Mind the Income Gap: Partial Hedging of Interest Rate Risk Within Banks' Business Model⋆

Daniel Platte[a], Fabian Wening[a]

[a] *Universiy of Münster, Universitätsstraße 14-16, 48143 Münster, Germany*

Abstract

Does maturity transformation inevitably expose banks to interest rate risk? We apply a recently established approach to a sample of banks mainly conducting traditional savings and loan business with extensive engagement in maturity transformation. We contribute to the emerging literature challenging modern banking theory's view on maturity mismatches and the corresponding interest rate risk. We find evidence for an alignment of the sensitivities of banks' interest income and expenses, indicating that their business models include an implicit hedge against interest rate risk. However, we also confirm a remaining exposure to changing market rates. When we include information on banks' use of derivatives, we find that the sensitivity alignment is mainly induced by derivatives rather than the business model itself. This suggests maturity transformation induces rather than hedges interest rate risk. Our results shed light on an implicit hedging mechanism within the traditional business model of banks, its (in)completeness, and implications for adequate regulation.

Keywords: Interest rate risk, maturity transformation, banking regulation

JEL classification: G21 (banks), G28 (regulation)

⋆ We thank participants at the 2021 Annual Meeting of the German Finance Association, the American Finance Association 2022 Annual Meeting, the French Finance Association 2022 Annual Meeting, Maren Baars, Victoria Böhnke, Friedrich Lorenz, Huyen Nguyen, Andreas Pfingsten, and Christoph Schneider for helpful comments and suggestions. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Declarations of interest: none.

Email addresses: daniel.platte@wiwi.uni-muenster.de (Daniel Platte), fabian.wening@wiwi.uni-muenster.de (Fabian Wening)

October 25, 2022

1. Introduction

Maturity transformation allows banks to earn a term spread equivalent to the difference between long-term loans and short-term deposits if the yield curve has a positive slope. From a theoretical perspective, there are several drawbacks, including vulnerability to fast-rising market interest rates; banks' profits decrease as a result of the immediate increase in deposit interest expenses for required refinancing. However, banks' market power to set customer deposit rates plays a unique role when policy rates rise. An emerging strand of literature sheds light on the so-called *deposits channel*, which enables commercial banks to reliably and cheaply refinance through their deposit franchise. As a result, deposits behave like long-term liabilities, and maturity transformation is even assumed to hedge banks' interest rate risk (e.g., Drechsler et al., 2017, 2021).

In this paper, we analyze whether maturity transformation contributes to or even hedges the interest rate risk of German savings banks and credit cooperatives, whose widened maturity mismatches have recently come to the attention of banking supervisors. In doing so, we contribute to the ongoing discussion on the relationship between maturity transformation and interest rate risk in the banking sector. Our analysis relies on the view that banks' asset exposure may hedge long-term stable deposit financing, possibly explaining banks' historically-stable interest business (see Brunnermeier and Koby, 2019). We focus in particular on banks with high levels of maturity transformation and a strong reliance on customer deposits as part of their traditional business model.

First, we identify and confirm the positive exposure of banks' net interest margin to rising interest rates—the traditional *gap risk*, which is also subject to regulation. Further, we find evidence for the alignment of banks' interest income and expense sensitivities; in the aggregate, banks isolate large parts of their net profits from fluctuating market interest rates. More precisely, banks in our sample might actively steer their interest-income sensitivity through the repricing maturity of their loans. Banks with lower interest-expense sensitivity show longer loan maturities and higher proportions of loans in their balance sheets; this is especially the case for banks with closely aligned income and expense sensitivities.

The high sensitivity alignment explains the rigidity observed in banks' net interest margin on the aggregate level. However, our analysis, which includes consideration of interest rate derivatives, implies that banks' sensitivity alignment is driven more by the use of those derivatives than it is by the business model itself. Thus, we find no evidence that interest rate risk is hedged by maturity transformation, at least for our sample of banks. We cannot confirm the "built-in" hedging mechanism suggested by Drechsler et al. (2021).

We use data from German savings banks and credit cooperatives for our analyses. Our sample consists of an extensive dataset of 1,056 savings banks and credit cooperatives with yearly balance sheet data from 1988 to 2019. In 2019, the German national supervisor classified 57% of credit cooperatives and 38% of savings banks as institutions with increased interest rate risk (Deutsche Bundesbank, 2019). Such banks are of particular interest as they deal with high levels of interest rate risk but have, on average, exhibited surprisingly stable net interest margins over the last several decades. These relatively small and non-listed financial institutions currently hold 45% of all customer deposits and are responsible for lending almost half of the German banking sector's total credit to private households and enterprises (Deutsche Bundesbank, 2021). The relevance of these institutions for the banking sector and the economy became evident after the global financial crisis in 2008. When private banks reduced the volume of their lending to the real economy in the aftermath of the crisis, savings banks and credit cooperatives filled this gap by providing necessary long-term debt, thereby stabilizing the German economy (Deutsche Bundesbank, 2019).

Methodically, we follow the model of Drechsler et al. (2021), which is central to the alternative view on banks' risk exposure. It provides a theoretical framework for maturity transformation without interest rate risk due to matching interest rate sensitivities on both sides of the balance sheet. First, we estimate every bank's interest-income and expense sensitivity to the three-month EURIBOR via time-series regressions and calculate the related mean sensitivities of our sample. No substantial difference between the sensitivities indicates a net interest income (NII) relatively insulated from changes in the market rate. In the second step, we investigate a cross section of banks and estimate the relationship between banks' income and expense sensitivities. If banks were able to coordinate their interest-income and expense sensitivity, a large part of interest rate risk would be eliminated in the aggregate banking sector, explaining the observed sluggishness of net interest margins on the national level. Third, we test for differences in banks' asset composition and maturities depending on their expense sensitivities to check for possible explanations for the alignment of income and expense sensitivities within the business model. Finally, we investigate whether interest rate derivatives influence any of the results.

The remainder of the paper is organized as follows. In Section 2, we provide an overview of the related literature, and briefly summarize the current interest rate risk regulation in Section 3. Section 4 outlines banks' interest business and maturity transformation within Germany. Section 5 presents a novel banking model from the literature that deviates from the standard theoretical approach and the data we use for our analysis. In Section 6, we estimate interest-expense and income betas and examine the link to matching activities in this regard. We then analyze how sensitivity matching might be implemented in banks' balance sheets and, finally, investigate the relevance of interest rate derivatives for our results. Section 7 concludes.

2. Literature review

One of the fundamental intermediation functions of banks is the maturity transformation of short-term deposits into long-term funds, which is associated with interest rate risk (Diamond and Dybvig, 1983; Bhattacharya and Thakor, 1993; Purnanandam, 2007).[1] Essentially, the stability of the overall banking system becomes vulnerable to an increase in nominal interest rates initiated by monetary policy (Di Tella and Kurlat, 2021). Even if interest-bearing assets and liabilities were linked one-to-one to market rates, banks would still face losses in the short run. Due to the difference in maturities, interest expenses rise faster than the mainly long-term fixed-income streams (Busch and Memmel, 2017). Previous studies follow the "traditional view" that rapidly rising interest rates depress banks' profitability, finally resulting in declining stock prices (Aharony et al., 1986; Akella and Greenbaum, 1992). However, if the earned term premium is positive, banks may be motivated to expand their maturity transformation for additional profits, known as the "lure of interest rate risk" (Greenbaum et al., 2015; Entrop et al., 2015). In the literature on maturity transformation and bank risk, the US savings and loan crisis of the 1980s represents the first wake-up call for leading

[1] We are aware that maturity transformation also results in liquidity risks, but for the purpose of this paper, we solely focus on the interest rate risk resulting from different maturities of a bank's assets and liabilities.

industrial nations to limit the maturity mismatch of banks' assets and liabilities (DeYoung and Yom, 2008). Bank managers and policymakers alike have a considerable incentive to understand banks' vulnerability to interest rate risk.

