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

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De Nederlandsche Bank NV
P.O. Box 98
1000 AB AMSTERDAM
The Netherlands

Monetary policy effects in times of negative interest rates: What do bank stock prices tell us?*

Joost V. Bats[†] Massimo Giuliodori[‡] Aerdt C.F.J. Houben[§]

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Abstract

Do negative interest rates matter for bank performance? This paper investigates whether monetary policy surprises impact bank stock prices differently in times of positive and negative interest rates. The analysis controls for broad stock market movements and finds that an unanticipated downward shift in the yield curve and a flattening of the shorter-end of the yield curve resulting from monetary policy announcements reduce bank stock prices in a low and especially negative interest rate environment. The effects persist in the days after the monetary policy announcement and are larger for banks relatively dependent on deposit funding. By contrast, a surprise movement in the slope of the longer-end of the yield curve does not impact bank stock prices in a negative interest rate environment. The results indicate that when market interest rates are negative but deposit rates stuck at zero, monetary policy instruments that target the longer-end of the yield curve are less detrimental to bank performance than those that target the shorter-end of the yield curve.

JEL codes: E43, E44, E52, G12, G21

Key Words: Monetary policy, bank stock prices, negative interest rates

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[†]De Nederlandsche Bank, University of Amsterdam. E-mail address: j.v.bats@dnb.nl.

[‡]University of Amsterdam. E-mail address: M.Giuliodori@uva.nl.

[§]De Nederlandsche Bank, University of Amsterdam, OECD. E-mail address: a.c.f.j.houben@dnb.nl

1 Introduction

Over the past 40 years, interest rates have steadily declined worldwide, recently turning negative in Europe and Japan (See Figure 1). In Europe and Japan, interest rates are expected to remain negative and yield curves flat for long. A prolonged period of negative interest rates has implications for the performance of banks, as retail deposit rates are sticky at the zero lower bound. In a negative interest rate environment, additional rate cuts may reduce bank profits, particularly if these endure. This reduces the lending capacity of capital-constrained banks and can thus 'reverse' accommodative monetary policy (Borio and Gambacorta, 2017, Brunnermeier and Koby, 2018, Cavallino and Sandri, 2018, Gropp et al., 2019, Gomez et al., 2020).

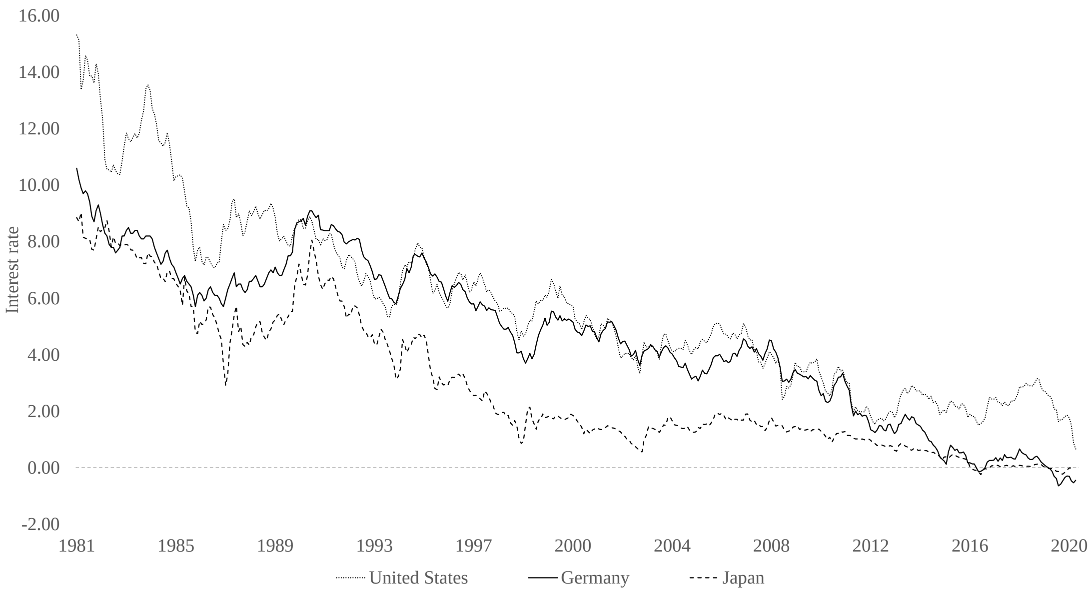

Figure 1: 10-year government bond yield developments
Notes: This figure shows developments in the 10-year government bond yields for Germany, Japan and the United States. The data indicate that interest rates have trended downward worldwide. The data are from the Economic Data of the Federal Reserve Bank of St. Louis.

Despite retail customers' ability to clear their sight deposit balances at any point in time, retail deposits are a stable funding source for banks and thus have a positive duration. Hoffmann et al. (2019) estimate the average duration of retail sight deposits at 2 years. In practice, banks replicate portfolios of fixed-rate assets that match the estimated duration of their deposit liabilities (Kalkbrener and Willing, 2004) using interest rate swaps (Jarrow and van Deventer, 1998). The difference between the swap and deposit rate represents the deposit margin (Figure 2, bracket C). While banks may supply loans with an average duration longer than their replicating portfolio (Figure 2, bracket B), the remaining interest rate exposure is generally hedged (Chaudron, 2018, Drechsler et al., 2018, Hoffmann et al., 2019). In addition, banks earn a lending margin, defined as the difference between the rate on lending and swap contracts with an equivalent average duration (Figure 2, bracket A).[1] The relationship between swap rates at different maturities is identified as the swap curve, which is the equivalent of a risk-free yield curve.

Monetary policy shapes the yield curve in different ways (see also Altavilla et al., 2019b). First, changing the central bank's policy rate affects interest rates with maturities up to 1 to 2 years. However, this effect adjusts in a negative interest rate environment (Lane, 2019). A policy rate cut in negative territory may influence interest rates with maturities up to 5 years almost equivalently, if it signals the effective lower bound on interest rates is lower than previously perceived by market participants. Second, providing forward guidance on a central bank's future monetary policy intentions generates most effect on interest rates with maturities between 2 and 5 years. Third, offering central bank longer-term refinancing operations, which fund banks for periods up to 4 years, influences interest rates with maturities up to 4 years. Fourth, purchasing long-term bonds under quantitative easing (QE) policies mostly impacts interest rates with maturities of 5 years and longer. Fifth, targeting longer-term interest rates under yield curve control (YCC) policies, as implemented by the Bank of Japan, affects interest

[1]For banks that rely on deposit funding, the deposit and lending margin make up the net interest margin.

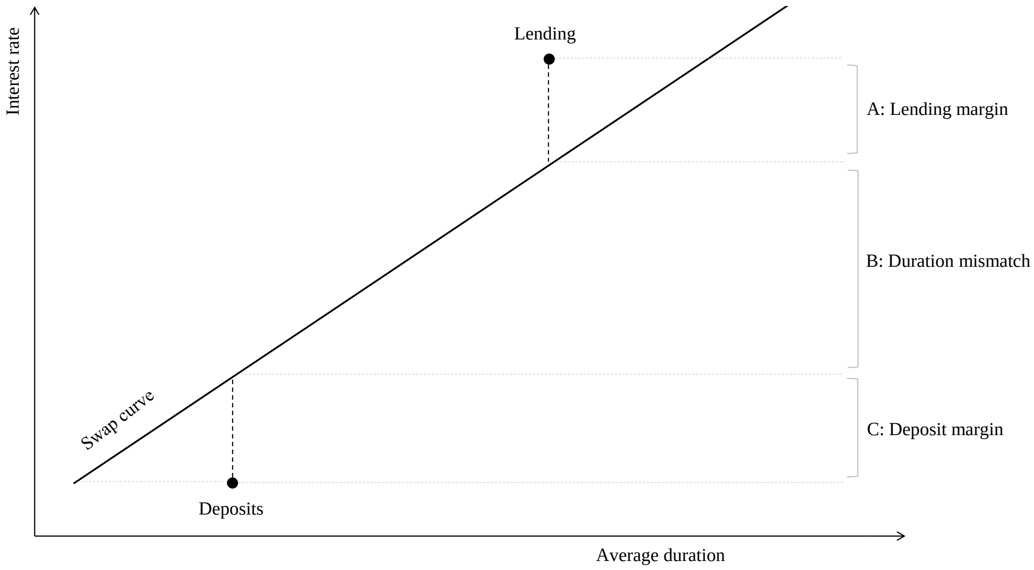

Figure 2: The net interest margin

Notes: This figure illustrates banks' net interest margin in a nominal interest rate environment with a positively sloped yield curve. The vertical axis represents the interest rate. The horizontal axis is the average duration. To match the duration of deposit liabilities, banks use replicating portfolios equivalent to particular interest rate swaps. The difference between the swap and deposit rates represents the deposit margin (bracket C). The difference between the swap and lending rates is the lending margin (bracket A). The interest rate exposure resulting from the duration mismatch between replicating portfolios and lending (bracket B) is generally hedged.

rates with maturities of around 10 years.[2]

As a result of retail deposit rates bound at zero, monetary policy effects on the yield curve can hurt bank performance and impede monetary transmission when policy rates are negative.[3] When the yield curve shifts downward in a negative interest rate environment, the deposit margin shrinks and eventually turns negative (Figure 3, Panel A). Subsequent yield curve flattening can turn the deposit margin even more negative,

[2]While short-term interest rates have not been driven far in negative territory, the Bank of Japan has effectively steered the 10-year yield to flatten the longer-end of the curve. The Australian Reserve Bank has also undertaken YCC, albeit their intention was to reinforce the central bank's forward guidance by targeting shorter-term interest rates.

[3]Bank performance not only depends on the net interest margin, since a share of bank revenue stems from fee income. As such, banks may try to offset interest income losses under a low and negative interest rate regime by shifting towards more fee-related activities, as well as by charging higher fees (Borio et al., 2019, Lopez et al., 2020)

despite banks hedging the remaining interest rate exposure, as banks match the duration of deposits with replicating portfolios (Figure 3, Panel B). However, the deposit margin may be less affected if only the longer-end of the yield curve flattens (Figure 3, Panel C). By contrast, changes to the yield curve do not necessarily affect the lending margin. The lending margin mainly represents a credit risk premium and is not constrained in a negative interest rate environment. While the lending margin temporarily increases thanks to a delayed decline in interest income on account of banks' fixed rate assets having a longer duration (i.e. accruing capital gains), it returns to its original size over time.

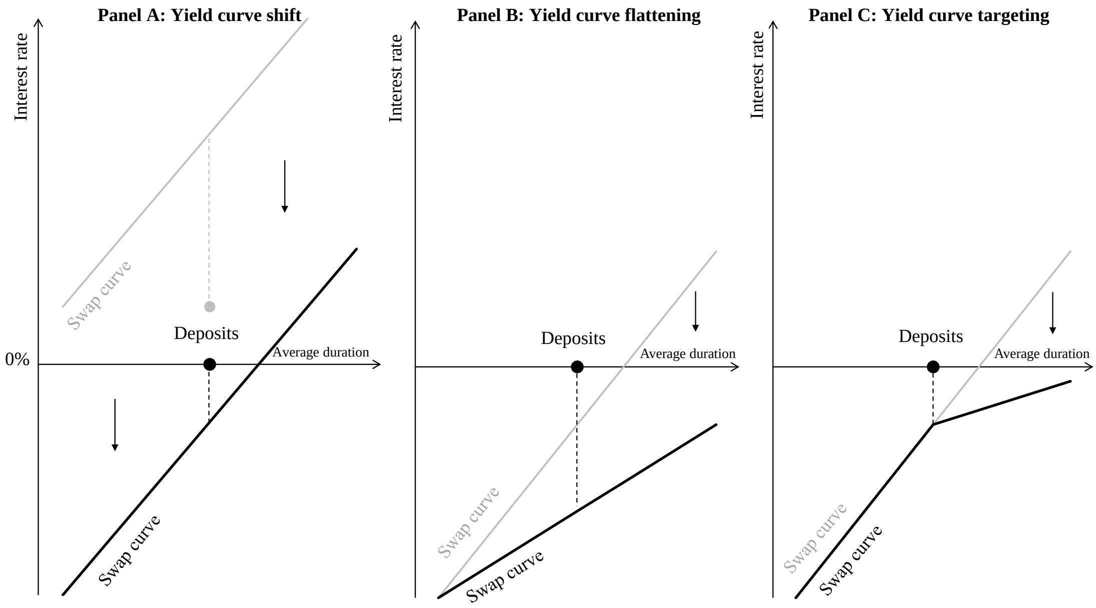

Figure 3: Monetary policy and the deposit margin when interest rates are negative
Notes: This figure depicts the stylized impact of a negative interest rate environment on banks' deposit margins. The vertical axis represents the interest rate. The horizontal axis is the average duration. In this figure, deposit rates are bound at zero. Panel A shows deposit margins permanently shrink and turn negative following a downward parallel yield curve shift into a negative interest rate territory. Panel B shows that in a negative interest rate environment, yield curve flattening makes deposit margins even more negative, since sight deposits effectively have a duration larger than 0. Panel C indicates that in times of negative interest rates, deposit margins are less affected when the yield curve is targeted such that only the longer-end flattens.

Studies confirm that a low and negative interest rate environment has adverse effects on the performance of banks (see e.g. Borio et al., 2017, Claessens et al., 2018, Eggertsson et al., 2019, Heider, et al., 2019), though some claim the implications are limited (see e.g. Altavilla et al., 2018, Lopez et al., 2018, Altavilla et al., 2019a). These studies measure bank performance using balance sheet and income statement items such as the net interest margin, lending and profitability. The advantage of these measures is that they are based on actual reported bank performance data. However, their caveat is that they are backward-looking and do not reflect the full impact of negative interest rates, which takes time to materialize. Backward-looking measures only respond to a drop in the interest rate with a lag due to banks' capital gains on fixed rate assets. In terms of the sustainability of bank profits, backward-looking indicators may in fact be biased; several studies show that banks temporarily respond to negative interest rates by increasing their lending volumes (Basten and Mariathasan, 2018, Bottero et al., 2019, Demiralp et al., 2019, Tan, 2019), but a prolonged negative interest rate environment may require banks to eventually increase lending margins (see also Eggertson et al., 2019), which will reduce their lending volumes, market share and profits.

To address these caveats, this paper explores the impact of negative interest rates on bank performance using a forward-looking indicator: bank stock prices. These reflect the market valuation of banks' equity based on the expected future discounted cash flows at any given time. As such, they provide a forward-looking indicator of the impact of interest rate changes on bank performance. A drop (rise) in bank stock prices following a change in the interest rate or slope of the yield curve indicates that investors expect lower (higher) future discounted cash flows. Stock prices can therefore be considered a 'summary measure' of bank performance (Ampudia and van den Heuvel, 2018). As bank stock prices may anticipate changes to the yield curve in the future, this paper identifies unanticipated interest rate changes with high-frequency data around 269 ECB monetary policy announcements from January 1999 to January 2020. The analysis focuses on the Eurosystem since the interest rate environment has been more negative in the euro area than in other major currency areas.

