/to-the-reporter/mfi-data-collection/. The data are sourced internally at the bank of Finland and cannot be distributed for confidentiality reasons. The series for these home mortgages are extracted using the following specification:

- Creditors are MFIs that belong to the 12 biggest bank groups in Finland. Of these groups, 10 have been consistently granting mortgages and we select these groups into our main sample (when using panel data and estimating fixed effects). However, we keep all 12 bank groups when we are constructing aggregate series.[26]
- Debtor country: Finland.
- Debtor sector: households and non-profits serving households.
- Instrument: loans excluding repos and credit card debt.
- Purpose: Mortgage.
- Transaction: new contracts (including renegotiated loans) up to December 2013. True new contracts from January 2014 onward.

26. Keeping only the ten consistent bank groups when constructing aggregate series would have minuscule but non-zero impacts on our results.

- Measures: amount flows and contractual interest rates.

The above choices define "normal" mortgages used to finance purchase or renovation of a home. Importantly, our sample does not include "enterprise" or "business" mortgages.

A.2 Deposit-to-asset Ratios

Our main data sources provide data only for Finnish functions of the bank groups. Some groups are international banks with the bulk of their activities outside of Finland. Our aim for the DAR has been to construct series that reflect the situation at the consolidated bank-group level. The reasoning behind this is that funds are assumed to be fungible within a given bank group.

We derive the DARs as follows. For the international bank groups, we use a dataset provided by S&P Capital IQ Pro. We extract year-end data separately for the numerator (deposits from customers for fiscal year, mnemonic *SNL_TOTAL_DEPOSITS*) and for the denominator (all assets owned by the company for fiscal year, mnemonic *SNL_TOTAL_ASSETS*) and then divide them to obtain the DAR. To obtain monthly series, we forward-fill each December value to next year's months January–November.

For bank groups operating primarily in Finland, we use our main data source. In this case, the numerator is total deposits excluding deposits from monetary financial institutions (in an attempt to better match the deposits definition used for international groups) and the denominator is total assets.[27] Both series are originally at the monthly frequency. To match the treatment of our alternative data source, we first down-sample the series to yearly frequency by choosing December values, and then forward-fill December values similarly as above.

A.3 Key Policy Rates, Monetary Policy Dates, and Policy Shocks

The ECB's monetary policy decision dates were extracted from the ECB's web page. The series for the DFR and the MRO rate were sourced from the Bank of Finland's internal database but are also available from the ECB's web page.[28]

The EA-MPD data used to derive the policy shocks are from January 30, 2022. The most up-to-date dataset is available at www.ecb.europa.eu/pub/pdf/annex/Dataset_EA-MPD.xlsx.

A.4 Covered Bonds

As mentioned in Section 2, Finnish banks obtain a significant amount of market-based funding by issuing bonds collateralized by pools of mortgage loans (we refer to these simply as "covered bonds" going forward). To a first order, since the mortgages

27. Here, both the numerator and the denominator include intra-group items.

28. Decision dates: www.ecb.europa.eu/press/govcdec/mopo/html/index.en.html. Key interest rates: www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html.

earmarked for the covered bond pools remain on the bank's balance sheet like other bank loans, we do not expect the transmission mechanism to mortgages to be significantly different than to other types of bank loans. However, there is a, relatively second order, potential effect that can affect the transmission mechanism to mortgages once the policy rate goes into negative territory. We describe this mechanism in the following paragraphs.

In positive territory, the interest rates on deposits and covered bonds move very similarly with the DFR, and the banks "settle on" a certain funding mix. As rates start going into negative territory, the interest rates on deposits mostly get stuck at zero, while the rates on covered bonds mostly follow the DFR into negative territory. This might tilt the incentives of banks to start funding more of their operations with covered bonds (which are getting relatively cheaper compared to deposits). If the only way that banks can issue covered bonds is by having enough mortgages (which is true in Finland because essentially only mortgages are used as collateral on covered bonds), and if the mortgage constraint is "binding" (in the sense that banks are using close to their total amount of mortgages as collateral for covered bonds already), then tilting the funding mix also implies tilting the asset mix more toward mortgages (to be able to use the newly issued mortgages as collateral for new covered bonds which are now cheaper). In order to issue more mortgages than they were issuing before, then the banks would need to lower the rates on mortgages more than in the absence of this mechanism, so the transmission of the policy rate to mortgage rates might be stronger.