The opposing "matching view" in the literature contradicts the idea of banks' inevitable exposure to interest rate risk as a result of maturity transformation (Hoffmann et al., 2019). An early model of Hellwig (1994) shows that banks can isolate themselves from interest rate risks by providing variable-rate loans funded by variable-rate deposits. More recently, Drechsler et al. (2021) show that depending on the banks' market power, and as a result of that power, bank deposits are relatively insensitive to interest rate changes, which are offset by long-term assets. Finally, the interest rate sensitivities of assets and liabilities are almost equal in both models, and the financial intermediary does not bear any interest rate risk (see Hoffmann et al., 2019). Authors contradicting the traditional view on interest rate risk argue that maturity mismatches within banks' balance sheets are part of a deliberate hedging strategy (Di Tella and Kurlat, 2021).

Drechsler et al. (2021) show that credit institutions exhibit historically-stable interest margins despite ongoing maturity mismatches in their balance sheets during times of fluctuating market interest rates. Although recent studies confirm a decline in share prices of listed banks following announcements of rising interest rates by the Federal Open Market Committee, the effect was weaker for banks with considerably higher levels of maturity mismatch (English et al., 2018). Purnanandam (2007) indicates that immunity to monetary policy shocks is attributable to the significantly higher use of interest rate derivatives, especially for more exposed banks avoiding costly financial distress. Contrary to this, Begenau et al. (2015) reveal that only half of US banks hold interest rate derivatives, and aggregated derivative positions may even amplify their exposures. The existence of numerous opportunities to hedge interest risks on the capital market has led to the emergence of a debate as to why banks expose themselves to interest rate risks at all (Hellwig, 1994; Di Tella and Kurlat, 2021). One explanation might be the corresponding reward of doing so; for instance, Bologna (2018) finds that maturity transformation corresponds to higher net interest margins, whereas "excessive" maturity transformation leads to significantly higher risk exposures as well as lower margins.

Researchers examining the underlying effects of changing interest rates on bank profitability and risk identify further contradictory directions (English et al., 2018). Interest rate risk borne by banks appears to be heterogeneous across different bank types and business models, and the variation is even more extensive between countries as a result of bank loans and the country-specific type of fixed or variable mortgages (Hoffmann et al., 2019). In addition, Borio et al. (2017) suggest that the market interest rate itself determines how strongly monetary policy shocks affect bank profitability across fourteen major advanced industrialized nations. Recent studies identify banks' share of deposits as determining interest rate risk exposures. The banks concerned are predominantly small and medium-sized banks. Additionally, as compared to large international institutions, derivative instruments have only been used by few of these banks to hedge interest rate risk (Urbschat, 2018). The empirical banking literature investigates the impact of monetary policy on bank risk and profitability under conventional conditions. However, the drop of market interest rates to below zero in many industrialized countries represents a major change (Kerbl and Sigmund, 2017). There is mixed evidence as to whether the transmission channels of monetary policy work properly below the zero bound (Urbschat, 2018; Ulate, 2021).

Although Altavilla et al. (2022) suggest that banks can pass negative rates on to corporate depositors without loss of refinancing sources, the majority of studies claim the opposite. Many retail banks still do not charge negative deposit rates in the retail sector—at least for relatively small amounts—implying a zero lower bound. As a result, banks' interest margins decline, resulting in an overall negative impact on bank stability (Eggertsson et al., 2019). Therefore, having a large share of liabilities in the form of deposits has recently been identified as a burden for banks' net interest margin in an environment of persistently negative interest rates (Bubeck et al., 2020). However, Basten and Mariathasan (2018) provide empirical evidence that small banks affected by negative monetary-policy-induced rates can pass through costs indirectly to their depositors. If a bank's market power is sufficiently high, it can increase fees instead of directly charging negative deposit rates. Simultaneously, banks relying on large shares of deposits might take even more risk to stabilize their net interest margins in the ongoing "search for yield" induced by continuous low-interest environments (Rajan, 2005; Martinez-Miera and Repullo, 2017; Heider et al., 2019).

Our study connects with the lively discussion on whether banks' maturity mismatch inevitably leads to exposure to interest rate risk. The related literature examines the impact of interest rate fluctuations on deposits and refers to a new channel for transmission of monetary policy—the deposits channel. Drechsler et al. (2017) show that operating a deposit franchise gives banks market power, allowing them to keep deposit rates low even when short-term rates rise and despite the contractual maturity of deposits being quite short. Based on their previous work on the deposits channel (see Drechsler et al., 2017), Drechsler et al. (2021) develop a theoretical model that includes banks' market power in the deposit business. Here, the bank's deposit franchise has two key features: its expenses are insensitive to varying market interest rates, and the bank can refinance reliably at below-market deposit rates. Both elements are comparable to those of a payer swap. The income stream generated by a bank's assets—interest rates are fixed long-term—then hedges the payment structure of the deposit franchise. The study also tests the model empirically and shows that US banks match the sensitivities of their interest expense and income and thereby isolate their net interest margins from fluctuating policy rates.[2]

Earlier studies examine how quickly deposit rates adjust when market interest rates fall. This effect, combined with a substantial delay in adjusting loan interest rates, has a positive impact on the interest margin (Hannan and Berger, 1991). Driscoll and Judson (2013) confirm the upwards-rigidity and downwards-flexibility of deposit rates. Notably, checking and money market accounts exhibit greater inertia than other liabilities. On average, their related interest rates first change after 20 weeks and 37 weeks, respectively. Further evidence suggests that commercial banks are able to pass through a fraction of positive fed funds rate changes to their depositors due to their market power in the deposit business and households' lack of financial literacy (Yankov, 2014). It is less controversial yet equally important that the effective maturity of core deposits is many times longer than the maturity contractually

[2] In the German literature, the concept of interest rate elasticities represents an instrument for banks' interest rate risk management and seems also related to the observed pattern of stable interest margins. In this concept, different adjustments of assets' and liabilities' variable interest rates to market interest rate changes are considered to change the net interest income (e.g., Rolfes, 1985, 2001). Parts of this concept are also reflected in the international literature on studies of interest rate risk. Here, the focus is on changes in interest income and expenses due to changing central bank or market interest rates, the *interest rate sensitivities*. This is also the view adopted in our paper and the subsequent analyses.

agreed with customers (Wagner, 1857; Flannery and James, 1984; O'Brien, 2000). The deposit base theory is also reflected in the regulations. The pattern of sticky deposits even holds at the bank level, as Adams et al. (2021) empirically prove using savings account information from commercial banks in the UK.

Finally, current studies investigate banks' deposit business and competitive position for the German banking market, providing empirical evidence that their payments on deposits are only slightly related to market rate changes. Furthermore, banks in rural districts with less competition can pay comparably lower rates for their deposits which still holds in the low-interest rate environment induced by the European Central Bank (Busch and Memmel, 2021). Our paper extends and contributes to the existing literature by further investigating the opposing views on interest rate risk for banks that, by the design of their business model, are highly engaged in maturity transformation. Additionally, we assess whether or not specific features within the business model of small and medium-sized banks need to be considered within the principles of interest rate risk regulation.