Three recent papers have also analyzed the effect of unanticipated interest rate changes around monetary policy announcements on bank stock prices.[4] The first paper looks at the US in a positive interest rate environment and shows that bank stock prices drop when the yield curve unexpectedly shifts upwards or steepens (English et al., 2018). This may reflect banks' hedging activity and a combination of capital losses on longer-term assets, higher discount rates on future earnings, higher expected credit losses and/or lower anticipated economic activity due to monetary tightening. The second paper looks at Japan and shows that bank stock prices dropped by more than 5% on the day the Bank of Japan announced their negative interest rate policy (Hong and Kandrac, 2018). The third paper looks at Europe and finds that a drop in the 1-month interest rate, holding the 2-year yield constant, increases bank stock prices in a positive interest rate environment, but reduces bank stock prices in a low and negative rate environment (Ampudia and van den Heuvel, 2018). The findings of the latter two papers likely indicate banks' decreased future profits due to a reduction in the net interest margin when the interest rate environment turns negative. Conversely, however, Ampudia and van den Heuvel (2018) show that an unanticipated flattening of the 2-year yield curve increases European bank stock prices in times of negative interest rates. This may reflect that banks' deposit margin is not much affected by only targeting up to 2-year yields, since the duration of retail deposits reaches up to 5 years.[5] In addition, European bank stock prices may increase in response to lower discount rates on future earnings and/or higher anticipated economic activity due to monetary easing.

The contribution of this study to the above papers is threefold. First, this paper investigates whether bank stock prices react differently to changes to the shorter- versus

[4] Several other studies use high-frequency data for the identification of unanticipated interest rate changes, but they do not explore the impact on bank stock prices (Bagliano and Favero, 1999, Kuttner, 2001, Cochrane and Piazzesi, 2002, Faust et al., 2004, Bernanke and Kuttner, 2005, Gürkaynak et al., 2005, Piazzesi and Swanson, 2008, Gertler and Karadi, 2015, Nakamura and Steinsson, 2018).

[5] Hoffmann et al. (2019) estimate the mean and standard deviation of retail sight deposits' duration at 2 and 1.6 years, respectively.

the longer-end of the yield curve in times of positive and negative interest rates. The above literature indicates that the effects of yield curve changes on bank stock prices depend on the interest rate environment. This has implications for monetary policy making. But monetary policy has different instruments and central banks intervene on different segments of the yield curve. For example, large-scale purchases of longer-term assets can be designed such that only the longer-end of the yield curve is targeted, leaving shorter-term interest rates relatively unchanged. This may reduce the adverse impact of monetary policy on bank performance in a negative interest rate environment. By the same token, the adverse effects on bank stock prices of a downward shift and flattening of the entire yield curve may stem mostly from changes to shorter-end up to the 5-year yield.

Second, rolling regressions are employed to provide insight into how the impact of monetary policy accrues over time in a negative interest rate environment. Compared to a state-dependent model, as for example applied by Ampudia and van den Heuvel (2018), a rolling regression model can provide a quantification of how bank stock prices become affected as the interest rate environment changes. The negative impact of a rate drop on bank performance likely magnifies over time when interest rates remain negative for longer. Moreover, rolling estimations can show whether a drop in the interest rate already reduces bank performance in a low but positive interest rate environment due to shrinking deposit margins. Rolling local projections are used to gauge the persistence of the effects.

Third, in contrast to the above papers, this study identifies the specific disadvantage banks face in times of negative interest rates by controlling for broad stock market movements. While the monetary policy surprises in the above papers do not necessarily reflect structural macroeconomic developments (Gertler and Karadi, 2015), they do generate endogenous signaling effects when they represent unexpected changes to the macroeconomic outlook (Jarociński and Karadi, 2020). This impacts stock prices in general. In addition, a drop in the interest rate may increase stock prices when it leads to capital gains, a decrease in future discount rates and/or equity premiums, and an increase in economic activity (see also Bernanke and Kuttner, 2005). This contrasts with the potential negative effect of interest rate reductions specifically on bank stock prices when banks' expected future cash flows decline as a result of deposit margins turning negative. To address these identification issues, this paper analyzes the effect of monetary policy surprises on bank stock prices while holding movements in European broad stock market prices constant. The broad stock market is assumed to also react to unexpected interest rate changes and their resulting macroeconomic signaling effects, while being insensitive to the specific additional negative effect of interest rate declines, which banks face in times of negative interest rates.

The results show that a low and especially negative interest rate environment hurts bank stock prices. Controlling for the broad stock market, negative surprises to the level and shorter-end slope of the yield curve have large adverse effects on bank stock prices once the interest rate environment is negative. Local projections indicate that in times of negative interest rates, the effects persist in the days after the monetary policy announcement. Banks thus face a disadvantage when interest rates are negative. The data on bank stock prices suggest this is the result of the lower bound on deposit rates for three reasons. First, while the relative capitalization of banks does not influence the results in times of negative interest rates, the effects are significantly larger for banks that are relatively dependent on deposit funding. Second, the effects are also more persistent for these banks. Third, a negative surprise to the longer- rather than the shorter-end of the yield curve does not reduce bank stock prices in times of negative interest rates. Together, the results signal that a lowering of longer-term interest rates is less detrimental to bank stock performance than a lowering of short-term rates in a negative interest rate environment. The findings are robust to sample changes and alternative specifications that address potential concerns the effects are asymmetric or dynamic.

The rest of this paper is organized as follows. Section 2 describes the data. Section 3 presents the methodology. The results are discussed in Section 4. Section 5 concludes.

2 Data

Unanticipated changes (i.e. surprises) in interest rates and stock prices are identified with high-frequency data around 269 ECB monetary policy announcements. The data stem from the Euro Area Monetary Policy Event-Study Database by Altavilla et al. (2019b) and cover the period from January 1999 to January 2020. This paper considers the beginning of 2009 as the start of the low interest rate environment. During that time, the DFR was set to 1% and the 1-month OIS rate dropped below 1.25%. This is in line with Claessens et al. (2018), who denote the interest rate environment as "low" once risk-free short-term interest rates are below 1.25%. Moreover, rolling regression estimations allow for defining different cutoffs for what constitutes a low interest rate environment. June, 2014 is considered as the start of the negative interest rate environment. This is when the ECB announced the introduction of a negative interest rate policy by lowering the rate on its deposit facility for banks (DFR) to -0.1%.[6] In September 2014, when the DFR was reduced to -0.2%, the 1-month Overnight Index Swap (OIS) rate turned negative (Figure 4). By the end of the sample period, longer-term interest rates also became negative, as indicated by developments in the 10-year German government bond yield (Figure 1).

The surprises are measured as the difference between the median quote 10 to 20 minutes before the press release and 10 to 20 minutes after the press conference, or alternatively, 15 to 25 minutes after the press release if no press conference took place.[7]

[6] While the monetary policy announcement took place on June 5, 2014, the measure took effect 6 days later, on June 11, 2014.

[7] Measurement outcomes of the surprises are relatively insensitive to changes in the measurement windows (Altavilla et al., 2019b).

The press release is at 13:45, followed by the press conference starting at 14:30 and ending at 15:30. Including the press conference in the monetary event window is essential, as interest rates and stock prices may react to new monetary information revealed at the Q&A session during this event.

Figure 4: 1-month OIS rate developments

Notes: This figure shows developments in the 1-month OIS rate for the euro area. The data show that since 2014, the short-term interest rate is negative in the euro area. The data are from Bloomberg.

The frequency of ECB monetary policy announcements has changed during the sample. From January 1999 until November 2001, the ECB announced monetary policy decisions twice a month. Every first decision of the month was accompanied by a press conference. Between November 2001 and January 2015, monetary policy announcements occurred on the first Thursday of each month only, generally accompanied by a press conference.[8] Since January 2015, announcements of ECB monetary policy decisions take place every 6 weeks on Thursdays.[9]

The measures of the interest rate surprises are the intraday changes in the 1-month

[8]Exceptions are provided by Ehrmann and Fratzscher (2009).
[9]Altavilla et al. (2019b) summarize the details.

OIS rate, the difference between the 5-year German government bond and 1-month OIS rate, and the difference between the 10- and 5-year German government bond rate. These measures are respectively categorized as changes in the level, shorter-end slope and longer-end slope of the yield curve (also in the remainder of this study).[10] Figure 5 plots the interest rate surprises around the monetary policy decisions. While longer OIS rates are considered a better proxy for identifying the risk-free yield curve, high-frequency data on the 5- and 10-year OIS rates are only available from, respectively, August and July 2011. By way of alternative, German government bond rates are used, as they generally do not comprise a credit risk premium. German government bond rates have incorporated a small scarcity premium since the implementation of the Asset Purchase Programme (APP) in 2015 (Schlepper et al., 2017), but endogeneity issues are likely to be neglibile since the surprises are intraday. Moreover, the correlation between movements in the slopes of OIS and German yield curves are above 0.9. A separate robustness check substitutes the German rates with 5- and 10-year OIS rates for the period after August 2011.

The measures of the stock price surprises are the intraday changes in the logs of the European bank stock index (SX7E) and broad stock market index (STOXX50E). The SX7E is a capitalization-weighted index that includes 24 large listed banks headquartered in 7 large euro area countries (though most of these banks are active across Europe). The SX7E is reviewed periodically. Table 1 displays the banks included in the SX7E in the last years of the sample period, when the interest rate environment is negative. The last three columns show the average ratios of customer deposits to total assets, and total and Tier 1 capital to total risk-weighted assets during the negative interest rate environment; i.e. between 2014 and 2019.[11] Data on customer deposits include current accounts, demand

[10] Despite deposits' average duration of 2 years, the end of the shorter-end slope of the yield curve is set to the 5-year interest rate. This is to account for the share of deposits with a duration larger than 2, which generally are matched with replicating asset portfolios of a similar duration; a drop in the 2- to 5-year interest rates is then still expected to reduce deposit margins in a low rate environment.

[11] This paper is not interested in the degree of deposit funding relative to loans, since that is a liquidity

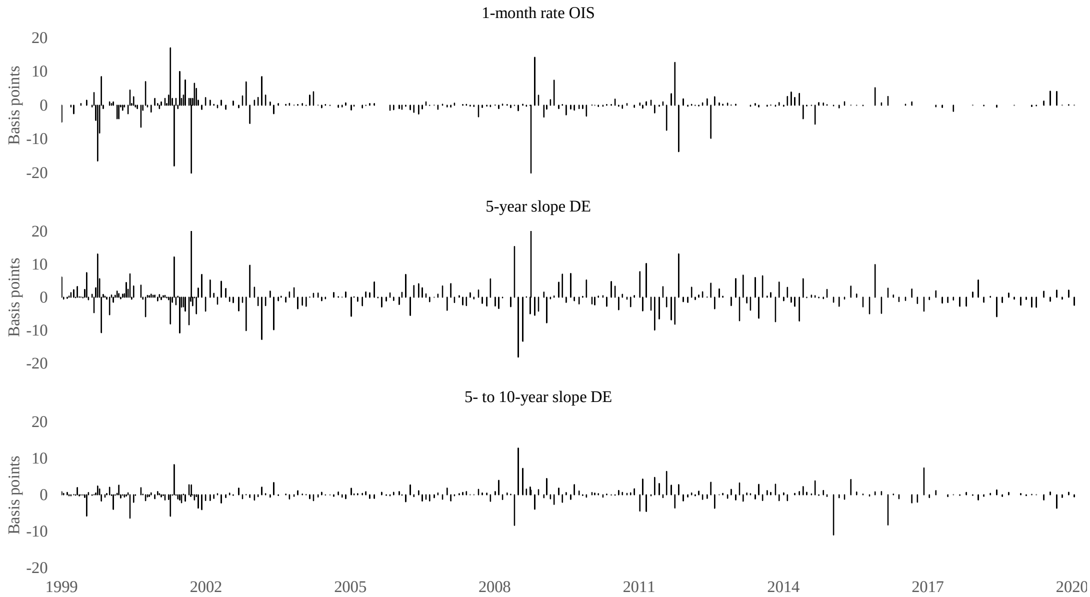

Figure 5: Interest rate surprises around monetary policy decisions
Notes: This figure shows interest rate surprises around every monetary policy decision between January 1999 and January 2020. The surprises measure intraday changes in the 1-month OIS rate, the difference between the 5-year German government bond rate and the 1-month OIS rate, and the difference between the 10-year German government bonds rate and the 1-month OIS rate. The intraday changes are measured as the difference between the median quote 10 to 20 minutes before the monetary policy press release and 10 to 20 minutes after the ECB press conference, or alternatively, 15 to 25 minutes after the monetary policy press release if no press conference took place. The data are from the Euro Area Monetary Policy Event-Study Database by Altavilla et al. (2019b).

deposits and time deposits from households and non-bank corporations.[12] Interbank deposits are excluded. The balance sheet data are from the annual reports published by each individual bank. Except for Natixis, the share of customer deposit funding is above 25% for all banks. Figure 6 plots the price-to-book ratio of the SX7E. The data show that the performance of European banks has deteriorated since the great financial crisis. Compared to the period before 2008, the price-to-book ratio of the SX7E reduced by 75%. The STOXX50E is a broad stock market index that tracks the stock prices of the 50 largest financial and non-financial corporations in the euro area. The volatility

rather than a funding indicator; wholesale and retail banks may have relatively similar loan-to-deposit ratios, while differing significantly in terms of dependence on deposit funding.

[12]Since not all banks report data on retail deposits in their annual reports, Table 1 does not include these data.

of the SX7E relative to the volatility of the STOXX50E is considered the equity beta of bank stocks.