While most of the logical steps in the previous paragraph are true, the one that is in doubt is whether "the mortgage constraint is binding". That is, whether banks were using close to their total amount of mortgages as collateral for covered bonds during the relevant period of our analysis. Obtaining data for the ratio of mortgages used as collateral for covered bonds to total mortgages is not straightforward. From the information that we could gather from the public financial reports of the largest banking groups, it seems that most Finnish banks were not against the "mortgage constraint" during most of the years in our sample. Therefore, we tentatively conclude that this channel is unlikely to substantially alter the transmission to mortgages rates. Additionally, we note that this entire discussion would also apply to other Nordic countries like Sweden (were covered bonds are also prevalent), so this issue does not decrease the salience of the differences between our results and those of Eggertsson et al. (2024).

Appendix B: Additional Results

Table B.1 presents results similar to Table 2 but using weighted least-squares regressions instead of ordinary least-squares regressions.

Table B.2 presents results similar to Table 2 but using as independent variable the first difference of a version of the policy rate that is a combination of the rate on MRO and the DFR. The combination is as follows: Up to July of 2008, it is just the MRO, in August of 2008, it is 80% MRO + 20% DFR, in September, it is 60% MRO + 40% DFR, in October, it is 40% MRO + 60% DFR, in November, it is 20% MRO + 80% DFR, and from December of 2008 onwards, it is just DFR. This weighting scheme

TABLE B.1. Results from correlation analysis, weighted regressions.

Change in the mortgage rate (pp)				
β_0	β_1	β_2	β_3	$\sum_{k=0}^{3} \beta_k$
0.622*** (0.026)	0.335*** (0.022)	0.039* (0.021)	−0.114*** (0.010)	0.882*** (0.015)
μ_0	μ_1	μ_2	μ_3	$\sum_{k=0}^{3} \mu_k$
−0.228*** (0.047)	−0.300*** (0.052)	0.086* (0.044)	0.150* (0.071)	−0.291*** (0.042)
$\beta_0 + \mu_0$	$\beta_1 + \mu_1$	$\beta_2 + \mu_2$	$\beta_3 + \mu_3$	$\sum_{k=0}^{3} \beta_k + \mu_k$
0.394*** (0.037)	0.035 (0.035)	0.125*** (0.026)	0.037 (0.068)	0.591*** (0.045)
Number of observations			1774	
Adjusted R^2			0.61	
Bank group fixed effects			Yes	

Notes: This table presents selected coefficients and standard errors (in brackets) estimated from the regression in equation (1) with $K = 3$ and the dependent variable being the 1-month difference (from $t - 1$ to t) in the rate on new mortgage loans in percentage points. The change in the policy rate is also measured in percentage points. The regression uses weighted least-squares such that bank group observations within each period receive a weight according to their relative new-loans volume, whereas periods are weighted equally. Standard errors are clustered at the bank group level. Asterisks denote statistical significance: $* = 10\%$, $** = 5\%$, $*** = 1\%$.

is standing in for the fact that during the second half of 2008, as the Great Financial Crisis was unfolding, the main policy rate of the ECB transitioned from being the MRO to being the DFR as the European banking system was flooded with liquidity and most banks started holding excess reserves at the ECB. When most banks have excess reserves, the relevant rate in a corridor system becomes the rate on reserves, which in the euro area is precisely the DFR. Table B.3 presents results similar to those in Table 4 but using this concatenated policy rate.

Table B.4 presents results similar to Table 3 but including one lag of the shocks.

Appendix C: High-Frequency Monetary Policy Surprises

In this section, we provide further information on the extraction method of monetary policy surprises. This is a combination of the approaches used by Gurkaynak, Sack, and Swanson (2005) (here GSS for short) and Altavilla et al. (2019b) (here ABGMR for short). The former extract two policy shocks ("target" and "path" shocks) for the federal funds rate from U.S. asset yield changes around Federal Reserve monetary policy decision dates. The latter investigate monetary policy surprises of the ECB—from yield changes of the approximated euro area yield curve—and, in addition to the two shocks in GSS, also identify a third shock, namely surprises about the future of

TABLE B.2. Results from correlational analysis using concatenated policy rate.