3. Regulatory requirements for interest rate risk

This section gives a brief overview of the current regulation of interest rate risk. We focus on the banking book regulations, as the banks in our sample for later analysis are usually banks without trading books. Regulators of the Basel Committee on Banking Supervision (BCBS) and the European Banking Authority (EBA) are aware of the importance of interest rate risk and its relevance for banking stability (BCBS, 2016). The current regulations are based on the 2018 EBA guidelines, following the 2016 BCBS standards. The EBA guidelines are expected to be updated in 2022 as the new draft guidelines were published in December 2021; the final regulations will be published after the evaluation of the consultation period, which continued until April 2022. In the current regulatory framework, there are two measures of interest rate risk in the banking book, concerning the banks' economic value of equity (EVE) and the NII. The first one captures a long-term perspective and focuses on a bank's economic value, while the second one is a short- to medium-term earnings-based measure and thereby addresses banks' traditional *gap risk* resulting from maturity transformation.

The regulations currently define a quantitative threshold of a 20% loss of a bank's EVE in the ±200 basis points (bps) parallel shift of the interest rate curve. Losses exceeding this threshold will result in additional capital requirements. The revised EBA guidelines will tighten restrictions by lowering the threshold loss to 15%, among further changes. Exceeding the threshold losses classifies a bank as having increased interest rate risk. Additionally, the revised guidelines establish a quantitative threshold for the loss in a bank's NII, which is not yet integrated. Banking supervisors monitor the current EVE threshold and banks' interest rate management in general, and, depending on a bank's individual risk, might require additional capital (BCBS, 2016; EBA, 2018; EBA, 2021).[3]

4. Maturity transformation and interest business in Germany

Our paper analyzes the relationship between maturity transformation and interest rate risk for German savings banks and credit cooperatives. As these banks mainly follow a savings and loan business model, they mostly refinance through deposits. Having extended their maturity transformation, they are currently the focus of interest rate risk regulation. As an approximation for a bank's maturity transformation, we derive the fixed-interest periods of the balance sheet positions or the repricing maturities, i.e., the time of a balance sheet position until the subsequent fixing of the interest rate. The contractual maturity of a balance sheet position does not necessarily be identical to the repricing maturity. We explore the repricing maturities of banks' assets and liabilities derived from the residual maturity buckets reflected in their annual reports.[4] The respective balance sheet positions are divided into five maturity buckets; the first for items with a maturity of one day and the last for those with a maturity of ten years.[5]

[3] Detailed information on the calculation requirements for the risk measures can be found in the EBA guidelines and the BCBS standards (BCBS, 2016; EBA, 2018; EBA, 2021).

[4] This is the best solution to approximate the differences between the fixed-interest rate positions of a bank's assets and liabilities resulting from maturity transformation, given that our data consists of public balance sheet data from Fitch Connect.

[5] Annual reports specify maturity buckets for loans to customers and banks, bonds and other fixed-income securities, deposits, and bank debt issuances. We follow (Drehmann et al., 2010) and assign positions with maturities of more than five years to the final bucket. Furthermore, we suppose that items in the last three buckets follow a uniform distribution across calendar quarters. Since the German banking market is dominated by a traditional buy-and-hold strategy (Entrop et al., 2015), we assume that assets remain on the balance sheet after closing and are hold until repayment or amortization.

Figure 1 shows the estimated repricing maturity of assets and liabilities from 1988 to 2019.[6] On average, the repricing maturity of assets within our sample is slightly above four years, and the repricing maturity of liabilities is less than eight months, resulting in a maturity gap of 3.5 years.[7] Therefore, in the traditional view, these banks are exposed to interest rate risk over the entire observation period. Consequently, rising interest rates should lead to a faster rise in interest expenses than in interest income, thus squeezing the NII as the resulting difference (Drechsler et al., 2021).

Figure 2 shows the development of the aggregated net interest margin for savings banks and credit cooperatives and the annual average of the three-month market interest rate.[8] At first glance, the short-term interest rate level is quite volatile; it peaked at 9.25% in 1991 and broke the zero lower bound in 2015. A yearly standard deviation of 2.84% confirms the high volatility. By contrast, the aggregated net interest margin ranges between 1.69% and 3.20% for more than 30 years. Indeed, the margins seem to decrease when the market interest rate increases. However, the effect appears to be only marginal and delayed. Compared to fluctuating market rates, there is few variation in the aggregated net interest margin, with a standard deviation of 0.37%.

To highlight the origin of this rigidity in the net interest margin, we separate two components from profit and loss statements. Figure 3 plots aggregated interest income and interest expenses relative to a bank's total assets. It should be noted that banks' income streams seem to follow the direction of varying market interest rates. The aggregate expenses part of the net interest margin behaves similarly despite substantially shorter maturities—being around 2.4 percentage points lower. Visually, it is clear that interest expenses rise comparatively slowly in periods of upward-moving market rates, smoothing banks' aggregated net interest margins accordingly.

[6] The development of the maturities corresponds to the rising levels of interest rate risk since 2012, as reported by German supervisors (Deutsche Bundesbank, 2019).

[7] We use the contractual repricing maturity of deposits. As outlined in Section 2, we could use deposits' behavioral maturities, resulting in a smaller maturity gap. However, for the later quantitative analysis, we do not use the repricing maturity of a bank's liabilities.

[8] We use the FIBOR from 1988 to 1999 and the three-month EURIBOR until 2019. The three-month rate is primarily chosen in the finance literature to study fluctuations in short-term interest rates (e.g., see Avouyi-Dovi et al., 2017).

We connect these observations with insights on banks' market power from the literature (see Section 2) by additionally examining the development of the average deposit rate. Given substantial market power, we expect banks' deposit rates to be resistant to changes in market interest rates—at least in the short term. Figure 4 shows the deposit facility of the central bank, the three-month EURIBOR, and an aggregate deposit rate. Since we do not have information on deposit rates at the level of the individual depositor or bank, we rely on aggregate information from the Deutsche Bundesbank. The corresponding data contain information since 1975 and therefore provide comprehensive insights into the national retail market conditions.

We see that the deposit rate for standard savings products continued to be way below the market rates. Additionally, the deposit rate only marginally adjusted to market rates in periods of an upward trend. Therefore, the spread between the deposit and the market interest rate actually widened in these periods. For example, when the three-month EURIBOR rapidly increased before the global financial crisis, the newly agreed interest rates on overnight deposits were not even close to market rates. We also see from Figure 4 that the price advantage of deposit refinancing disappeared in the third quarter of 2009, as the average deposit rate on sight deposits exceeded the market interest rate. As the average deposit rate approaches zero percent and the market rate falls further below zero, the deposit margin is likely to be negative.

In sum, with respect to the German savings banks and credit cooperatives, we find substantial maturity transformation in the banks' balance sheets and a relatively stable net interest margin, despite fluctuating market rates. Thus, the traditional and existing regulatory view on maturity transformation might not fully explain the interest rate risk of German banks in general, which in turn provides scope for an alternative view on banks' exposure to interest rate risk. Our observations connect with the recent literature and motivate the empirical approach of our paper. We adopt the model of Drechsler et al. (2021), which accounts for these observed features of banks' interest rate business, to investigate whether maturity transformation even hedges the interest rate risk of banks and, if so, which mechanisms are involved. As the maturity transformation has increased over the last years and the cost advantage of deposit refinancing has reduced dramatically, these observations require an even more sound understanding of the mechanisms of maturity transformation and interest rate risk.