Table 1: SX7E banks and their average share of customer deposit funding

	Banks	Country	Customer deposit ratio	Total capital ratio	Tier 1 capital ratio
1	ABN AMRO	NL	0.60	0.24	0.18
2	Banco BPM	IT	0.55	0.16	0.13
3	Bank of Ireland	IR	0.62	0.19	0.16
4	Bankinter	ES	0.61	0.13	0.12
5	BAWAG Group	AT	0.66	0.16	0.14
6	BBVA	ES	0.54	0.15	0.13
7	BNP Paribas	FR	0.37	0.14	0.13
8	Caixabank	ES	0.54	0.16	0.13
9	Commerzbank	DE	0.51	0.17	0.14
10	Credit Agricole	FR	0.34	0.19	0.14
11	Deutsche Bank	DE	0.32	0.17	0.16
12	Erste Bank	AT	0.67	0.18	0.13
13	Finecobank	IT	0.89	0.25	0.25
14	ING Group	NL	0.63	0.18	0.16
15	Intesa	IT	0.39	0.17	0.15
16	KBC Group	BE	0.54	0.20	0.17
17	Mediobanca	IT	0.27	0.16	0.13
18	Natixis	FR	0.11	0.15	0.13
19	Raiffeisen Bank	AT	0.61	0.18	0.14
20	Sabadell	ES	0.63	0.14	0.13
21	Santander	ES	0.50	0.14	0.13
22	Soc. Générale	FR	0.30	0.17	0.14
23	UBI	IT	0.51	0.15	0.12
24	UniCredit	IT	0.53	0.15	0.13

Notes: This table presents the average ratios of customer deposits to assets, and total and Tier 1 capital to risk-weighted assets of 24 European banks between 2014 and 2019. Together, these banks make up the European capitalization-weighted bank stock index (SX7E) during the last years of the sample period (the index is reviewed periodically). The deposit data include current accounts, demand deposits and time deposits from households and non-bank corporations. Interbank deposits are excluded. The balance sheet data are from the annual reports published by each individual bank.

Table 2 shows the descriptive statistics of the interest rate and stock price surprises in basis and percentage points, respectively. The descriptive statistics are provided in times of positive (r>0) and negative (r<0) interest rates.[13] A general observation stands out. The standard deviations of the interest rate surprises other than the surprise to the 5- to 10-year German slope are lower in the negative than the positive interest rate environment. This suggests that, to some extent, the magnitude of the rate surprises decreases over time as interest rates reach and fall below the zero lower bound. A similar pattern is observed in Figure 5.

[13]The interest rate period is considered positive (negative) the period before (after) the monetary policy announcement in June 2014.

Figure 6: Developments in the price-to-book ratio of the SX7E
Notes: This figure shows developments in the price-to-book ratio of the SX7E. The data show that European banks are performing worse compared to before the great financial crisis of 2008. The data are from Bloomberg.

Further to the surprise data, two types of daily data series from Bloomberg are analyzed. First, developments in the SX7E and STOXX50E are studied the days after the monetary policy announcements using daily data. Second, together with their average customer deposit ratios, the individual stock prices of the banks presented in Table 1 are examined to check the impact of banks' relative dependence on deposit funding; a negative interest rate environment may have more adverse implications for banks relatively dependent on deposit funding.[14] Motivated by recent findings that especially low capitalized banks shift from interest-generating towards more fee-related and trading

[14]The data on customer deposits include deposits from non-bank corporates. A caveat is that rates on deposits from non-bank corporates have to a small extent dropped below zero during the sample period, thus potentially preventing deposit margins turning negative in some occasions. While individual balance sheet data exist on the retail deposits of individual bank subsidiaries (e.g. the IBSI database by the ECB), these databases do not include data on all banking subsidiaries of the banking groups in the sample. Using this incomplete data would therefore generate identification issues; data on bank stock prices relate to each individual banking group on aggregate (i.e. including all subsidiaries). Given these complications, this paper uses customer deposits from households and non-bank corporations, recognizing this is an approximation of a bank's relative dependence on retail deposits.

Table 2: Descriptive statistics of the surprise data

Variables	Sample period	Obs		Median		Mean		Std Dev		Min		Max	
		r>0	r<0	r>0	r<0	r>0	r<0	r>0	r<0	r>0	r<0	r>0	r<0
SX7E	01.1999-01.2020	221	48	-0.07	0.01	-0.16	-0.04	0.89	1.23	-6.81	-3.13	3.02	3.02
STOXX50E	01.1999-01.2020	221	48	-0.07	0.06	-0.09	0.00	0.60	0.85	-2.77	-3.65	1.83	2.01
1-month rate OIS	01.1999-01.2020	221	48	0.00	0.00	-0.06	0.14	4.44	1.63	-35.00	-5.60	17.00	5.18
5-year slope DE	01.1999-01.2020	221	48	0.00	-0.63	0.07	-0.29	5.23	2.89	-18.15	-5.87	32.20	9.93
5- to 10-year slope DE	01.1999-01.2020	221	48	0.00	0.00	0.05	-0.19	2.15	2.61	-8.35	-11.00	12.80	7.35
5-year slope OIS	08.2011-01.2020	34	48	-1.02	-0.45	-0.81	-0.24	4.35	2.40	-8.00	-4.99	9.25	7.79
5- to 10-year slope OIS	08.2011-01.2020	34	48	0.36	-0.09	0.48	-0.06	2.27	1.61	-5.00	-6.05	8.60	3.71

Notes: This table presents the descriptive statistics of the monetary policy surprises. The first two variables represent the intraday surprises to the bank stock and broad stock market index, respectively. The last five variables are the intraday surprises to the 1-month OIS rate, the difference between the 5-year German government bond rate and the 1-month OIS rate, the difference between the 10- and 5-year German government bond rate, the difference between the 5-year and 1-month OIS rate, and the difference between the 10- and 5-year OIS rate, respectively. The second column shows for which sample period the surprise data are available. The descriptive statistics are shown in times of positive (r>0) and negative (r<0) policy interest rates (DFR) separately. The interest rate period is considered positive (negative) the period before (after) the monetary policy announcement in June 2014. The data are from the Euro Area Monetary Policy Event-Study Database by Altavilla et al. (2019b).

activities in response to low interest rates (Brei et al., 2019), this paper also analyzes the impact of banks' total and Tier 1 capital ratios. The additional daily stock price data cover the period from January 2000 to January 2020 and represent end-of-day index quotes; i.e., after the press conference ending at 15:30. In addition, similar to Ampudia and van den Heuvel (2018), announcements related to (Targeted) Longer-Term Refinancing Operations ((T)LTROs) are controlled for using binary data, equal to 1 on days of announcement and 0 otherwise. (T)LTROs provide banks with certainty over attractive funding, which enhances their performance relative to the broad market.[15]

3 Methodology

Rolling regression estimations are employed to analyze the effects of interest rate surprises on the bank stock index and individual bank stock prices in times of positive and negative interest rates. Using a rolling window allows for a quantification of how bank stock prices become affected over time as interest rates drop and turn negative. The estimations quantify the announcement effects of changes to the level and slope of the

[15] At the bank-level, the actual amount borrowed under the (T)LTROs is not controlled for, since this information is not made publicly available and thus does not influence bank stock prices during the monetary policy announcements.

yield curve, and check the persistence of these effects the days after the monetary policy decisions using local projections.

3.1 Effects on the bank stock index

To determine the effects on the bank stock index of a parallel shift and flattening of the shorter- and longer-end of the yield curve, rolling estimations are employed on the following baseline regression model:

$$
\begin{aligned}
\Delta SX7E_d = \alpha + \beta_1 \Delta Rate_d^{1m} + \beta_2 \Delta Slope_d^{5y-1m} + \beta_3 \Delta Slope_d^{10y-5y} + \beta_4 \Delta STOXX50_d \\
+ \beta_5 (T)LTRO_d + \epsilon_d
\end{aligned}
\tag{1}
$$

where $\Delta SX7E_d$ represents intraday movements in the log of the bank stock index, $\Delta Rate_d^{1m}$ indicates the 1-month OIS rate surprise, $\Delta Slope_d^{5y-1m}$ denotes the surprise to the difference between the German 5-year interest rate and 1-month OIS rate, $\Delta Slope_d^{10y-5y}$ represents the surprise to the difference between the German 10-year and 5-year interest rate, $\Delta STOXX50_d$ indicates intraday movements in the log of the broad stock market index, $(T)LTRO_d$ is a dummy variable that indicates Eurosystem announcements regarding (T)LTROs, ϵ_d is the error term, and the subscript d denotes one of the 269 days of monetary policy announcements between 1999 and 2020. In a separate robustness check, the first lag of the dependent variable is included on the right-hand side of the equation to evaluate potential concerns that the effects are dynamic (also using the other models of this paper).

The coefficient of the 1-month OIS rate surprise estimates the effect of a level surprise to the yield curve, since movements in the shorter- and longer-end slope of the yield curve are held constant (also in the other models of this paper). The intraday movements in the stock market indices and interest rates are in percentage and basis points, respectively. The estimations are done over fixed windows of 48 observations, such that the last window covers the maximum period from the introduction of the ECB's negative interest rate policy in June 2014 until the most recent available date in the sample. The window size thus maximizes the number of observations (therefore minimizing the potential for instability) over the negative interest rate period in the sample. The fixed windows move by 1 observation each time (also in the other rolling estimations of this paper). The size of the estimation window is changed in a separate robustness check (also using the other models of this paper). The estimated rolling coefficient of the variable controlling for broad stock market movements represents the equity-beta of bank stocks.

Two additional robustness checks are performed using model (1). First, for the period after August 2011, German interest rate surprises are substituted with OIS rate surprises, since these are considered a better proxy for identifying the risk-free yield curve. Second, the extent of asymmetry in the effects is analyzed, because stock market prices may react differently to positive versus negative surprises to the yield curve. For example, accommodative monetary policy surprises, associated with worsening economic conditions, may have larger signalling effects on investors' expectations than monetary policy tightening. To check for asymmetric effects, rolling estimations are performed using an augmented version of model (1):

$$\begin{aligned}\Delta SX7E_d = \alpha &+ \beta_{1,positive}(\Delta Rate_d^{1m} * Positive_d^{1m}) + \beta_{1,negative}(\Delta Rate_d^{1m} * Negative_d^{1m})\\ &+\beta_{2,positive}(\Delta Slope_d^{5y-1m} * Positive_d^{5y-1m}) + \beta_{2,negative}(\Delta Slope_d^{5y-1m} * Negative_d^{5y-1m})\\ &+\beta_{3,positive}(\Delta Slope_d^{10y-5y} * Positive_d^{10y-5y}) + \beta_{3,negative}(\Delta Slope_d^{10y-5y} * Negative_d^{10y-5y})\\ &+\beta_4 \Delta STOXX50_d + \beta_5 (T)LTRO_d + \epsilon_d\end{aligned} \tag{2}$$

where $positive_t^{1m}$, $positive_t^{5y-1m}$, $positive_t^{10y-5y}$ and $negative_t^{1m}$, $negative_t^{5y-1m}$, $negative_t^{10y-5y}$ represent dummies that respectively indicate whether the surprises are positive or negative. The rolling Z-test is used to test the significance of the difference between the coefficient estimates for positive and negative surprises.

To determine the persistence of the effects the days after the monetary policy announcements, rolling local projections are estimated using model (3):

$$\begin{aligned} SX7E_{t+h} - SX7E_{t-1} = \alpha_h + \beta_{1,h}\Delta Rate_t^{1m} + \beta_{2,h}\Delta Slope_t^{5y-1m} + \beta_{3,h}\Delta Slope_t^{10y-5y} \\ +\beta_{4,h}(STOXX50_{t+h} - STOXX50_{t-1}) + \beta_{5,h}(T)LTRO_t + \epsilon_{t+h} \end{aligned} \tag{3}$$

for $h = 1$ and 4, where $SX7E_{t+h} - SX7E_{t-1}$ and $STOXX50_{t+h} - STOXX50_{t-1}$ respectively indicate end-of-day changes in the log of the bank stock and broad stock market index, $Rate_t^{1m}$, $Slope_t^{5y-1m}$ and $Slope_t^{10y-5y}$ represent the interest rate surprises on the days of announcement and zero otherwise, and the subscripts t and h respectively denote the daily time period and forecast horizon. The local projections are based on Jordà (2005). The estimations are run over fixed windows of 1461 observations, such that the last window covers the maximum period from the introduction of the ECB's negative interest rate policy in June 2014 until the most recent available date in the sample. The forecast horizon length is changed in a separate robustness check (also using models (4) and (5) of this paper). The projections are local at each forecast horizon and accordingly account for changes in the broad stock market. This is central in identifying the effects of surprises to the yield curve on bank stock prices as a result of shrinking deposit margins, since interest rate changes also impact future discount rates and equity premiums, and generate endogenous signalling effects.

3.2 Effects on individual bank stock prices

The effects of surprises to the yield curve on the bank stock index may be driven by the largest banks, as the SX7E is capitalization-weighted. Moreover, unobserved differences between banks may influence the results. To determine the average effects of yield curve surprises on individual bank stock prices, rolling fixed effects panel local projections are performed using model (4):

$$Bank_{i,t+h} - Bank_{i,t-1} = \alpha_h + \beta_{1,h}\Delta Rate_t^{1m} + \beta_{2,h}\Delta Slope_t^{5y-1m} + \beta_{3,h}\Delta Slope_t^{10y-5y} + \beta_{4,h}(STOXX50_{t+h} - STOXX50_{t-1}) + \beta_{5,h}(T)LTRO_t + \mu_i + \epsilon_{i,t+h} \tag{4}$$

for $h = 0$, 1 and 4, where $Bank_{i,t+h} - Bank_{i,t-1}$ indicates end-of-day changes in the log of individual bank stock prices, μ_i represents bank fixed effects that capture unobserved differences between banks, and the subscript i denotes each one of the 24 banks captured by the SX7E presented in Table 1. The estimations are run over fixed windows of 1461 observations, such that the last window covers the maximum period from the introduction of the ECB's negative interest rate policy in June 2014 until the most recent available date in the sample.

The effects of yield curve surprises on bank stock prices may depend on banks' relative share of customer deposit funding. A change in the deposit margin likely has larger effects on the performance of banks relatively dependent on deposit funding. To account for this, rolling panel local projections are estimated using a model that includes interactions between the interest rate surprises and two dummies that respectively indicate whether a bank is relatively dependent or independent on deposit funding:

$$\begin{aligned} Bank_{i,t+h} - Bank_{i,t-1} = \alpha_h &+ \beta_{1,high,h}(\Delta Rate_t^{1m} * High_i) + \beta_{1,low,h}(\Delta Rate_t^{1m} * Low_i) \\ &+ \beta_{2,high,h}(\Delta Slope_t^{5y-1m} * High_i) + \beta_{2,low,h}(\Delta Slope_t^{5y-1m} * Low_i) \\ &+ \beta_{3,high,h}(\Delta Slope_t^{10y-5y} * High_i) + \beta_{3,low,h}(\Delta Slope_t^{10y-5y} * Low_i) \\ &+ \beta_{4,h}(STOXX50_{t+h} - STOXX50_{t-1}) + \beta_{5,h}(T)LTRO_t + \mu_i + \epsilon_{i,t+h} \end{aligned} \tag{5}$$

for $h = 0$, 1 and 4, and where $High_i$ and Low_i represent dummies that respectively indicate whether, during 2014 and 2019, the average ratio of customer deposits to assets of bank i is higher or lower than the time-invariant sample median. Again, the estimations are run over fixed windows of 1461 observations, such that the last window covers the maximum period from the introduction of the ECB's negative interest rate policy in June 2014 until the most recent available date in the sample. The two dummies in model (5) are also substituted with dummies that respectively indicate whether a bank is relatively capitalized or not (looking at both total and Tier 1 capital ratios). However, the results show that in times of negative interest rates, the effects on stock prices of relatively capitalized and undercapitalized banks are not significantly different from each other (available upon request).