Change in the mortgage rate (pp)				
β_0	β_1	β_2	β_3	$\sum_{k=0}^{3} \beta_k$
0.542***	0.225***	0.114***	−0.042	0.839***
(0.049)	(0.051)	(0.032)	(0.040)	(0.024)
μ_0	μ_1	μ_2	μ_3	$\sum_{k=0}^{3} \mu_k$
−0.178*	−0.114	0.064	0.077	−0.151**
(0.085)	(0.064)	(0.059)	(0.077)	(0.055)
$\beta_0 + \mu_0$	$\beta_1 + \mu_1$	$\beta_2 + \mu_2$	$\beta_3 + \mu_3$	$\sum_{k=0}^{3} \beta_k + \mu_k$
0.364***	0.111	0.178***	0.035	0.688***
(0.101)	(0.063)	(0.040)	(0.073)	(0.064)
Number of observations			1774	
Adjusted R^2			0.42	
Bank-group fixed effects			Yes	

Notes: This table presents selected coefficients and standard errors (in brackets) estimated from the regression in equation (1) with $K = 3$. The dependent variable is the 1-month difference in the rate on new mortgage loans in percentage points and the independent variable is the first difference of a concatenated version of the policy rate that is a combination of the rate on MRO and the DFR. The combination is as follows: Up to July of 2008, it is just the MRO, in August of 2008, it is 80% MRO + 20% DFR, in September, it is 60% MRO + 40% DFR, in October, it is 40% MRO + 60% DFR, in November, it is 20% MRO + 80% DFR, and from December of 2008 onwards, it is just DFR. The change in the policy rate is measured in percentage points. The sample period is January 2005 to October 2020. Standard errors are clustered at the bank-group level. Asterisks denote statistical significance: $* = 10\%$, $** = 5\%$, $*** = 1\%$.

TABLE B.3. Results from exposure-measure analysis using concatenated policy rate.

	Change in the mortgage rate (bps)
β	−0.185
	(0.102)
μ	−1.049*
	(0.521)
Number of observations	244
Adjusted R^2	0.84
Bank group fixed effects	Yes
Period fixed effects	Yes

Notes: This table presents selected coefficients and standard errors (in brackets) estimated from regression equation (3) with the dependent variable being the 1-month difference in the mortgage rate in basis points. The independent variable is the first difference of a concatenated version of the policy rate that is a combination of the rate on MRO and DFR. The combination is as follows: Up to July of 2008, it is just the MRO, in August of 2008, it is 80% MRO + 20% DFR, in September, it is 60% MRO + 40% DFR, in October, it is 40% MRO + 60% DFR, in November, it is 20% MRO + 80% DFR, and from December of 2008 onwards, it is just DFR. The change in the policy rate is measured in basis points and the DAR is measured as a number between 0 and 1. Standard errors are clustered at the bank-group level. Asterisks denote statistical significance: $* = 10\%$, $** = 5\%$, $*** = 1\%$.

TABLE B.4. Results from high-frequency analysis, one lag.

	Change in the mortgage rate (bps)	
	Contemporaneous	1st Lag
Target shock (S^T)		
S^T pre-NIRP (β^T)	7.24***	2.93
	(2.55)	(3.19)
S^T NIRP ($\beta^T + \mu^T$)	3.05***	1.65***
	(0.86)	(0.61)
S^T difference (μ^T)	−4.19	−1.29
	(2.71)	(3.24)
Path shock (S^P)		
S^P pre-NIRP (β^P)	1.15	0.82
	(1.80)	(1.67)
S^P NIRP ($\beta^P + \mu^P$)	1.00	0.48
	(0.86)	(0.75)
S^P difference (μ^P)	−0.14	−0.35
	(2.00)	(1.82)
Number of observations	185	
Adjusted R^2	0.06	
Single Shock		
Pre-NIRP (β)	6.72**	2.69
	(3.03)	(2.46)
NIRP ($\beta + \mu$)	2.95*	1.74
	(1.72)	(1.48)
Difference (μ)	−3.76	−0.96
	(3.49)	(2.87)
Number of observations	185	
Adjusted R^2	0.04	

Notes: The top part of the table presents the coefficients and standard errors (in brackets) estimated from the regression in equation (2) but including one lag of each of the two shocks. The bottom part of the table presents the results of a similar regression where there is a single extracted shock that is the first principal component of the asset prices described in the text, normalized to move the short rate one-for-one. Standard errors are HAC robust with a maximum of one lag. Asterisks denote statistical significance: $* = 10\%$, $** = 5\%$, $*** = 1\%$.