5. Methodology and data

5.1. Methodology

We investigate the banks' interest rate risk using the model of Drechsler et al. (2021). The authors provide a simple model in which a bank maximizes the present value of its future profits (income minus expenses). Its deposit franchise allows the bank to pay its depositors only a fraction of the current market rate (see Drechsler et al. (2017) for further details on the market power component of the model). While the expenses for deposits depend on the market interest rate, the costs for the deposit franchise are primarily fixed. Drechsler et al. (2021) show that banks will choose to match the sensitivities of their interest income and expense to the market rate, thereby hedging their interest rate risk. Even though bank refinancing occurs mainly through deposits, the sensitivity of their interest expenses is relatively low. Long-term assets with low interest-rate sensitivity are thus needed to match the expense sensitivity. Following this argument, maturity transformation hedges the banks' interest rate risk. Drechsler et al. (2021) find this prediction confirmed in the aggregate time series of their dataset and also in the cross section.

We investigate banks' interest rate risk in our sample, taking an earnings-based perspective, with earnings derived from the banks' balance sheets and profit and loss statements. We determine the impact of a changing market interest rate on a bank's interest income and expense to quantify its interest rate risk. This view relates to the gap risk and the regulatory risk measure concerning the NII as outlined in Section 3. In the following, the bank's estimated sensitivities are also referred to as *expense beta* or β^{Exp} and *income beta* or β^{Inc}.

A different approach to quantify the interest rate risk is the economic value perspective which corresponds to the EVE-related regulatory risk measure. Here, the impact of changing interest rates on the bank's equity is calculated. As all banks in our sample are non-listed banks and do not have a market price of equity, we cannot implement the economic value perspective for the purposes of this analysis. However, Drechsler et al. (2021) point out that both perspectives make the same assessment but by different routes. While the earnings-based perspective measures the loss of income due to a changing interest rate over time, the economic value perspective calculates this loss immediately as a present value. The authors also emphasize the separate estimation and analysis of banks' interest income and expenses when adopting the earnings-based perspective.

5.2. Data

We construct our sample based on annual financial statements from Bankscope and Fitch Connect for all available savings banks and credit cooperatives from 1988 until 2019. As the first analysis is based on individual-bank time series, we restrict our sample to banks with at least 15 observations (years) and no more than one break in the time series.[9] This gives us a panel dataset with 25,318 bank-year observations from 1988 until 2019. Our sample cross section consists of 1,056 banks (403 savings banks and 653 credit cooperatives). Especially in the earlier years of our sample, until the mid-1990s, the database has limited coverage of savings banks and credit cooperatives, with substantially lower numbers reflected than the number of banks active in these years. However, our sample as a whole is representative of the banking sector in respect of savings banks and credit cooperatives. We account for the numerous mergers in the banking sector by keeping the absorbing banks in the data. The absorbed banks remain in the sample as long as they are active on the market.[10] Table A.1 in the Appendix provides an overview of the selection process of the banks included in the sample. We use the banks' balance sheet positions and income statements as reflected in the databases and use this data to calculate our required variables for the analysis. Table 1 provides an overview and descriptions of the variables used.

For data on market interest rates, we use the time series database of the Deutsche Bundesbank.[11] We use the three-month EURIBOR as a proxy for market interest rates. As our bank data comprises only yearly observations, we implement a rolling average approach to

[9] Relaxing this assumption and using a minimum of seven observations (years) does not change our results substantially, see Section 6.5.

[10] We account for changing names of the absorbing banks as a consequence of the merger. We cannot control the reason for the merger, although individual banks might be forced to merge due to tightening economic and regulatory conditions or too large risk exposures. Given the large number of banks in the panel, we claim that these individual mergers do not bias the interest rate risk of the sample.

[11] Data available at `https://www.bundesbank.de/en/statistics/time-series-databases`.

capture variation in the interest rate over the calendar year.[12] For the period prior to 1998, we use the corresponding three-month FIBOR as the market interest rate; this was the rate used in Germany until the introduction of the Euro in 1999.[13]

Table 2 shows descriptive statistics for our sample.[14] The average share of loans in the sample is ≈ 60%, and customer deposits amount to ≈ 73% of total assets. These numbers reflect the traditional business model of savings banks and credit cooperatives that mainly engage in lending and deposit business. Panel B shows identical statistics for the largest 10% of banks in the sample. These banks generally exhibit a lower NII, longer asset and liability maturities, fewer customer deposits, less equity, and more market power than the rest of the sample, based on a t-test between the sample means, shown in Column (7) of Table 3.

In the next section, we assess the interest rate risk of the banks in our sample. We first obtain average estimates for the banks' income and expense sensitivities to market interest rates. In the next step, we investigate whether there is a relationship between these estimates and, finally, test for evidence how the alignment may be achieved to hedge against interest rate risk.

6. Empirical results

6.1. Sensitivity to market interest rates

We follow Drechsler et al. (2021) for the empirical estimation and tests of their model's predictions. First, we analyze the banks' sensitivities to the market interest rate for interest income and expenses separately. To do so, we run a time series regression for each bank in our data to estimate the relationship between the change in a bank's interest expenses:

$$\Delta IntExp_t = \alpha + \beta^{Exp} \Delta 3MEur\_rm_t + \epsilon_t \,, \tag{1}$$

[12]Our results do not depend on the choice or specific definition of the interest rate (see Section 6.5).

[13]In 1999, the Euro was introduced for accounting and electronic payments. The banknote was launched at the beginning of 2002.

[14]The aggregate results of the analysis in Section 6.1 are also presented at the bottom of the table. These results and variables are explained in the respective section.

where $\Delta IntExp_t$ is a bank's yearly change of interest expenses from time $t-1$ to time t, $\Delta 3MEur\_rm_t$ the corresponding change in the rolling mean of the three-month EURIBOR, and β^{Exp} is the coefficient of interest. As outlined in Section 5.2, we only use time series data of an individual bank if there are at least 15 (years of) observations available for the regression. Similar to Equation (1), we calculate our estimates for β^{Inc}, β^{NIM}, and β^{ROA}, replacing the dependent variable by changes in the bank's *interest income*, *net interest margin* (NIM), and *return on assets* (ROA), respectively.[15] For subsequent analyses, we remove from our sample seven "outlier banks" with a negative expense beta.[16] The bottom lines of Table 2 show the aggregate results for the time series regressions. Figure 5 shows the distribution of expense betas across the banks in our sample, as well as the distribution of income betas, ROA betas, and NIM betas.

The average β^{Exp} for our sample is 0.178 and implies that a 100 bps increase in the market interest rate results, ceteris paribus, in an average increase in banks' interest expenses margin of about 18 bps. This result accords with the observation in Section 4 that banks in our sample generally exhibit low sensitivity of their interest expenses to the market interest rate. For the largest banks in our sample, we observe an average β^{Exp} of 0.215, which is slightly larger than the expense beta for the overall sample.

The average β^{Inc} is 0.103, which corresponds to an increase in the interest-income margin of about 10 bps if the market interest rate increases by 100 bps. For the largest banks in the sample, the average income beta is 0.155. Again, the adjustment of interest income to market rates is substantially lower than the adjustment of interest expenses.

According to Drechsler et al. (2021), we should expect similar values for the expense and income betas and a NIM beta close to zero. As outlined in Section 5.1, such a result would indicate a low or even no exposure of banks' NII to fluctuating market interest rates. Our results do not suggest a fully hedged interest income. The difference between the average expense and income beta (β^{NIM}) is -0.075 for the total sample and a marginally smaller

[15] We additionally estimate a β for a bank's interest income from securities and total non-operating profit for later analyses.

[16] In the underlying model of (Drechsler et al., 2021), the expense beta is a proxy for a bank's market power and should take values between 0 and 1. Negative values might stem from our restricted time series having only yearly observations. However, our results are robust to including the negative values.

gap of −0.060 for the largest banks. Applying pairwise t-tests for mean comparison between the estimated expense and income betas, we find the negative difference is significant at the 1% level.