4 Results

This section presents the main results.

4.1 Effects on the bank stock index

Figures 7 and 8 present estimations for model (1), rolled over fixed windows of 48 observations. The dotted lines represent the 90% confidence interval (also in the remainder of this study). Newey-West standard errors robust to heteroscedasticity and autocorrelation up to the third lag are used.

The results suggest that in a positive interest rate environment, a level surprise to the yield curve does not impact the bank stock index when movements in the broad stock market are held constant (Figure 7, Panel A). Investors thus do not foresee that banks face a disadvantage compared to the broad stock market following a surprise to the level of the yield curve in times of positive interest rates. Bank stock index movements are then solely associated with broader stock market movements; Figure 8 shows the estimated rolling coefficient of the broad stock market index is highly significant over the entire sample period. However, a level surprise starts to significantly impact the bank stock index once the low interest rate environment enters the sample period. During the period of low but positive interest rates, a parallel 10 basis points drop in the yield curve

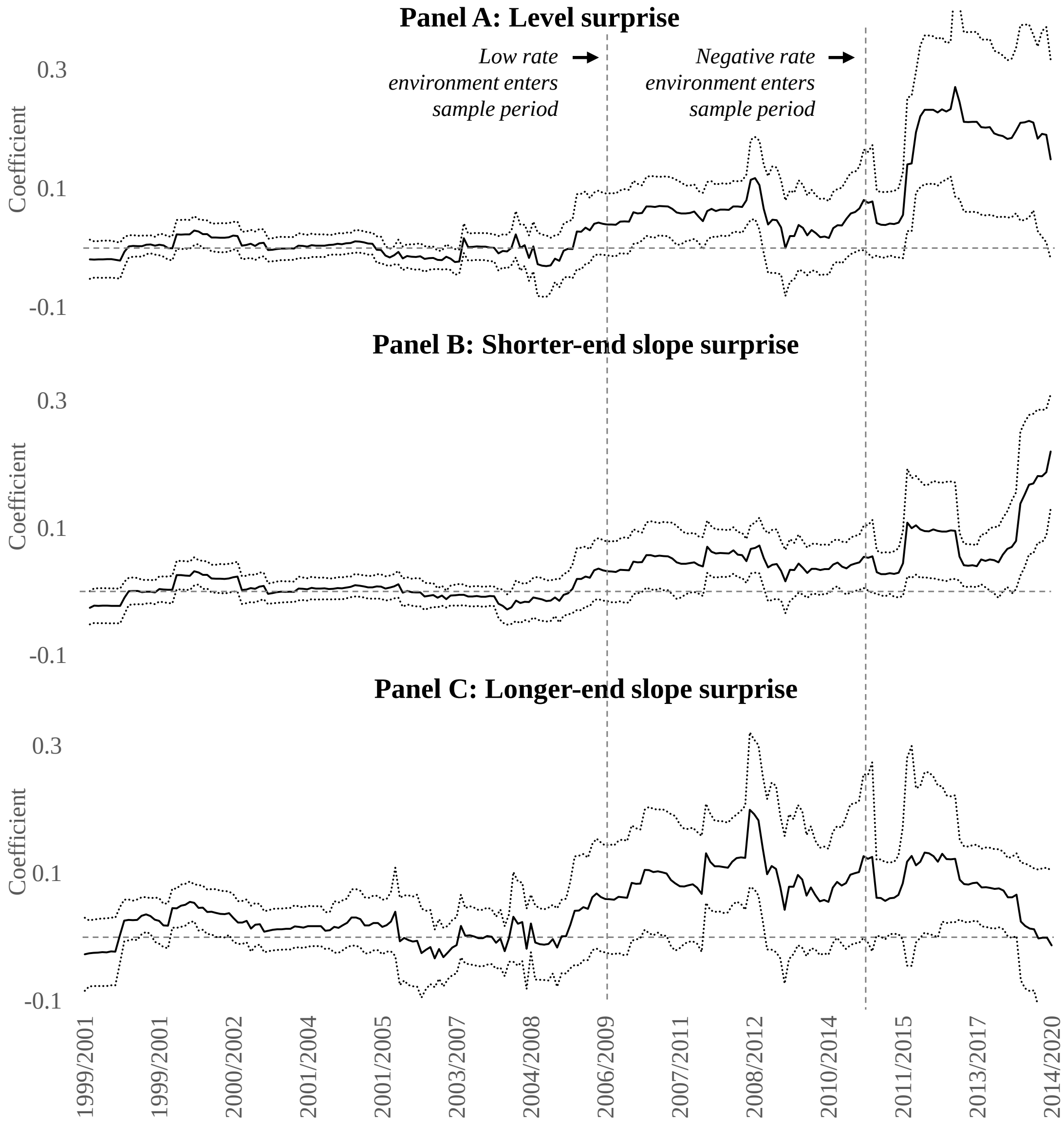

Figure 7: Effects of yield curve surprises on the bank stock index at announcement

Notes: This figure shows the rolling estimations for model (1). The estimations are run over fixed windows of 48 observations, such that the last window covers the maximum period from the introduction of the ECB's negative interest rate policy in June 2014 until the most recent available date in the sample. As monetary Eurosystem meetings occur less frequently over time, the fixed window period widens. The dependent variable measures intraday movements in the log of the bank stock index (SX7E). Panel A shows the rolling effect of a level surprise to the yield curve. Panel B shows the rolling effect of a surprise to the difference between the 5-year and 1-month rate. Panel C shows the rolling effect of a surprise to the difference between the 10- and 5-year rate. Intraday movements in the log of the broad stock market index (STOXX50) and (T)LTRO announcements are controlled for. The dotted lines represent the 90% confidence interval using Newey-West standard errors robust to heteroscedasticity and autocorrelation up to the third lag.

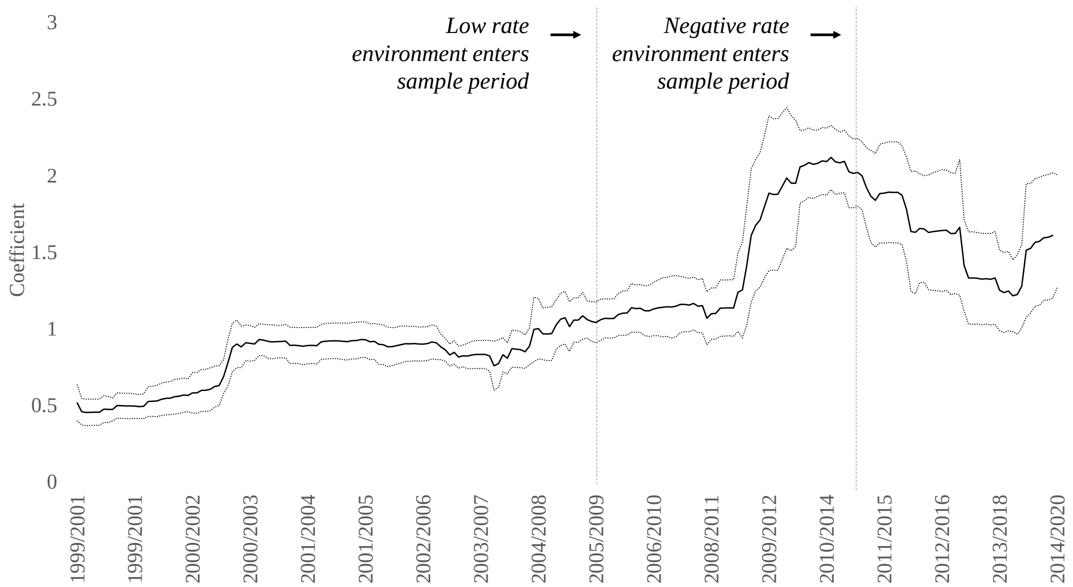

Figure 8: Effect of the broad stock market on the bank stock index at announcement
Notes: This figure shows the rolling effect of the broad stock market index on the bank stock index, as estimated by model (1). See also the notes to Figure 7.

decreases the bank stock index by around 0.5 percentage points. The magnitude of this effect increases as the interest rate environment turns negative. By the end of the sample period, a parallel 10 basis points drop in the yield curve decreases the bank stock index by around 2 percentage points. The effect becomes statistically significant after the low interest rate environment enters the sample period.

A broadly similar pattern is identified looking at the rolling effect on the bank stock index of an unanticipated change to the 1-month to 5-year slope of the yield curve (Figure 7, Panel B). This shorter-end slope surprise has no effect on the bank stock index in times of positive interest rates, but significantly impacts the bank stock index during periods of low and especially negative interest rates, while accounting for banks' equity-beta. Relative to the 1-month rate, a 10 basis points drop in the 5-year rate decreases the bank stock index by around 0.5 percentage points in the environment of low but positive interest rates. Once the rate environments turns negative, a negative shorter-end slope surprise of 10 basis points decreases the bank stock index by around 2 percentage points. This effect is statistically significant in the low and negative interest rate environment

By contrast, the rolling effect on the bank stock index of a surprise to the slope of the longer-end of the yield curve follows a different pattern (Figure 7, Panel C). While controlling for broad stock market movements, a slope surprise to the 5- to 10-year yield curve affects the bank stock index when the interest rate environment is low but positive. Relative to the 5-year rate, a drop in the 10-year rate of 10 basis points decreases the bank stock index by around 1 percentage point, statistically significant in the estimation windows covering 2007 to 2012. However, when the interest rate environment turns negative by the end of the sample period, the effect on the bank stock index of a slope surprise to the longer-end of the yield disappears both economically and statistically.

As a robustness check, Figure 9 presents rolling estimations for model (1), substituting the German government bond rates with longer-term OIS rates for the period after August 2011. The results confirm that the effects of a level and shorter-end slope surprise on the bank stock index are significant in times of negative interest rates. In the last estimation windows, either a 10 basis points drop in the level or flattening of the shorter-end slope of the yield curve significantly reduces bank stock prices by around 2 percentage points (Figure 9, Panel A and Panel B). By contrast, longer-end slope surprises are not found to significantly impact the bank stock index in the later estimation windows (Figure 9, Panel C).

To check for asymmetry in the effects of the baseline estimation, Figure 10 presents rolling estimations using model (2). The p-values of the rolling Z-test for the significance of the difference between the coefficient estimates for positive and negative surprises are displayed in Figure 11. The results indicate that the pattern of the rolling effects of a level and shorter-end slope surprise look relatively similar for positive and negative surprises. Both a positive and negative surprise to the level and shorter-end slope of

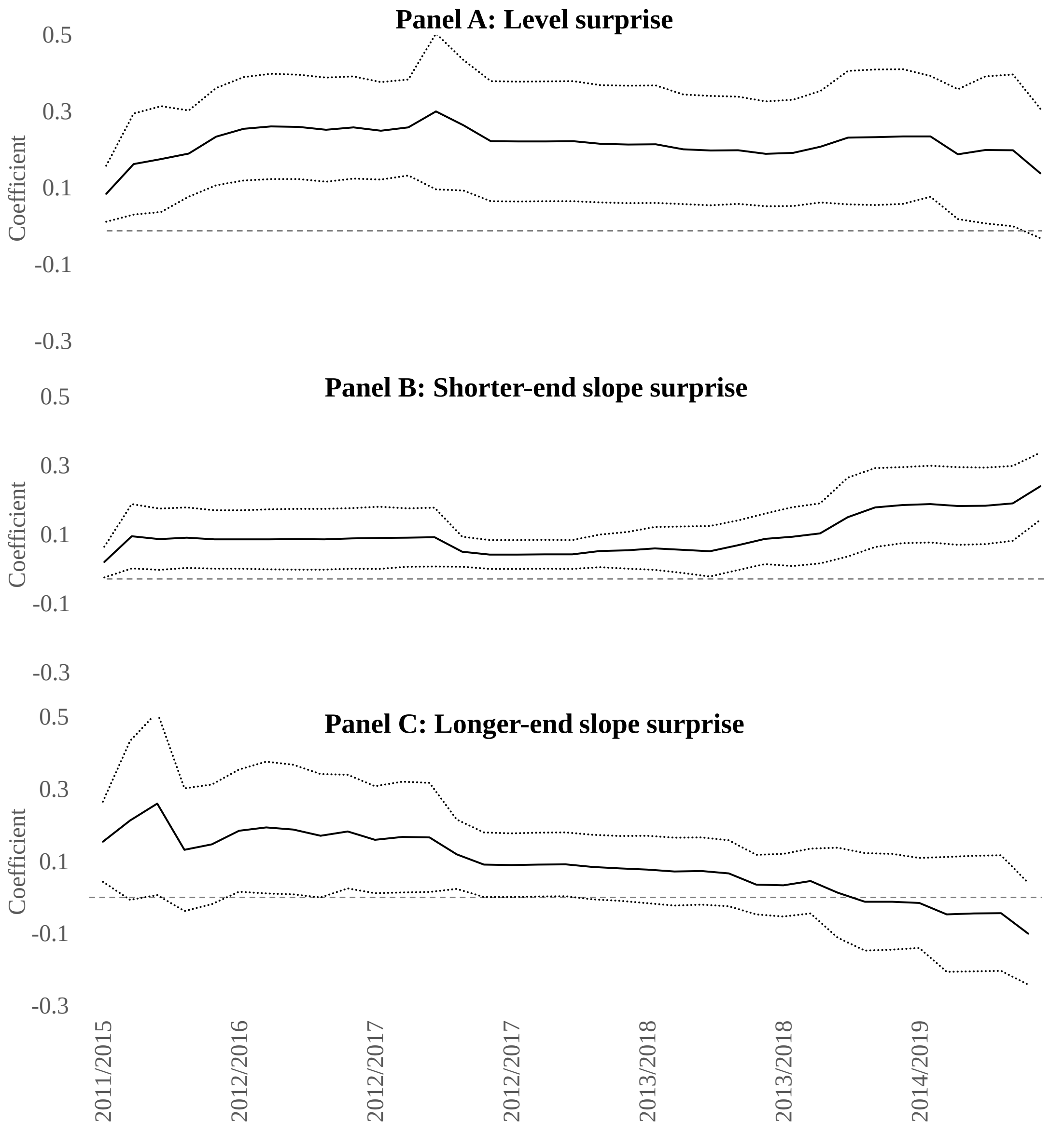

Figure 9: Effects of OIS yield curve surprises on the bank stock index at announcement

Notes: This figure shows the rolling estimations for model (1), substituting the German government bond rates with longer-term OIS rates. See also the notes to Figure 7.