QE programs. In our approach, we extract two shocks (target and path) for the ECB monetary policy decisions as in GSS but using the ABGMR dataset for the euro area.[29]

We begin by selecting into matrix $\hat{X}$ (indexed at each monetary policy decision date) changes in seven asset yields (same series as in ABGMR, describing the euro area yield curve from 1 month to 10 years) in a tight window around the ECB's monetary policy decision events. The asset yield series include indexed swaps of EONIA with 1-, 3-, 6- and 12-month maturities (OIS1M, OIS3M, OIS6M, and OIS12M) as well as German government bond yields for 2-, 5-, and 10-year maturities (DE2Y, DE5Y, and DE10Y). The series are taken directly from the EA-MPD Excel file from the sheet

29. Extracting three shocks instead of two would make very little difference for our results.

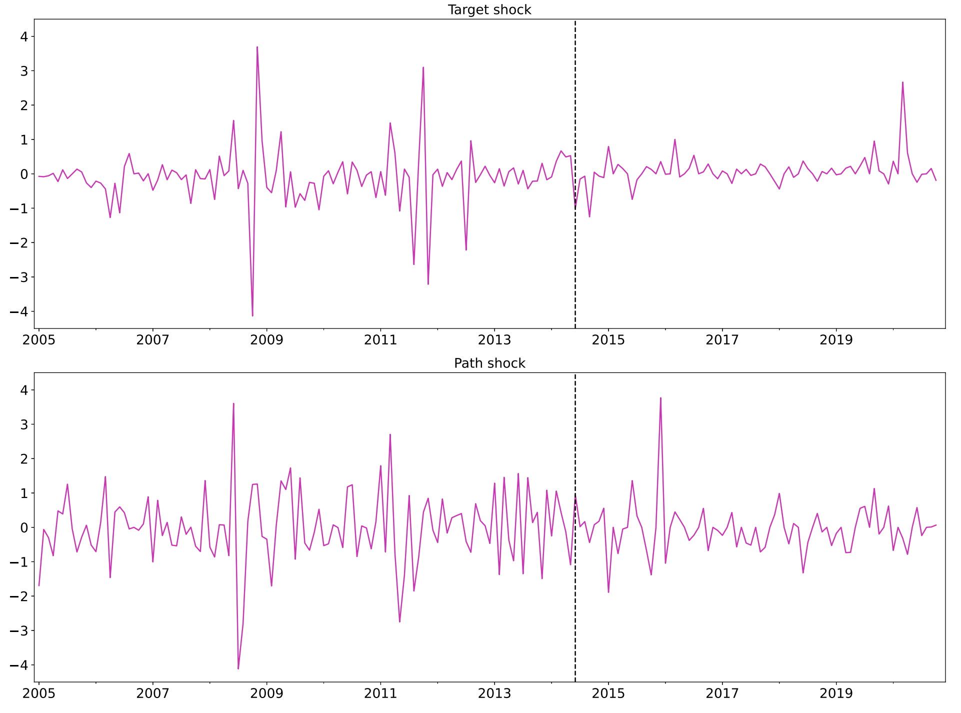

FIGURE C.1. Derived monetary policy shocks. This figure displays the target and path shocks using our extraction method akin to Gurkaynak, Sack, and Swanson (2005) and Altavilla et al. (2019b). The shocks are derived for each monetary policy decision date and grouped to monthly frequency by summing shocks within each month. The vertical dashed line denotes the start of NIRP in June 2014. Source: EA-MPD and authors' calculations.

"*Monetary Event Window*".[30] First, we obtain a normalized matrix X by applying a z-score transformation on each of the columns $\hat{X}_j$ in $\hat{X}$. Next, we extract the first two principal components of X, yielding a matrix $\hat{F}$ of orthogonal column vectors $\hat{F}_j$, $j = 1, 2$. Lastly, we normalize each of the columns in $\hat{F}$ to have unit variance, resulting in factor matrix F and associated loading matrix $\aleph$.