This difference is the traditional gap risk that is attributed, in the existing literature and by banking regulators, to banks' maturity transformation. If market interest rates rise, banks' NII declines. The negative NIM beta is also reflected in the average ROA beta for our sample of −0.041 (−0.028 for the largest banks), indicating that a 100 bps increase in the market interest rate would, on average, be accompanied by a reduction of about 4 bps in banks' ROA.[17]

We observe substantial variation in the distribution of the betas. However, we also observe that the majority of banks show negative NIM betas, indicating gap risk for most banks in our sample (see Figure 5). Consequently, from our first analysis, we find a positive exposure of banks' NII to fluctuating market rates. For further analysis, we split our sample into *low-gap* and *high-gap* banks at the median of the absolute difference between the expense and income betas. As seen in Column (6) of Table 3, high-gap (low-gap) banks have, on average, higher (lower) NII and ROA, higher (lower) shares of securities, fewer (more) savings deposits, more (less) equity and higher (lower) levels of total assets.

6.2. Matching of sensitivities

After estimating the banks' respective sensitivities to market interest rates, we look for evidence indicating a matching of sensitivities across banks. Based on the model of Drechsler et al. (2021), we expect banks with a high expense beta to have a high income beta and, finally, a 1:1 match between expense betas and income betas. If banks match their sensitivities in the cross section, this could be an indicator for hedging interest rate risk—at least at the aggregate banking-sector level. The scatter plot in Figure 6 shows the relationship between income and expense betas for the entire sample; there seems to be a positive, linear relationship. Banks with high expense betas tend to have high income betas, and banks with low expense betas usually have low income betas. The correlation of income and expense betas across our sample is 0.628 for the entire sample and 0.809 for the largest banks. To quantify the relationship,

[17] Again, based on a t-test, the ROA average is smaller than zero at a 1% confidence level.

we run a cross-sectional regression of the bank's income beta on the expense beta:

$$\beta_i^{Inc} = \alpha + \delta\beta_i^{Exp} + \epsilon_i \,, \tag{2}$$

where α is a constant, δ is the coefficient of interest, and β_i^{Inc} and β_i^{Exp} are a bank's income and expense betas, estimated according to Equation (1). The stronger the alignment of the sensitivities, the closer to 1 the δ has to be.

Panel A of Table 4 shows the regression results. For our total sample, the estimate of δ is 0.737 in Column (1) and is highly significant. The corresponding constant is -0.029 and close to zero. If a bank shows an expense sensitivity of zero, we also expect an income sensitivity close to zero. Columns (2) and (3) show a more pronounced relationship if we split the sample into banks with low and high income gap (low gap: 0.913, high gap: 0.809). The coefficient for the largest banks, in Column (4), is 0.897. All coefficients are significant at the 1% level. The estimated matching coefficients are not precisely one, as Drechsler et al. (2021) predict, but they are a strong indicator of sensitivity matching at the aggregate level.[18]

The relationship between the NIM beta and the expense beta of banks allows us to investigate the corresponding, "remaining" component of the sensitivity matching. Therefore, we run Equation (2) with the NIM beta as the dependent variable; the results are set out in Panel B of Table 4. The overall coefficient of -0.263 indicates that banks with a higher expense beta exhibit a higher difference in their income and expense sensitivities.[19] The relationship between NIM beta and expense beta is only insignificant for the largest banks in our sample, so for these banks, we cannot exclude a "perfect" relationship of one between income and expense beta. Thus, while we find a strong indication of the alignment of income and expense sensitivities, we find that the gap risk of banks corresponds to the expense sensitivities at the same time.

In the next step, we check whether there is also a relationship between banks' income gap and ROA sensitivity. From the aggregate time series analysis in Section 6.1, we estimated an

[18]All coefficients except for the coefficient of the Top 10% of banks are also different from 1 (perfect hedge) on the 1% level, based on a Wald test.

[19]It corresponds to an estimated value of 0.737 for the relationship between income and expense betas and is the extent of its deviation from a regression coefficient of 1.

average ROA beta of −0.041. In our sample, 669 of 1,056 banks show both a negative NIM and negative ROA beta. However, for 341 banks, the ROA beta is positive despite an, on average, negative NIM beta. Therefore, we estimate Equation (2) with a bank's ROA beta as the dependent variable and the NIM beta as the independent variable. We expect a positive relationship between the two variables based on the cross section's previous relationships.

In general, and based on Drechsler et al. (2021), the more a bank's NII is hedged, the closer to zero we expect the NIM and ROA betas to be. A more negative NIM beta should result in a more negative ROA beta. Table 5 shows the relevant regression coefficients. The estimate for the total sample is 0.363 and is highly significant, which is in line with our expectations. The coefficients for the sub-samples are also positive and significant, at varying levels of significance. The constant coefficients are very close zero and fit the expectation that a bank has a ROA beta of zero if its NIM beta is zero. These results indicate that in the cross section of banks, a higher income gap is associated with a more negative ROA sensitivity.[20]

To investigate the relevance of a bank's non-interest profit to the previous results and relationships identified, we estimate the $NonIntResBeta$, similarly to Equation (1). The average sensitivity in our sample is 0.011, which is fairly low (see Table 2). We then estimate the relationship between the $NonIntResBeta$ and the NIM beta in the cross section of banks in a regression similar to Equation (2). The results are shown in Table 6. The coefficient is −0.269 and highly significant. Banks with higher income gaps (and, respectively, more negative NIM betas) also show significantly higher non-interest profit sensitivities. For low-gap banks, the relationship in Column (2) is not significant. Therefore, banks, and in particular riskier banks, might use income from their non-interest business as a counterpart. Banks vulnerable to rising market interest rates may avoid financial distress through non-

[20] According to Drechsler et al. (2021), a bank is exposed to interest rate risk if income and expense sensitivities are not equal. Most banks in our sample show the traditional income gap, with the expense beta larger than the income beta. If we calculate the absolute difference of sensitivities, taking positive and negative deviations into account, and then estimate the relationship of this difference with the ROA beta, we obtain very similar results but with the inverse sign. However, we find that low-gap banks do not exhibit a significant relationship, indicating that these banks may be better hedged; the results are shown in Table A.2.

interest profits that rise with market rates.[21]

Summarizing the results, we find solid indicators of an alignment between banks' interest-income and expense sensitivities. However, we do not find the 1:1 alignment expected according to Drechsler et al. (2021). Banks with larger income gaps show a more negative ROA sensitivity. The results from this section complement those from the aggregate time series analysis, both of which indicate a traditional gap risk for most banks in our sample.

6.3. Market power hypothesis underlying the model

Market power is an important factor in Drechsler et al. (2021). Banks with higher market power are expected to show lower than average sensitivities of their interest expenses to changes in market interest rates; they thus have lower expense betas, which they match with lower income betas. As shown in Section 3, banks in Germany were able to keep interest rates on deposits below market rates for most of the period under consideration, possibly indicating the substantial market power of banks. We follow the approach of Drechsler et al. (2021) to test whether variation in market power is accompanied by variation in the corresponding expense beta. In a second step, we test whether banks match these differences with their income betas. We perform the regression on our panel data and run the following two-stage OLS regressions:

$$\Delta IntExp_{i,t} = \alpha_i + \nu_t + \beta MP_{i,t} \times \Delta 3MEur\_rm_t + \epsilon_{i,t} \quad (3)$$

$$\Delta IntInc_{i,t} = \lambda_i + \gamma_t + \delta \Delta \widehat{IntExp}_{i,t} + \epsilon_{i,t} \quad (4)$$

where $\Delta IntExp_{i,t}$ is the change of bank *i's* interest expenses at time t, $MP_{i,t}$ is the proxy of bank *i's* market power at t, $\Delta 3MEur\_rm_t$ is the corresponding change of the rolling mean of the three-month EURIBOR, and $\Delta \widehat{IntExp}_{i,t}$ is the predicted change for bank *i's* interest expenses at t based on the first stage. α_i and λ_i are bank-fixed effects, and ν_t and γ_t are time-fixed effects. β captures the relationship between market power and interest-expense

[21] Drechsler et al. (2021) use the relationship of the ROA and expense beta to rule out the influence of non-interest business on the alignment of sensitivities. For completeness, we also implement these regressions and display the results in Appendix A, Table A.3. We do not find significant estimates for the relationship, but the negative and highly significant constants—similar to the average ROA beta—indicate that irrespective of the bank's expense beta, its expected ROA beta is negative.

sensitivity, and δ is again the matching coefficient of interest-income and expense sensitivity.