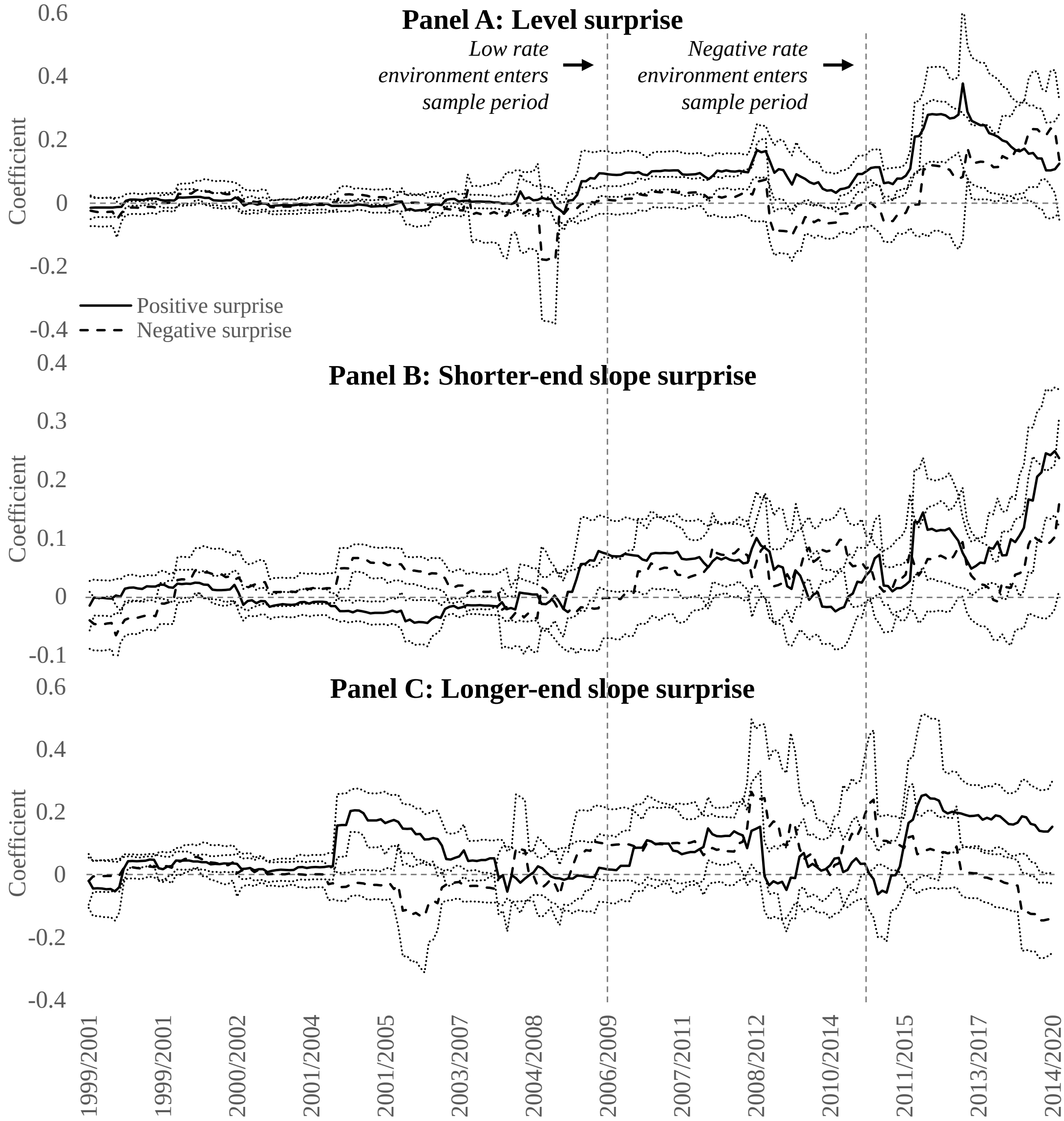

Figure 10: Asymmetric effects of yield curve surprises on bank stocks at announcement

Notes: This figure shows the rolling estimations for model (2). Panel A shows the rolling effect of a positive ($\beta_{1,positive}$) and negative ($\beta_{1,negative}$) level surprise to the yield curve. Panel B shows the rolling effect of a positive ($\beta_{1,positive}$) and negative ($\beta_{1,negative}$) surprise to the difference between the 5-year and 1-month rate. Panel C shows the rolling effect of a positive ($\beta_{1,positive}$) and negative ($\beta_{1,negative}$) surprise to the difference between the 10- and 5-year rate. See also the notes to Figure 7.

the yield curve have relatively similar significant effects on bank stock prices once the interest rate environment turns negative (Figure 10, Panel A and Panel B). Figure 11 shows that these effects are not statistically different from each other in times of negative

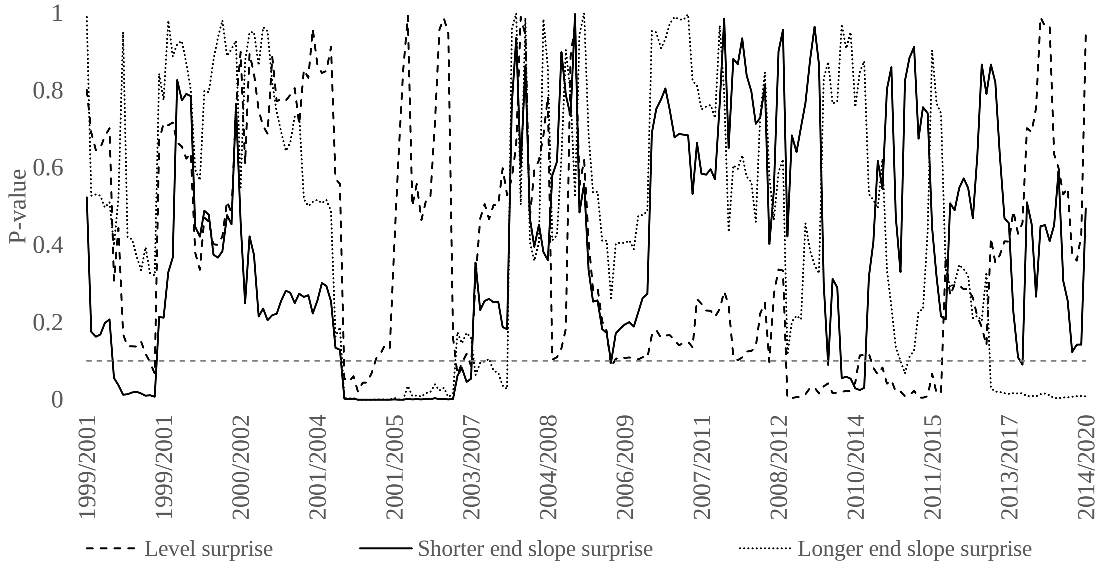

Figure 11: Statistical difference between positive and negative surprises

Notes: This figure shows the rolling p-values of the Z-test for the significance of asymmetry in the effects of model (2). 'Level surprise' represents the rolling test outcome for $H_0 : \beta_{1,positive} = \beta_{1,negative}$. 'shorter-end slope surprise' represents the rolling test outcome for $H_0 : \beta_{2,positive} = \beta_{2,negative}$. 'longer-end slope surprise' represents the rolling test outcome for $H_0 : \beta_{3,positive} = \beta_{3,negative}$. The dashed horizontal line represents the 10% significance level. See also the notes to Figure 7.

interest rates. This is in line with the results of Altavilla et al. (2019b) who find no evidence for asymmetric responses of European financial market variables to positive and negative surprises. However, when the interest rate environment is negative, asymmetry is observed in the effects of longer-end slope surprises on the bank stock index. While negative surprises have no significant effects, the bank stock index reacts significantly to a positive longer-end slope surprise (Figure 10, Panel C). The difference between these two effects is statistically significant in times of negative interest rates (Figure 11). This result again indicates that a flattening of the longer-end slope of the yield curve does not influence bank stock prices when interest rates are negative.

To check the persistence of the effects on the bank stock index, Figures 12 and 13 present local projections using model (3), showing the cumulative effects when the forecast horizon is 1 and 4 days, respectively. The estimations are run over fixed windows of 1461 observations. Together with the effects at announcement, the estimations analyze the persistence of the effects over an entire working week. Newey-West standard errors robust to heteroscedasticity and autocorrelation up to the ninth lag are used. The results suggest that in a negative interest rate environment, the effects on the bank stock index of a surprise to the level and shorter-end slope of the yield curve are persistent. When the interest rate environment is low but positive, the effects are not persistent.

On the first day after the announcement, the effects of a level and shorter-end slope surprise on the bank stock index are economically and statistically significant during the negative interest rate period (Figure 12, Panel A). When the interest rate environment is negative, a parallel downward yield curve shift of 10 basis points significantly decreases the bank stock index by more than 2 percentage points the next day. In times of low but positive interest rates, the effect of a level surprise on the bank stock index is insignificant the day after the announcement. Similarly, the first day after the announcement, a 10 basis points drop in the 5-year rate relative to the 1-month rate decreases the bank stock index by 2.5 percentage points when the rate environment is negative (Figure 12, Panel B). This effect is significant at the 1% level in the last estimation windows. In a low but positive interest rate environment, the effect of a longer end slope surprise is also found to significantly persist the first day after the announcement, but this effect disappears and becomes insignificant once interest rates turn negative (Figure 12, Panel C).

While reversing to some degree, the effects of a level and shorter-end slope surprise on the bank stock index persist the fourth day after the announcement in a negative interest rate environment. When the interest rate environment is negative, a parallel downward yield curve shift of 10 basis points decreases the bank stock index by around 1 percentage point the fourth day after the announcement. This is about half the size of the announcement effect. At the 10% level, these local projections are only significant in a few estimation windows however (Figure 13, Panel A). In times of low but positive interest rates, the effect of a level surprise remains insignificant. The effect of a shorter-end slope surprise on the bank stock index is significantly positive the fourth day after

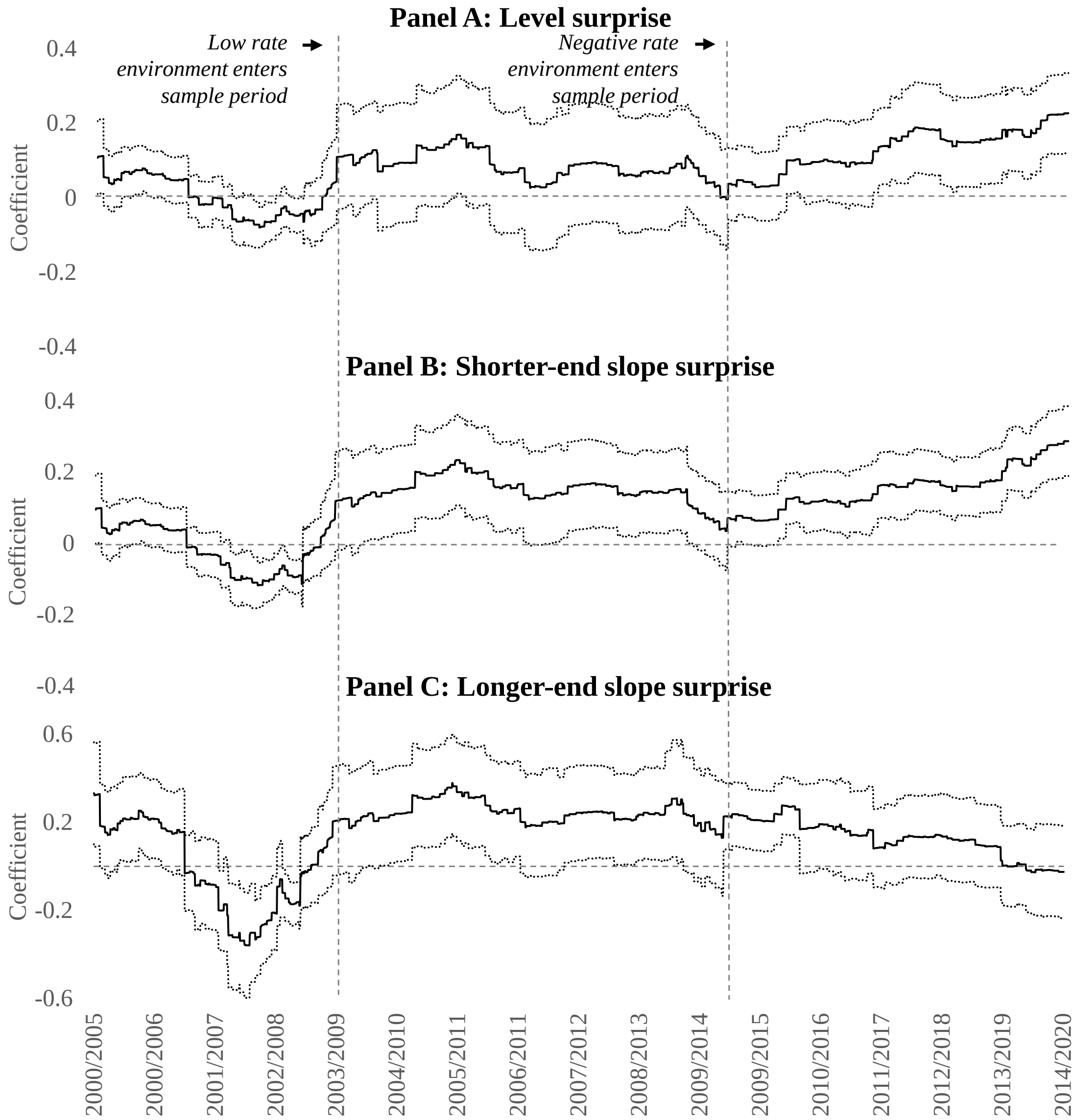

Figure 12: Cumulative effects on the bank stock index 1 day after announcement

Notes: This figure shows the rolling local projections for model (3) when the forecast horizon is 1 day. The estimations are run over fixed windows of 1461 observations, such that the last window covers the maximum period from the introduction of the ECB's negative interest rate policy in June 2014 until the most recent available date in the sample. The dependent variable measures end-of-day movements in the log of the bank stock index (SX7E). End-of-day movements in the log of the broad stock market index (STOXX50) and (T)LTRO announcements are controlled for. The dotted lines represent the 90% confidence interval using Newey-West standard errors robust to heteroscedasticity and autocorrelation up to the ninth lag. See also the notes to Figure 7.