Shocks $\hat{S}$ are obtained when we rotate F with a suitable matrix U. In particular, the shocks are given by

$$\hat{S} = F\,U, \tag{C.1}$$

where the rotation matrix U is identified by four restrictions as described in GSS, p. 91. Specifically, if we write U as

$$U = \begin{bmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{bmatrix}, \tag{C.2}$$

30. The series are taken from Excel "as is", that is, we do not perform similar adjustment for the first two columns as GSS (p. 89–90) to clean for the overlap in the expected path of the policy rate.

then the four restrictions can be described as follows:

$$1 = \alpha_1^2 + \alpha_2^2, \tag{C.3}$$

$$1 = \beta_1^2 + \beta_2^2, \tag{C.4}$$

$$0 = \alpha_1\beta_1 + \alpha_2\beta_2, \tag{C.5}$$

$$0 = \beta_1\aleph_{11} + \beta_2\aleph_{21}, \tag{C.6}$$

where $\aleph_{ij}$ is the element in the ith row and jth column of $\aleph$. With this rotation, we can define a new matrix of loadings $L = U'\aleph$. Finally, $\hat{S}$ can be re-scaled to obtain the final shock matrix S as follows: S^T moves the 1 month rate change (column X_1, that is, OIS1M) one-for-one, and S^T and S^P have the same effect on the 1 year rate change (column X_4, i.e., OIS1Y). This can be accomplished by defining

$$S = \hat{S} \cdot M, \tag{C.7}$$

where

$$M = \begin{bmatrix} L_{11} & 0 \\ 0 & L_{11}\frac{L_{24}}{L_{14}} \end{bmatrix}, \tag{C.8}$$

and L_{ij} is the element in the ith row and jth column of the loading matrix L.

References

Abadi, Joseph, Markus Brunnermeier, and Yann Koby (2023). "The Reversal Interest Rate." *American Economic Review*, 113(8), 2084–2120.

Altavilla, Carlo, Luca Brugnolini, Refet S. Gürkaynak, Roberto Motto, and Giuseppe Ragusa (2019a). "Data Supplement to: Measuring Euro Area Monetary Policy." *Journal of Monetary Economics, Elsevier*, 108, 162–179.

Altavilla, Carlo, Luca Brugnolini, Refet S. Gürkaynak, Roberto Motto, and Giuseppe Ragusa (2019b). "Measuring Euro Area Monetary Policy." *Journal of Monetary Economics*, 108, 162–179.

Ampudia, Miguel and Skander J. Van den Heuvel (2022). "Monetary Policy and Bank Equity Values in a Time of Low and Negative Interest Rates." *Journal of Monetary Economics*, 130, 49–67.

Amzallag, Adrien, Alessandro Calza, Dimitris Georgarakos, and João Sousa (2019). "Monetary Policy Transmission to Mortgages in a Negative Interest Rate Environment." Working Paper No. 2243, European Central Bank.

Balloch, Cynthia and Yann Koby (2023). "Low Rates and Bank Loan Supply: Theory and Evidence from Japan." Discussion Paper No. 884, Financial Markets Group.

Balloch, Cynthia, Yann Koby, and Mauricio Ulate (2022). "Making Sense of Negative Nominal Interest Rates." Working Paper No. 2022-12, Federal Reserve Bank of San Francisco.

Bank of Finland (2022). "Balance Sheet Items and Interest Rate Statistics of Finnish Monetary Financial Institutions." Internal Bank of Finland confidential dataset. Last accessed February 2022 at: https://www.suomenpankki.fi/en/statistics/to-the-reporter/mfi-data-collection/.

Basten, Christoph and Mike Mariathasan (2023). "Interest Rate Pass-through and Bank Risk-taking Under Negative-rate Policies with Tiered Remuneration of Central Bank Reserves." *Journal of Financial Stability*, 68, 101160.

Bats, Joost V., Massimo Giuliodori, and Aerdt C. F. J. Houben (2023). “Monetary Policy Effects in Times of Negative Interest Rates: What do Bank Stock Prices Tell us?” *Journal of Financial Intermediation*, 53, 101003.

Bittner, Christian, Diana Bonfim, Florian Heider, Farzad Saidi, Glenn Schepens, and Carla Soares (2022). “The Augmented Bank Balance-sheet Channel of Monetary Policy.” Working Paper No. 2745, European Central Bank.

Bloomberg (2022). “Multiple Series.” Last accessed October 2022 at: https://www.bloomberg.com/professional/contact-menu/.