This approach defines the bank's expense beta as a function of its market power: β from the first stage describes the relationship between expense rate and market power, δ from the second stage is the matching coefficient of changes in interest income and expenses. As a proxy for market power, we use the Lerner index (LE) as described in Appendix B. The results are set out in Table 7. Columns (1) and (3) are those for the first-stage regression, and Columns (2) and (4) for the second-stage regression. We find a significantly negative relationship between market power and interest-expense sensitivity, indicated by coefficients of −0.009 in Column (1) and −0.016 in Column (3). The resultant matching coefficient of 0.584 in Column (2) is slightly smaller, and the coefficient with time-fixed effects of 0.774 in Column (4) is similar to matching coefficient of 0.737 from the main analysis. These overall results are in line with the market power mechanism described in Drechsler et al. (2021) and confirm our results shown in Table 4.

6.4. Implementation of sensitivity matching

6.4.1. Repricing maturities of assets

The results in Section 6.2 show that banks with a relatively low expense beta also tend to have a relatively low income beta. Based on Drechsler et al. (2021), we expect that a bank with low expense sensitivity realizes the corresponding low income sensitivity by investing in assets with lower exposure to the market interest rate; that is, with longer repricing maturities. To test this expectation, we follow Drechsler et al. (2021) and explore the relationship between a bank's expense beta, β_i^{Exp}, and the average maturity of its assets. The scatter plot of a bank's average repricing maturity and a bank's interest-expense beta is shown in Figure 7; overall, the plot reveals no clear relationship, and the slope of the trend line is slightly negative. This observation corresponds to the descriptive statistics in which low-gap and high-gap banks do not show significant differences in asset maturities (see Column (6) of Table 3). We test the relationship by performing a cross-sectional regression with the repricing maturity of a bank's assets as the dependent variable. Specifically, we run the regression:

$$AssetMaturity_i = \alpha + \delta\beta_i^{Exp} + \gamma X_i + \epsilon_i \,, \tag{5}$$

where $AssetMaturity_i$ is the average repricing maturity of bank *i's* loans and securities in years and X_i is a vector of control variables of bank i. The coefficient of interest is δ, which we expect to be negative. We include control variables for bank averages over the respective time series for the share of savings deposits, the equity ratio, and the natural logarithm of total assets. The results are presented in Table 8. The coefficient for the univariate regression in Column (1) is -0.454, and the corresponding constant is ≈ 4.2, which matches the average asset maturity of our total sample. We find significant coefficients for the relationship between the repricing maturity and the expense beta for all except Column (2). However, the absolute magnitude and the economic relevance of the relationship is low since the coefficients are many times smaller than their corresponding constant. The results suggest differences in the repricing maturities of less than one year for banks with an expense beta of zero or one. For the largest banks in our sample, we find no significant relationship.

Next, we split up the different maturities of the respective balance sheet positions in loans and securities. We re-estimate Equation (5) using the average repricing maturity of loans and securities as the dependent variable. The results are shown in Table 9.[22] Panel A shows the results for the total sample. The corresponding coefficient for the loan maturity in Column (2) is -1.877 and highly significant. The coefficient for the maturity of securities in Column (3) is also significant but positive at 0.502. Based on Drechsler et al. (2021) we do not expect a positive relationship. A possible explanation for the positive relationship might be the liquidity aspect of securities; they are easier to sell in case of liquidity needs or to replace by other securities with different maturities. Banks with higher expense betas that engage in maturity transformation hold securities with longer maturities. These findings are confirmed by the results for the largest banks in Panel B. For these banks, the relationships are both more pronounced, with estimates of -3.6 for loan maturities and 1.284 for securities maturities. The relationships of loan and securities maturities seem to offset each other, resulting in small or insignificant estimates for the overall asset maturity.

Additionally, we separately look at banks with low and high income gaps. We show the regression results for Equation (5) for high and low gaps in Table 10. We find that for

[22]The total asset maturity in Column (1) corresponds to Column (5) of Table 8. We now provide only results for the regression with all control variables.

low-gap banks, the regression coefficients are substantially larger and in line with Drechsler et al. (2021). The regression coefficient for the loan maturity in Column (3) is −2.869 and highly significant, indicating that banks, particularly those with a low difference in betas or a narrow income gap, may achieve lower income sensitivity through having longer loan maturities. This stronger relationship is also reflected in a higher coefficient for the overall asset maturity in Column (1) of −1.686. We find a positive estimate of 0.782 in Column (5) for the securities maturities. For low-gap banks, all estimates are significant at the 1% level. Banks with higher gaps also show a significant, negative coefficient for the loan maturity of −1.356, but no significant relationship for the overall assets and securities maturities.

Based on these results, we conclude that the banks in our sample, especially those with a comparably low income gap, might actively adjust their interest-income sensitivity through the repricing maturity of loans.

6.4.2. Share of securities

A second possibility for banks to align their sensitivities is to vary the share of balance sheet items with the longest maturities. We expect banks with lower expense betas to realize the corresponding lower income sensitivity by holding more assets with lower exposure to market interest rates. In our sample, the average maturity of securities is substantially longer than the maturity of loans (see Table 2). Thus, banks with lower expense betas should have higher proportions of securities.

Figure 8 shows a scatter plot of the relationship. Similar to that in the previous section, the plot does not reveal a clear relationship, although the linear trend fitted to the plot is slightly increasing. To analyze the relationship quantitatively, we re-run Equation (5), with the average proportion of securities $Securities_i$ in bank i*'s* balance sheet:

$$Securities_i = \alpha + \delta\beta_i^{Exp} + \gamma X_i + \epsilon_i \,, \tag{6}$$

The corresponding results are set out in Table 11. We find a small but significant, positive coefficient of 0.133 for a bank's expense beta and the corresponding average share of securities in Column (5) with all control variables included. The largest banks show a more positive and significant relationship with a coefficient of 0.416. A positive coefficient contradicts our initial expectation, as banks with a higher expense beta hold more securities. However, securities are assumed to be easier to sell if a bank is in the need of liquidity (e.g., see de Haan and van den End, 2013; Drechsler et al., 2021) or replaced if a bank requires a different maturity profile.[23] If we differentiate between low- and high-gap banks, we find that the relation in the total sample is mainly driven by banks with high income gaps. For these banks, the coefficient is 0.168 and significant. As banks with a high difference in their betas are supposed to be more exposed to interest rate risk, the results suggest that these banks hold more securities as liquidity buffers. The results are shown in Columns (1) and (2) of Table 12.

As loans and securities account, on average, for $\approx 80\%$ of a bank's total assets, a similar regression with the proportion of loans as a dependent variable provides similar results with the opposite sign. The corresponding results are shown in Table A.4. Banks with lower expense betas hold significantly and substantially more loans. An expense beta of 1 would reduce the share of loans by almost 23% points compared to a bank with an expense beta of zero. These findings correspond to those in Section 6.4.1, where we found that banks with lower expense betas implement possible matching of expense and income sensitivities through higher loan maturity.