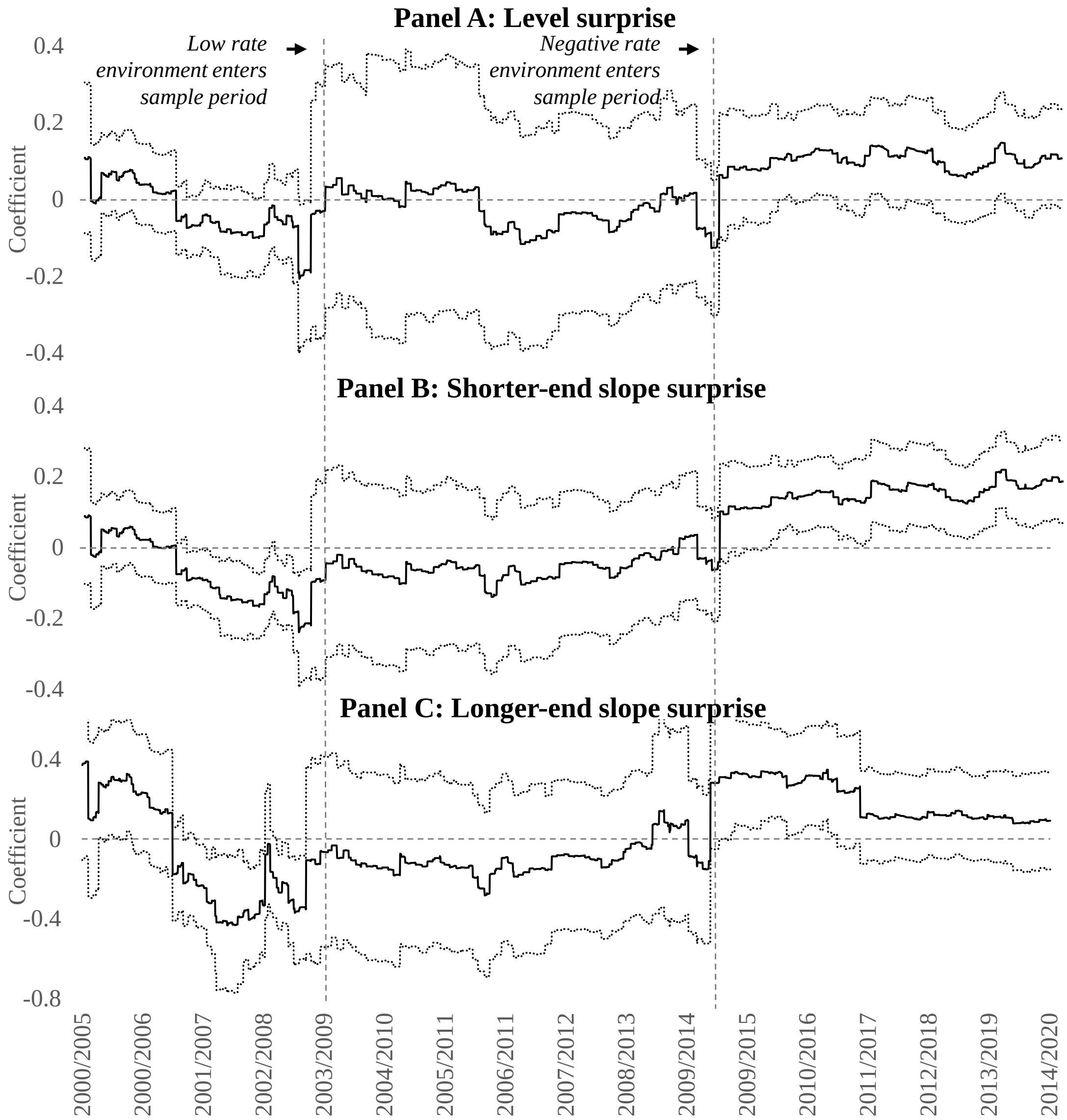

Figure 13: Cumulative effects on the bank stock index 4 days after announcement

Notes: This figure shows the rolling local projections for model (3) when the forecast horizon is 4 days. See also the notes to Figure 12.

the announcement in all estimation windows during the negative interest rate period. Economically, the bank stock index remains 2 percentage points lower the fourth day after a 10 basis points drop in the 5-year rate relative to the 1-month rate (Figure 13, Panel B). By contrast, the fourth day after the announcement in a low but positive interest rate environment, a shorter-end slope surprise no longer affects the bank stock index. Similar to previous estimations, the effect of a longer-end slope surprise on the bank stock index remains insignificant the fourth day after the announcement (Figure 13, Panel C). Also, substituting the German government bond rates with longer-term OIS rates does not change the persistence of the effects (available upon request).

4.2 Effects on individual bank stock prices

As the bank stock index is capitalization-weighted, the previous results may be driven by the largest banks. Moreover, unobserved differences between banks may drive the results. To analyze the average effects of yield curve surprises on individual bank stock prices, Figures 14, 15 and 16 present the rolling panel local projections using model (4) with bank fixed effects. The figures show the cumulative effects when the forecast horizon is 0, 1 and 4 days, respectively. The estimations are run over fixed windows of 1461 observations. Robust standard errors clustered at the bank-level are used.

The results indicate that at announcement, a surprise to the level, shorter-end slope and longer-end slope of the yield curve significantly affects bank stock prices once the low interest rate environment enters the sample period. In times of negative interest rates, the effects of the level and shorter-end slope surprise remain statistically significant, while the effect of a longer-end slope surprise turns insignificant in the last estimation windows.[16] A parallel 10 basis points drop in the yield curve decreases bank stock prices by around 1.5 percentage points in both a low but positive and negative interest rate environment (Figure 14, Panel A). Relative to the 1-month rate, a 10 basis points

[16]The bank fixed effects are significantly different from zero in almost all estimation windows (also in the remainder of this paper).

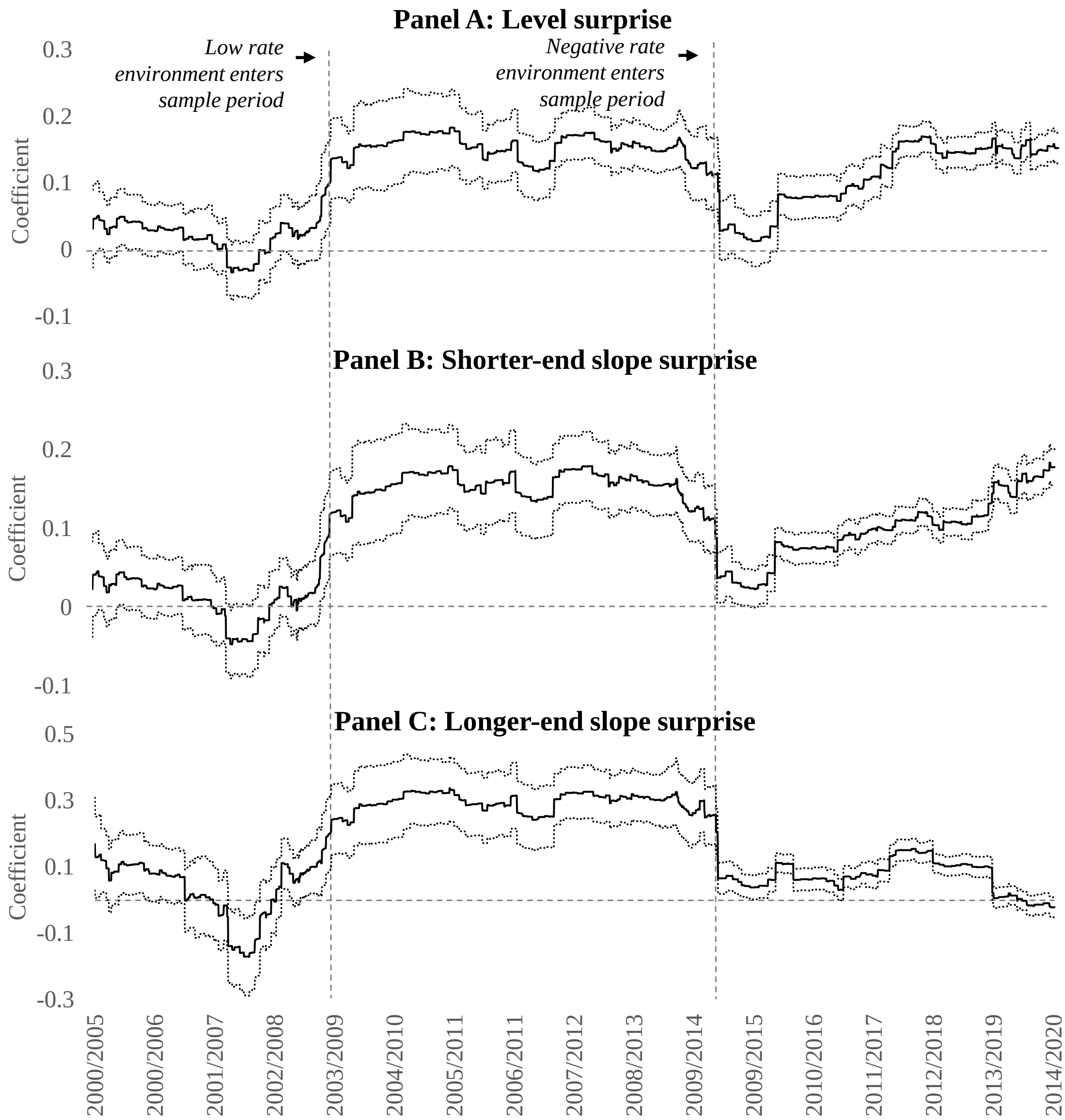

Figure 14: Effects of yield curve surprises on bank stocks at announcement

Notes: This figure shows the rolling panel estimations for model (4) on the day of the monetary policy announcement. The dotted lines represent the 90% confidence interval using robust standard errors clustered at the bank-level. See also the notes to Figure 12.

drop in the 5-year rate also decreases bank stock prices by around 1.5 percentage points in the low but positive and negative interest rate environment (Figure 14, Panel B). Relative to the 5-year rate, a 10 basis points drop in the 10-year rate decreases bank stock prices by around 3 percentage points in times of low but positive interest rates (Figure 14, Panel C). However, as the interest rate environment becomes negative, the effect of a longer-end slope surprise on bank stock prices decreases and eventually turns insignificant.

Turning to the 1- and 4-day forecasts, the results show the effects of a level and shorter-end slope surprise on individual bank stock prices are persistent when the interest rate environment is negative. In times of low but positive interest rates, individual bank stock prices also react significantly to a level and slope surprise the day after the announcement. However, the significance of these effects disappears the fourth day after the monetary policy decision took place. This suggests the effects of a level and slope surprise on bank stock prices are not persistent when interest rates are low but still positive. When the interest rate environment is negative, bank stock prices remain 1.5 percentage points lower the first and fourth day after a parallel downward yield curve shift of 10 basis points (Figure 15 and Figure 16, Panel A). Similarly, in the last estimation windows when the interest rate environment is negative, individual bank stock prices remain 2 to 3 percentage points lower on the first and fourth day after a 10 basis points drop in the 5-year rate relative to the 1-month rate (Figure 15 and Figure 16, Panel B). These local projections are significant in all estimation windows after the negative interest rate environment enters the sample period. While bank stock prices also react significantly to longer-end slope surprises the first day after the announcement in a low but positive interest rate environment, this effect turns insignificant on the fourth day (Figure 15 and 16, Panel C). In the estimation windows that include the start of the negative interest rate environment, a significant effect is observed the fourth day after a longer-end slope surprise, but this effect decreases both economically and statistically

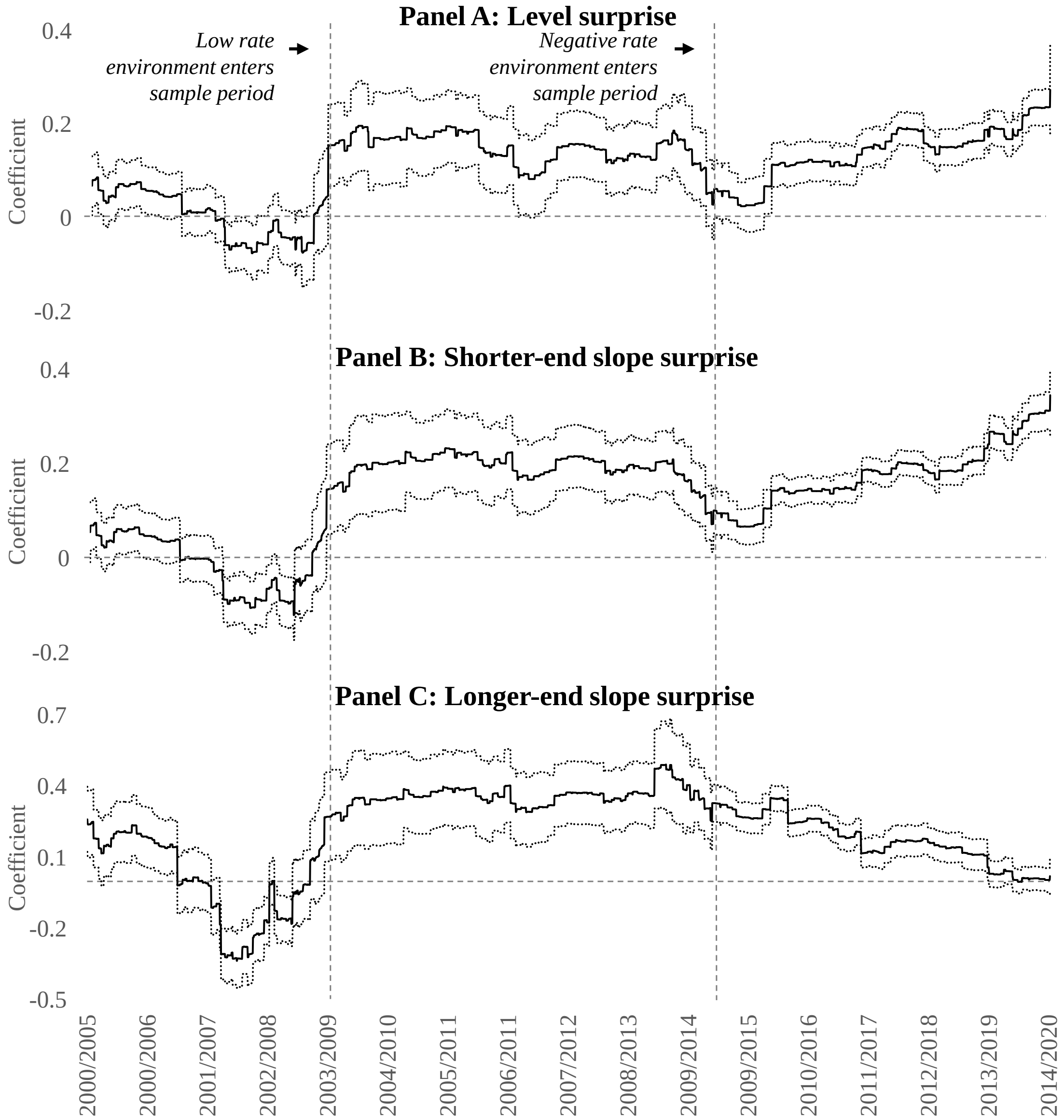

Figure 15: Cumulative effects on bank stocks 1 day after announcement

Notes: This figure shows the rolling panel local projections for model (4) when the forecast horizon is 1 day. See also the notes to Figure 14.

as the interest rate environment turns more negative.