Bottero, Margherita, Camelia Minoiu, JoséLuis Peydró, Andrea Polo, Andrea F. Presbitero, and Enrico Sette (2022). “ Expansionary yet Different: Credit Supply and Real Effects of Negative Interest Rate Policy.” *Journal of Financial Economics*, 146, 754–778.

Brandao-Marques, Luis, Marco Casiraghi, Gaston Gelos, Gunes Kamber, and Roland Meeks (2021). “Negative Interest Rates: Taking Stock of the Experience So Far.” IMF Departmental Papers 2021/003, International Monetary Fund. https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2021/03/01/Negative-Interest-Rates-Taking-Stock-of-the-Experience-So-Far-50115.

Bräuning, Falk and Botao Wu (2017). “ECB Monetary Policy Transmission During Normal and Negative Interest Rate Periods.” Working paper, CUHK Business School.

de Groot, Oliver and Alexander Haas (2023). “The Signalling Channel of Negative Interest Rates.” *Journal of Monetary Economics*, 138, 87–103.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl (2017). “The Deposits Channel of Monetary Policy.” *The Quarterly Journal of Economics*, 132, 1819–1876.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl (2021). “Banking on Deposits: Maturity Transformation without Interest Rate Risk.” *Journal of Finance*, 76, 1091–1143.

ECB (2024). “Official Interest Rates.” Last accessed October 2024 at: https://data.ecb.europa.eu/data/data-categories/ecbeurosystem-policy-and-exchange-rates/official-interest-rates.

Eggertsson, Gauti B., Ragnar E. Juelsrud, Lawrence H. Summers, and Ella Getz (2024). “ Negative Nominal Interest Rates and the Bank Lending Channel.” *The Review of Economic Studies*, 91, 2201–2275.

FRED (2024). “European Central Bank, ECB Deposit Facility Rate for Euro Area [ECBDFR].” Retrieved from FRED, Federal Reserve Bank of St. Louis, October, 2024 at: https://fred.stlouisfed.org/series/ECBDFR.

Gurkaynak, Refet, Brian Sack, and Eric Swanson (2005). “Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements.” *International Journal of Central Banking*, 55–93.

Hee Hong, Gee and John Kandrac (2022). “Pushed Past the Limit? How Japanese Banks Reacted to Negative Rates.” *Journal of Money, Credit and Banking*, 54, 1027–1063.

Heider, Florian, Farzad Saidi, and Glenn Schepens (2019). “Life below Zero: Bank Lending under Negative Policy Rates.” *The Review of Financial Studies*, 32, 3728–3761.

Heider, Florian, Farzad Saidi, and Glenn Schepens (2021). “Banks and Negative Interest Rates.” *Annual Review of Financial Economics*, 13, 201–218.

Lopez, Jose A., Andrew K. Rose, and Mark M. Spiegel (2020). “Why have Negative Nominal Interest Rates had Such a Small Effect on Bank Performance? Cross Country Evidence.” *European Economic Review*, 124, 103402.

Onofri, Marco, Gert Peersman, and Frank Smets (2023). “ The Effectiveness of a Negative Interest Rate Policy.” *Journal of Monetary Economics*, 140, 16–33.

Putkuri, Hanna (2020). “Asuntorahoituksen trendit Suomessa vuosituhannen vaihteen jälkeen.” Yleistajuiset selvitykset 2020/122, Bank of Finland. https://publications.bof.fi/handle/10024/43723. Accessed July 1, 2024.

S&P Global Market Intelligence (2021). “S&P Capital IQ Pro.”https://www.spglobal.com/market-intelligence/en. Accessed July 2021.

Tenreyro, Silvana (2021). “Let’s Talk About Negative Rates.” Speech given by Silvana Tenreyro, External Member of the Monetary Policy Committee of the Bank of England, at a UWE Bristol webinar on 11 January 2021. https://personal.lse.ac.uk/tenreyro/negatives.pdf.

Ulate, Mauricio (2021a). "Alternative Models of Interest Rate Pass-Through in Normal and Negative Territory." *International Journal of Central Banking*, 17, 3–34.
Ulate, Mauricio (2021b). " Going Negative at the Zero Lower Bound: The Effects of Negative Nominal Interest Rates." *American Economic Review*, 111(1), 1–40.
Wang, Olivier. "Banks, Low Interest Rates, and Monetary Policy Transmission." 2022. Working paper, New York University, Stern School of Business.

Supplementary Data

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