In summary, we find evidence for possible sensitivity alignment by banks through their loan maturities, especially for banks with a smaller income gap. Simultaneously, we find an opposing effect for the maturity of securities, resulting in a relatively less pronounced relationship for overall asset maturities. Additionally, banks with lower expense sensitivity hold significantly more loans, and banks with higher income gaps hold more securities if their expense sensitivity is higher—probably as a liquidity buffer.

6.5. Robustness of findings

We use the rich panel data structure of our sample with its many entities and replicate the results of the match of sensitivities presented in Section 6.2 within a panel regression setting. A detailed description of the implemented regression models and their corresponding results tables is presented in Appendix C. We find highly significant matching coefficients for banks'

[23] This is also reflected in the liquidity regulation of banks: much of a bank's liquidity reserve consists of highly liquid securities, such as long-term government bonds.

expense and income sensitivities of between 0.673 and 0.938, confirming the results of the cross-sectional analysis. We also find similar results for the positive relationship between the ROA and the NIM as an indicator of an income gap.

Our previous results show that a large proportion of the interest sensitivity of banks is matched, in line with the underlying model. However, the observed matching indicators may also be incidental, as some banks might face better lending facilities than others (Drechsler et al., 2021). In the context of the local restricted business models of the banks in our data sample, this might be a particular concern.[24] Following Drechsler et al. (2021), the securities market should have much lower segmentation and local restrictions, so we investigate the interest rate sensitivity of the banks' securities income. If market segmentation should drive the sensitivity matching, we expect to see no significant coefficients. To test this relationship, we re-run regression Equation (2) with a bank's securities beta as the dependent variable. The underlying model of Drechsler et al. (2021) now predicts no coefficient close to 1 (as this only applies for the total bank), but a positive relationship nonetheless. The results are presented in Table 13. We find a highly significant, positive relationship with a coefficient of 0.188. The coefficient for the largest banks of 0.123 is only significant at the 10% level. Generally, these results support the assumption of an active matching of interest sensitivities by banks.

As our analysis relies on yearly balance sheet data, we match it using the difference of the rolling 12-month average of the three-month EURIBOR. In further robustness analyses, we show that our results do not depend on a specific interest rate or calculation method. We replace the three-month EURIBOR rate by the deposit facility rate of the European Central Bank and use different methods to calculate the rolling 12-month average of the three-month EURIBOR. Specifically, we use the yearly, semiannual, and quarterly changes, either of the rolling mean (over three months) or the three-month difference of the interest rate, and use three lags to capture the initial period of a year. In general, the main findings are robust to these changes. The average sensitivities in the cross section vary dependent on the specific calculation. However, we always find a robust and significant income gap and significant

[24] For savings banks and credit cooperatives, there are substantial regional differences regarding loan volume and bank deposits between Western and Eastern Germany (see, e.g., Schildbach, 2019).

matching coefficients at similar levels, suggesting a high degree of aligned sensitivities but no indicators for a complete hedge of banks' NII. We obtain similar results when applying the panel regression approach with these settings. Moreover, the estimated relationship for the maturity of loans and the proportion of securities and loans remain similar. Table 14 contains an overview of the different methods and their corresponding coefficients.

6.6. Implication of derivatives usage

Our results suggest that banks have a positive exposure of their NII to fluctuating market rates but still align their sensitivities to a large degree via their loan maturities and the balance sheet proportions; this especially applies to banks with low income gaps. However, we cannot exclude that these results are also driven by interest rate derivatives, as these instruments influence interest income and expenses. To investigate the impact of derivatives on our previous results, we use information from banks' annual statements and disclosure reports on banks' use of derivatives to manage the interest rate risk. Information on the derivatives usage of banks is not included on their balance sheets and is thus absent from the Fitch Connect database. Therefore, the reports were manually collected and checked for statements on derivatives usage. For the banks in our sample, we have 6,361 reports for the period 2012 to 2019. Since we cannot infer reliable information about the direction of the derivatives, we merely split our sample into banks that use derivatives and those that do not.[25] If we identify a bank that uses derivatives at any point during the period, the dummy variable for derivatives use is one, and zero otherwise. We end up with 222 banks that do not use derivatives and 599 banks that do. These numbers contradict the existing literature, which emphasizes that banks, especially smaller and regional banks with traditional business models, rarely use derivatives.[26]

Finally, we repeat the major analysis presented in Sections 6.1, 6.2 and 6.4 for banks with and without derivatives usage. If derivatives do not influence our results, we expect no changes to our previous findings, especially for banks without derivatives. At first, we

[25] This approach is comparable to other studies in the literature dealing with banks' derivatives usage (e.g., Memmel, 2020; Drechsler et al., 2021).

[26] We admit our data collection is limited as our sample period is much longer than that for the annual statements and disclosure reports. However, extending the period would mostly reduce the number of banks without derivatives usage. Therefore, we claim our approach is valid for the purposes of this analysis.

find similar sensitivities for the group with no derivatives in use. Table 15 shows the corresponding mean values for the sensitivities in the sample. The average income gap for banks without derivatives is -0.084 and, based on a t-test, significantly higher than for banks with derivatives in use. Table 16 shows the regression results for the cross-sectional analysis. The alignment of expense and income sensitivities declines substantially. We still have a very linear and highly significant relationship for no-derivative banks, but the estimated coefficient is only 0.493. The relationship between income gap and ROA beta is not significant anymore, but 164 of 222 banks without derivatives usage show negative ROA sensitivities, indicating that, on average, these banks are exposed to rising interest rates. For the implementation of the alignment, we do not find any of our previous findings for banks without derivatives usage. Table 17 shows the regression results for the asset maturities, and Table 18 for the proportions of securities and loans. It is worth noting that we find more pronounced relationships in the regressions testing for alignment implementation for the sample consisting of banks that use derivatives. Consequently, we cannot exclude that the use of interest rate derivatives induces the findings of sensitivity alignment and corresponding implementation. Our results suggest that banks are exposed to the traditional income gap, which is induced by maturity transformation and eventually has to be limited by the use of derivatives.

7. Conclusion

In recent years, the fundamental understanding of interest rate risk has preoccupied economists in an ongoing debate on whether banks' stable net interest margins indicate independence from monetary policy shocks. The consensus in modern banking theory and reflected in the methods of European regulators stems from the causal linkage that, in the short run, NII declines when market rates increase due to the maturity overhang of fixed-rate and long-term assets. We took advantage of insights from recent literature and examined the interest rate risk of German savings banks and credit cooperatives.

Thereby, we provide three contributions. First, we contribute to the ongoing discussion on interest rate risk and maturity transformation by applying the model of Drechsler et al. (2021) to a sample of banks heavily engaged in maturity transformation due to their business models. Second, we show that the net interest margins of our sample are very insensitive to fluctuations in the market interest rate. However, we can still confirm a remaining exposure to market interest rates (gap risk). Third, we present evidence, contrary to the emerging literature, that banks' derivatives usage implies the alignment of banks' income and expense sensitivities rather than an implicit business model hedge.

Our results are relevant for banking regulators and supervisors, and particularly for supervisors concerned about rising levels of maturity transformation at savings banks and credit cooperatives in Germany. By focusing on banks with very traditional savings and loan businesses, our results provide insights into the discussion of these banks' interest rate risk, the relevance of their specific business model, and adequate regulation. Regarding the current and planned regulation of interest rate risk, our results do not imply that regulation neglects specific aspects of banks' business models. Concerning the exposure of banks' income to changing market rates, our results support the introduction of a regulatory threshold for the income-related risk measure in the EBA 2021 draft guidelines. The additional threshold adds a second dimension for banks' interest rate risk management with possible implications in opposition to the current threshold concerning the loss in a bank's economic value.