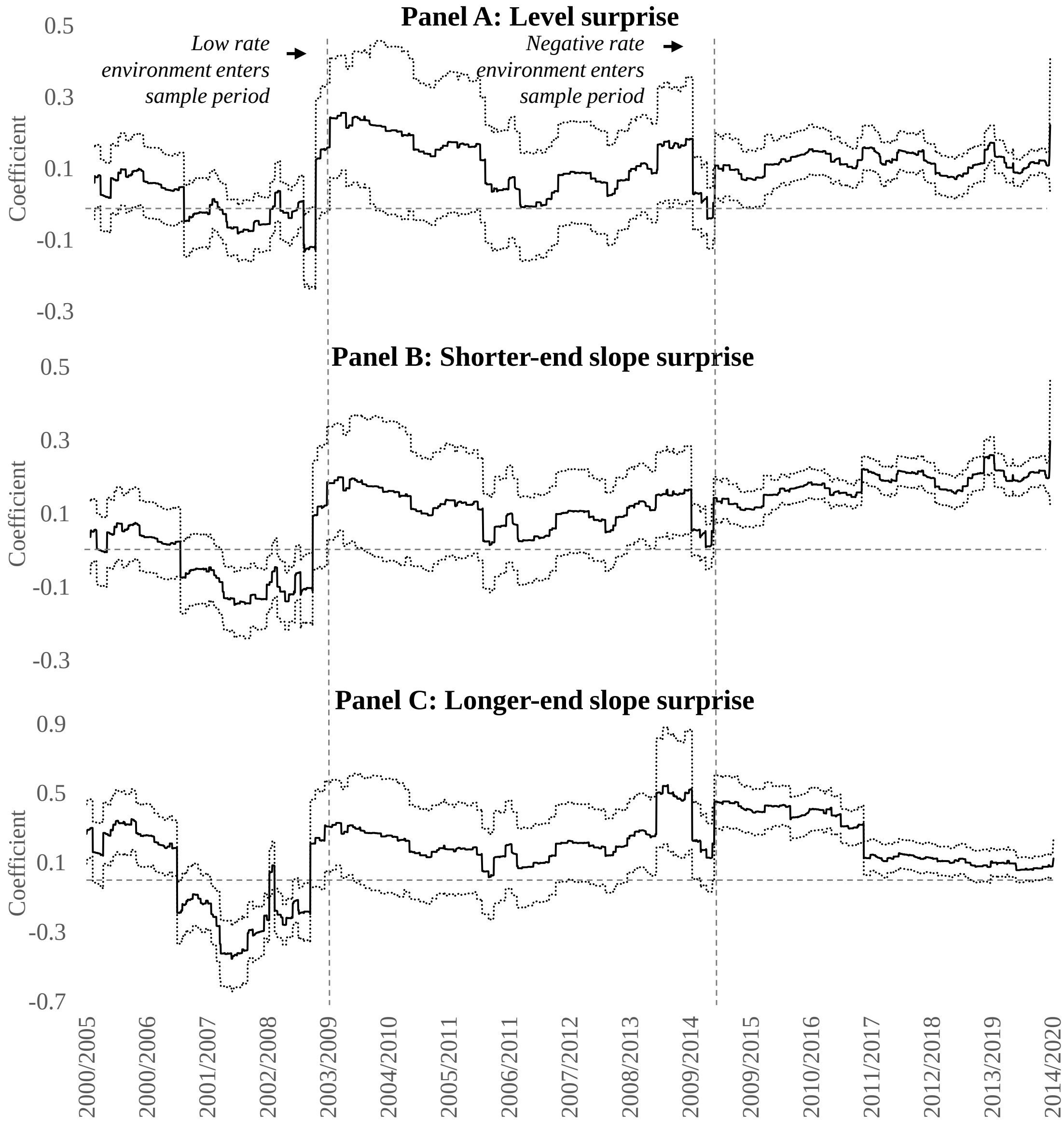

Figure 16: Cumulative effects on bank stocks 4 days after announcement

Notes: This figure shows the rolling panel local projections for model (4) when the forecast horizon is 4 days. See also the notes to Figure 14.

4.3 Effects on stock prices of banks relatively dependent on deposits

In times of low and negative interest rates, yield curve surprises are expected to have larger effects on stock prices of banks that are relatively dependent on deposit funding. This is because the performance of these banks is likely to be more affected by changes to the deposit margin than the performance of banks with a relatively small share of deposit funding. To analyze differences between the effects of yield curve surprises on stock prices of banks relatively dependent and independent on deposit funding, Figures 17, 18 and 19 display the rolling panel local projections using model (5). The figures show the cumulative effects when the forecast horizon is 0, 1 and 4 days, respectively. The estimations are run over fixed windows of 1461 observations. Robust standard errors clustered at the bank-level are used. The significance of the difference between the coefficient estimates for banks relatively dependent and independent on deposit funding is tested using a rolling Z-test.

The results indicate that in times of negative interest rates, the effects on stock prices of a level and shorter-end slope surprise are larger for banks relatively dependent on deposit funding. In times of negative interest rates, a 10 basis points parallel shift in the yield curve and flattening of the shorter-end of the yield curve reduce stock prices of deposit-dependent banks by around 2 percentage points (Figure 17, Panel A and Panel B). Stock prices of banks relatively independent on deposit funding only drop by around 1.5 percentage points in times of negative interest rates. These effects are statistically significant. By contrast, longer-end slope surprises are not found to have different effects on the two types of banks' stock prices in a negative interest rate environment. Relative to the 5-year rate, a 10 basis points drop in the 10-year rate does not have a larger effect on stock prices of banks relatively dependent on deposit funding in times of negative interest rates (Figure 17, Panel C). During those times, the effects of longer-end slope surprises on bank stock prices are insignificant for both deposit-dependent and deposit-independent banks. When interest rates are low but positive, the effects of the yield

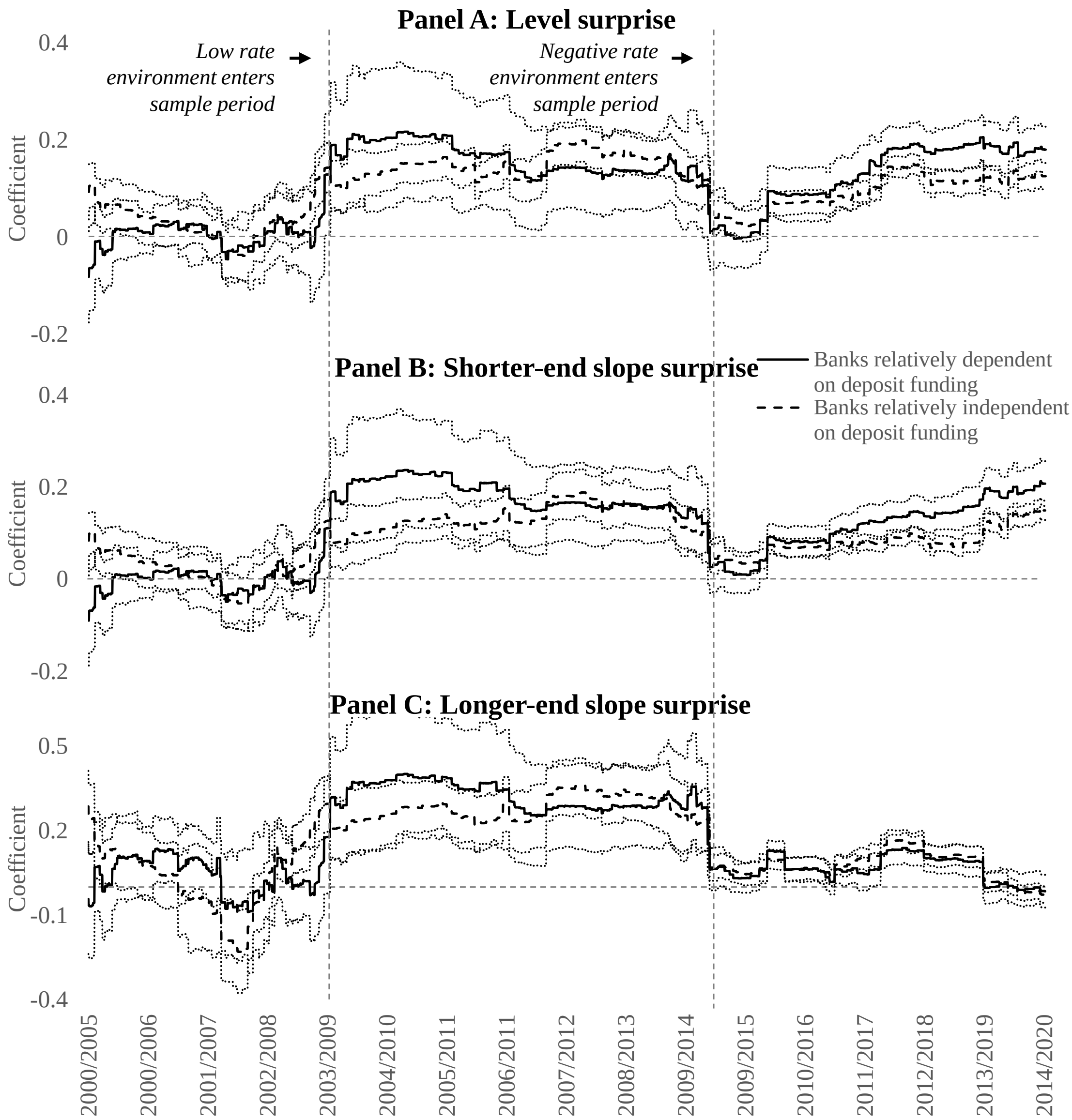

Figure 17: Effects of yield curve surprises on bank stocks at announcement

Notes: This figure shows the rolling panel estimations for model (5) on the day of the monetary policy announcement. The dependent variable measures end-of-day movements in the log of individual bank stocks. Panel A shows the rolling effect of a level surprise to the yield curve for banks relatively dependent ($\beta_{1,high,0}$) and independent ($\beta_{1,low,0}$) on deposit funding. Panel B shows the rolling effect of a surprise to the difference between the 5-year and 1-month rate for banks relatively dependent ($\beta_{2,high,0}$) and independent ($\beta_{2,low,0}$) on deposit funding. Panel C shows the rolling effect of a surprise to the difference between the 10- and 5-year rate for banks relatively dependent ($\beta_{3,high,0}$) and independent ($\beta_{3,low,0}$) on deposit funding. End-of-day movements in the log of the broad stock market index, (T)LTRO announcements and bank fixed effects are controlled for. The dotted lines represent the 90% confidence interval using robust standard errors clustered at the bank-level.

curve surprises are relatively similar for banks dependent and independent on deposit funding. Stock prices of deposit-dependent and -independent banks fall by around 1.5 to 2 percentage points in response to a 10 basis points parallel drop in the yield curve and flattening of the shorter-end of the yield curve. A downward longer-end slope surprise of 10 basis points reduces stock prices of banks relatively dependent and independent on deposit funding by around 3 percentage points. These effects are statistically significant.

Figures 18 and 19 show that the effects of a level and shorter-end slope surprise on stock prices of banks relatively dependent on deposit funding are persistent, especially in times of negative interest rates. The first and fourth day after a parallel yield curve shift of 10 basis points in a low but positive and negative interest rate environment, stock prices of banks relatively dependent on deposit funding are lower by 2 to 3 and 2 to 5 percentage points, respectively (Figures 18 and 19, Panel A). The first and fourth day after a 10 basis points drop in the 5-year rate relative to the 1-month rate, stock prices of banks relatively dependent on deposit funding are lower by 2 to 4 percentage points (Figure 18 and Figure 19, Panel B). These local projections are statistically significant when the negative interest rate environment enters the sample. During the period of low but positive interest rates, these effects are only significant in some of the estimation windows. Similarly, the effect of a longer-end slope surprise on stock prices of bank relatively dependent on deposit funding persists the first and fourth day after the announcement in a low but positive rate environment. However, these effects diminish as the negative interest rate environment enters the sample period. The first and fourth day after a 10 basis points drop in the 10-year rate relative to the 1-month rate, stock prices of banks relatively dependent on deposit funding are 1 percentage point lower in the last estimation windows (Figure 18 and Figure 19, Panel C). These estimations are significant in most of the last estimation windows.

When analyzing the stock prices of banks relatively independent on deposit funding, the local projections look different. The effect of a level surprise on stock prices of

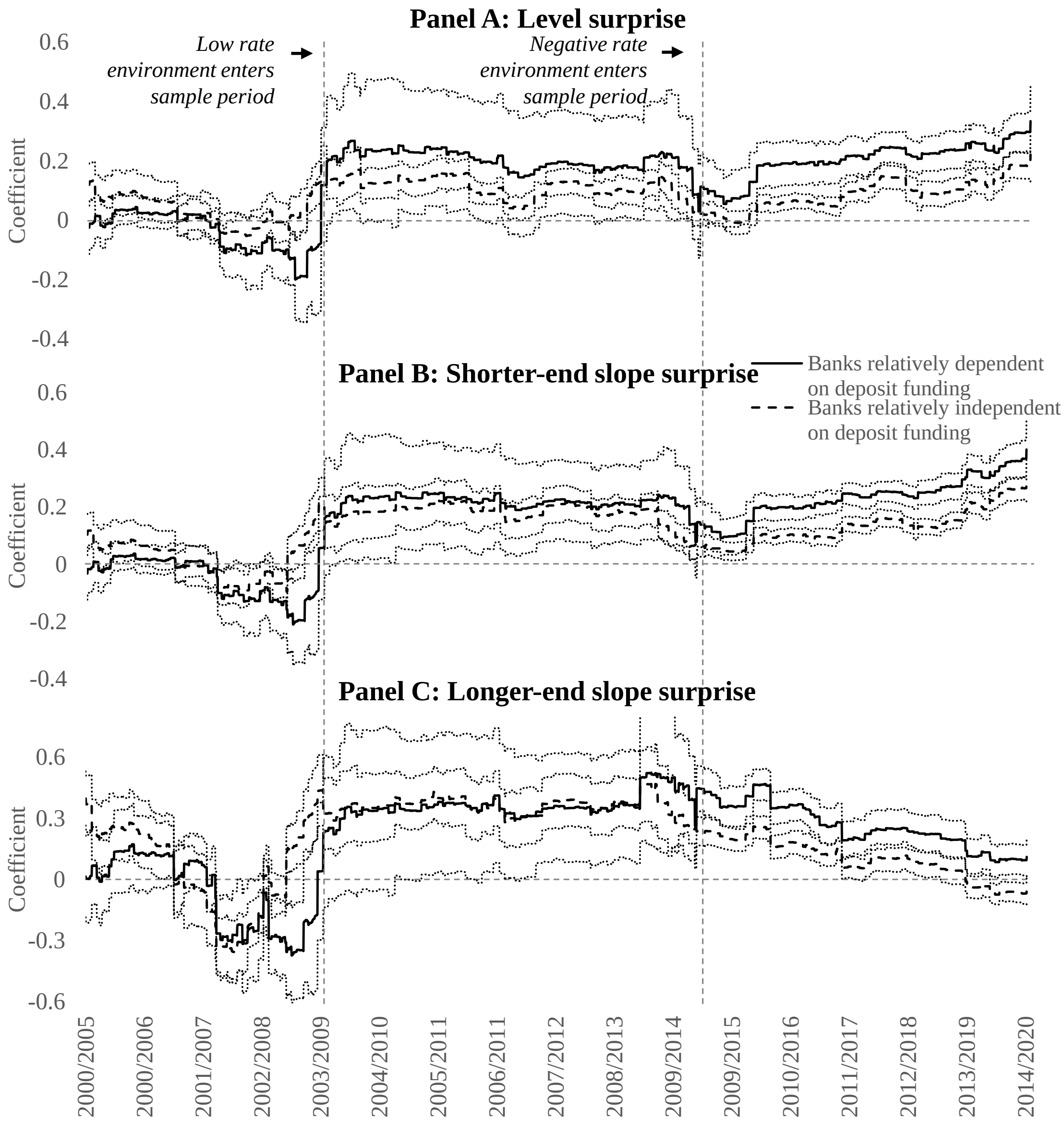

Figure 18: Cumulative effects on bank stocks 1 day after announcement

Notes: This figure shows the rolling panel local projections for model (5) when the forecast horizon is 1 day. See also the notes to Figure 17.

deposit-independent banks persists the first day after the announcement, but reverses the fourth day after the announcement. The effect of shorter- and longer-end slope surprises on stock prices of banks relatively independent on deposit funding also disappear the fourth day after the announcement in the low but positive interest rate environment. However, the effect of shorter-end slope surprises persists the fourth day when the interest rate environment is negative. The fourth day after a 10 basis points drop in the 5-year rate relative to the 1-month rate, stock prices of banks relatively independent on deposit funding remain 1 percentage point lower in the last estimation windows (Figure 19, Panel B). This effect is statistically significant.

Figure 20 shows the p-values of the rolling Z-test for the significance of the difference between the coefficient estimates for banks relatively dependent and independent on deposit funding. The forecast horizon is 0 days in Panel A, 1 day in Panel B and 4 days in Panel C. The horizontal dashed line represents the 10% significance level. The results show that in case of level and shorter-end slope surprises in times of negative interest rates, the effects on stock prices of deposit-dependent and -independent banks are statistically different from each other for all forecast horizons. At announcement, the effects of longer-end slope surprises are not statistically different from each other. However, the first and fourth day after the announcement banks relatively dependent on deposit funding also respond significantly different to longer-end slope surprises.

4.4 Other robustness checks

Several other robustness checks are performed (all available upon request). First, all models are augmented with the first lag of the dependent variable on the right-hand side of the equation to address potential concerns that the relationship is dynamic. The estimated coefficients of the lagged dependent variable are close to zero. The results remain similar, both statistically and economically. This is in line with the view that stock prices are forward-looking, reflecting the market valuation of equity based on the

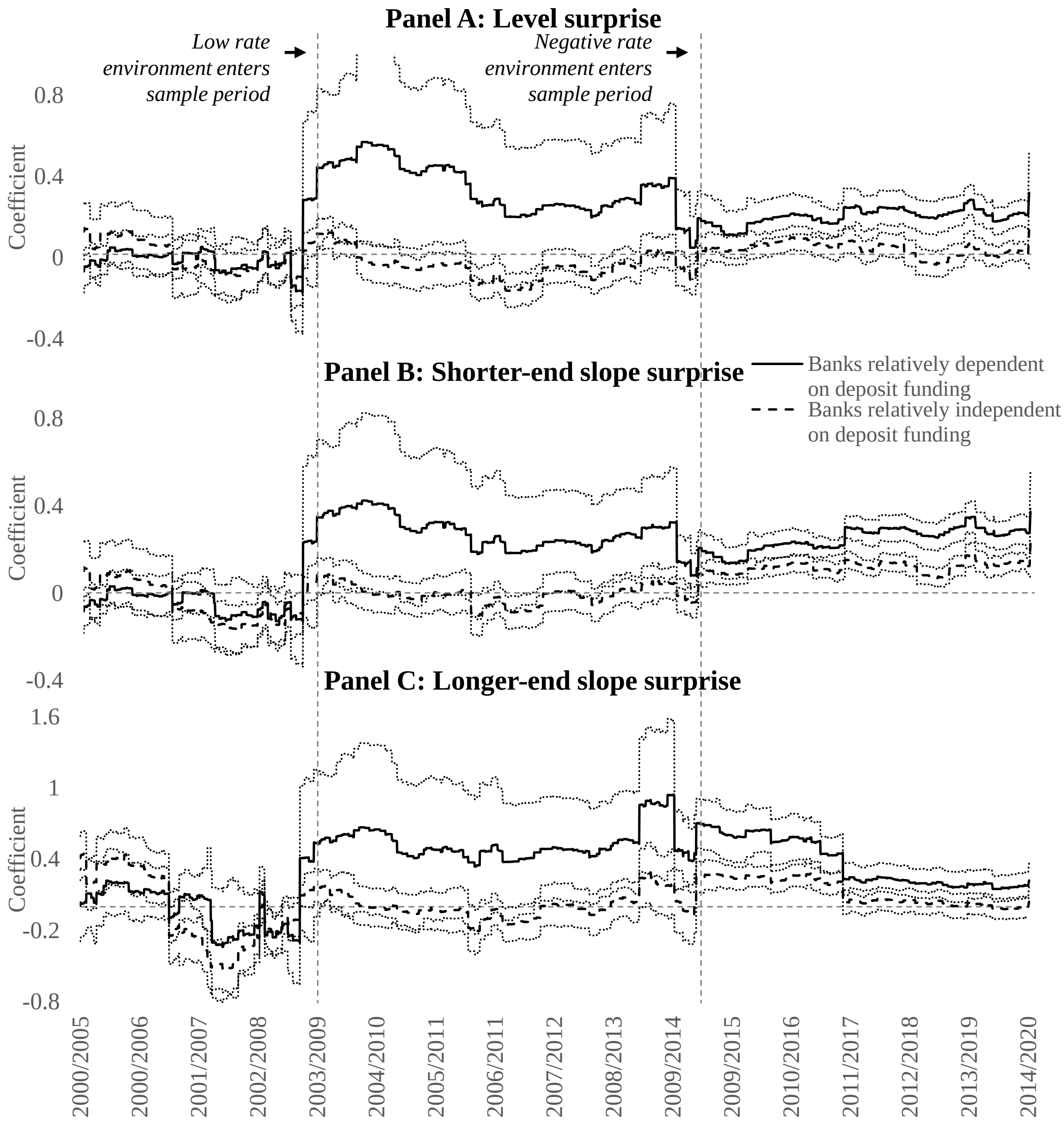

Figure 19: Cumulative effects on bank stocks 4 days after announcement

Notes: This figure shows the rolling panel local projections for model (5) when the forecast horizon is 4 days. See also the notes to Figure 17.

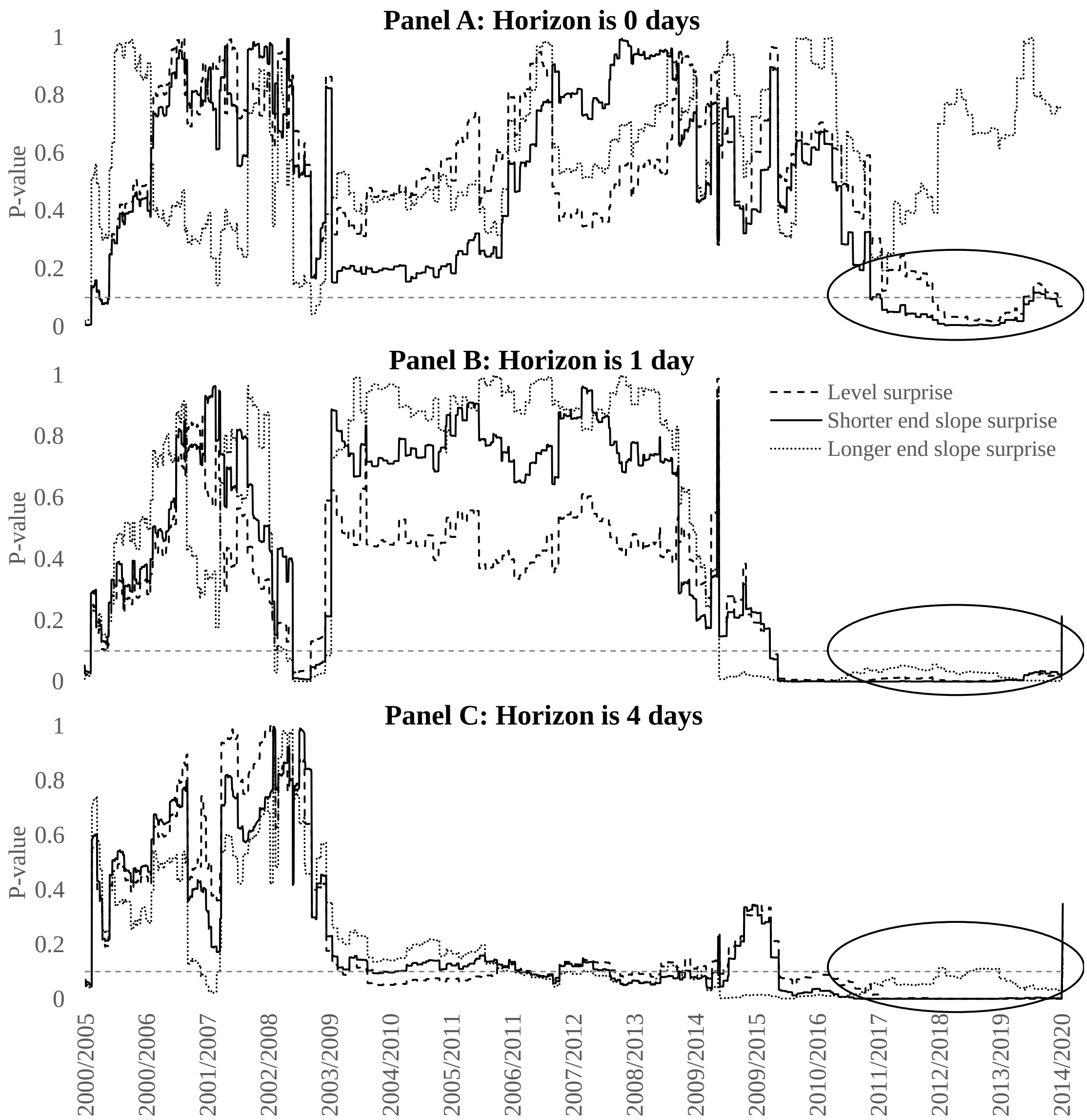

Figure 20: Statistical difference between deposit-dependent and -independent banks

Notes: This figure shows the rolling p-values of the Z-test for the significance of the difference between the coefficient estimates of model (5) for banks relatively dependent and independent on deposit funding. The forecast horizon is 0 days in Panel A, 1 day in Panel B and 4 days in Panel C. 'Level surprise' represents the rolling test outcome for $H_0 : \beta_{1,high,h} = \beta_{1,low,h}$ for $h = 0$, 1 and 4. 'shorter-end slope surprise' represents the rolling test outcome for $H_0 : \beta_{2,high,h} = \beta_{2,low,h}$ for $h = 0$, 1 and 4. 'longer-end slope surprise' represents the rolling test outcome for $H_0 : \beta_{3,high,h} = \beta_{3,low,h}$ for $h = 0$, 1 and 4. The dashed horizontal line represents the 10% significance level.

expected future discounted cash flow at any time. Second, the size of the fixed rolling estimation windows is changed using all models. Increasing the number of observations yields similar results. Decreasing the number of observations also gives similar results, except that the fourth day after a surprise to the level of the yield curve, the effect on bank stock prices reverses. The fourth day after an unanticipated flattening of the shorter-end of the yield curve, bank stock prices remain significantly lower. Third, the forecast horizon is extended with several days in models (3), (4) and (5). The persistence of the effects remains.

5 Conclusion

A prolonged period of negative interest rates has implications for the performance of banks, as retail deposit rates are stuck at zero. This paper investigates whether bank stock prices react differently to changes to the shorter- versus the longer-end of the yield curve in times of negative interest rates. Unanticipated interest rate changes are identified with high-frequency data around 269 ECB monetary policy announcements from 1999 to 2020.

The results indicate that negative interest rates matter for bank stock prices. Holding broad stock market movements constant, an unanticipated downward shift in the yield curve and flattening of the shorter-end of the yield curve persistently reduce bank stock prices in a low and especially negative interest rate environment. Bank stocks thus face a disadvantage compared to the broad stock market in times of negative interest rates. This seems to reflect sticky deposit rates for three reasons. First, once the interest rate environment turns negative, level and shorter-end slope surprises have a larger effect on stock prices of banks relatively dependent on deposit funding. In such an environment, deposit margins may turn negative, which impacts the performance of deposit-dependent banks. Second, the days after the announcement, the effects are more persistent for banks relatively dependent on deposit funding. Third, flattening the longer-end of the yield curve does not generate significant effects on bank stock prices in times of negative interest rates. Deposit margins may remain relatively unaffected when targeting only the longer-end slope of the yield curve due to the relatively low average duration of deposits.

Looking forward, a prolonged period of negative interest rates may be expected to hurt bank performance. This may reduce bank lending and hamper the transmission of monetary policy stimulus. The design of monetary policy can take this into account. The findings suggest that distortions stemming from deposit rates bound at zero are lower when targeting the longer- rather than the shorter-end of the yield curve in a negative interest rate environment. From this perspective, QE and YCC deserve special consideration when interest rates are negative and further monetary accommodation is called for.

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