References

Adams, P., S. Hunt, C. Palmer, and R. Zaliauskas (2021). Testing the effectiveness of consumer financial disclosure: Experimental evidence from savings accounts. *Journal of Financial Economics 141*(1), 122–147.

Aharony, J., A. Saunders, and I. Swary (1986). The effects of a shift in monetary policy regime on the profitability and risk of commercial banks. *Journal of Monetary Economics 17*(3), 363–377.

Akella, S. R. and S. I. Greenbaum (1992). Innovations in interest rates, duration transformation, and bank stock returns. *Journal of Money, Credit and Banking 24*(1), 27–42.

Altavilla, C., L. Burlon, M. Giannetti, and S. Holton (2022). Is there a zero lower bound? The effects of negative policy rates on banks and firms. *Journal of Financial Economics 144*(3), 885–907.

Avouyi-Dovi, S., G. Horny, and P. Sevestre (2017). The stability of short-term interest rates pass-through in the euro area during the financial market and sovereign debt crises. *Journal of Banking & Finance 79*, 74–94.

Basel Committee on Banking Supervision (2016). Interest rate risk in the banking book, Standards. Bank for International Settlements, April 2016.

Basten, C. and M. Mariathasan (2018). How banks respond to negative interest rates: Evidence from the swiss exemption threshold. CESifo Working Paper Series 6901, CESifo.

Begenau, J., M. Piazzesi, and M. Schneider (2015). Banks' risk exposures. NBER Working Paper 21334, National Bureau of Economic Research.

Bhattacharya, S. and A. V. Thakor (1993). Contemporary banking theory. *Journal of Financial Intermediation 3*(1), 2–50.

Bologna, P. (2018). Banks' maturity transformation: Risk, reward, and policy. IMF Working Paper No. 18/45.

Borio, C., L. Gambacorta, and B. Hofmann (2017). The influence of monetary policy on bank profitability. *International Finance 20*(1), 48–63.

Brunnermeier, M. K. and Y. Koby (2019). The reversal interest rate. Working Paper 25406, National Bureau of Economic Research.

Bubeck, J., A. Maddaloni, and J.-L. Peydró (2020). Negative monetary policy rates and systemic banks' risk-taking: Evidence from the euro area securities register. *Journal of Money, Credit and Banking 52*(S1), 197–231.

Busch, R. and C. Memmel (2017). Banks' net interest margin and the level of interest rates. *Credit and Capital Markets 50*(3), 363–392.

Busch, R. and C. Memmel (2021). Why are interest rates on bank deposits so low? *Credit and Capital Markets 54*(4), 641–668.

de Haan, L. and J. W. van den End (2013). Banks' responses to funding liquidity shocks: Lending adjustment, liquidity hoarding and fire sales. *Journal of International Financial Markets, Institutions and Money 26*, 152–174.

Deutsche Bundesbank (2015). Comparison of the German MFI interest rate statistics (new business) and the Bundesbank's former survey of lending and deposit rates.

Deutsche Bundesbank (2019). Financial stability review 2019.

Deutsche Bundesbank (2021). Banking statistics. Tables of the statistical series, as of 29 October, 2021.

DeYoung, R. and C. Yom (2008). On the independence of assets and liabilities: Evidence from U.S. commercial banks, 1990-2005. *Journal of Financial Stability 4*(3), 275–303.

Di Tella, S. and P. Kurlat (2021). Why are banks exposed to monetary policy? *American Economic Journal: Macroeconomics 13*(4), 295–340.

Diamond, D. W. and P. H. Dybvig (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy 91*(3), 401–419.

Drechsler, I., A. Savov, and P. Schnabl (2017). The deposits channel of monetary policy. *Quarterly Journal of Economics 132*(4), 1819–1876.

Drechsler, I., A. Savov, and P. Schnabl (2021). Banking on deposits: Maturity transformation without interest rate risk. *The Journal of Finance 76*(3), 1091–1143.

Drehmann, M., S. Sorensen, and M. Stringa (2010). The integrated impact of credit and interest rate risk on banks: A dynamic framework and stress testing application. *Journal of Banking & Finance 34*(4), 713–729.

Driscoll, J. C. and R. A. Judson (2013). Sticky deposit rates. Finance and Economics Discussion Series 2013-80, Board of Governors of the Federal Reserve System (U.S.).

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

English, W. B., S. J. Van den Heuvel, and E. Zakrajšek (2018). Interest rate risk and bank equity valuations. *Journal of Monetary Economics 98*, 80–97.

Entrop, O., C. Memmel, B. Ruprecht, and M. Wilkens (2015). Determinants of bank interest margins: Impact of maturity transformation. *Journal of Banking & Finance 54*, 1–19.

European Banking Authority (2018). Guidelines on the management of interest rate risk arising from non-trading activities. EBA/GL/2018/02.

European Banking Authority (2021). Consultation paper – Draft guidelines on the management of interest rate risk and credit spread risk arising from non-trading book activities. EBA/CP/2021/37.

Flannery, M. J. and C. M. James (1984). Market evidence on the effective maturity of bank assets and liabilities. *Journal of Money, Credit and Banking 16*(4), 435–445.

Greenbaum, S. I., A. V. Thakor, and A. Boot (2015). *Contemporary financial intermediation.* Academic press.

Hannan, B. T. H. and A. N. Berger (1991). The rigidity of prices: Evidence from the banking industry. *The American Economic Review 81*(4), 938–945.

Heider, F., F. Saidi, and G. Schepens (2019). Life below zero: Bank lending under negative policy rates. *Review of Financial Studies 32*(10), 3727–3761.

Hellwig, M. F. (1994). *Banking and finance at the end of the twentieth century.* Basel: Wirtschaftswissenschaftliches Zentrum der Universität.

Hoffmann, P., S. Langfield, F. Pierobon, and G. Vuillemey (2019). Who bears interest rate risk? *The Review of Financial Studies 32*(8), 2921–2954.

Kerbl, S. and M. Sigmund (2017). Negative interest rates: Forecasting banks' profitability in a new environment. *SSRN Electronic Journal*.

Martinez-Miera, D. and R. Repullo (2017). Search for yield. *Econometrica 85*(2), 351–378.

Maudos, J. and J. Fernández de Guevara (2004). Factors explaining the interest margin in the banking sectors of the European Union. *Journal of Banking & Finance 28*(9), 2259–2281.

Memmel, C. (2020). What drives the short-term fluctuations of banks' exposure to interest rate risk? *Review of Financial Economics 38*(4), 674–686.

O'Brien, J. M. (2000). Estimating the value and interest rate risk of interest-bearing transactions deposits. *SSRN Electronic Journal*.

Purnanandam, A. (2007). Interest rate derivatives at commercial banks: An empirical investigation. *Journal of Monetary Economics 54*(6), 1769–1808.

Rajan, R. G. (2005). Has financial development made the world riskier? Working Paper 11728, National Bureau of Economic Research.

Rolfes, B. (1985). Die Entstehung von Zinsänderungsrisiken [The emergence of interest rate risks]. *Betriebswirtschaftliche Blätter 34*(11), 468–473.

Rolfes, B. (2001). Das Elastizitätskonzept der Zinsrisikosteuerung [The elasticity concept of interest rate risk management]. In H. Schierenbeck, B. Rolfes, and S. Schüller (Eds.), *Handbuch Bankcontrolling [Manual of bank controlling]* (Second ed.)., pp. 943–965. Wiesbaden: Gabler Verlag.

Schildbach, J. (2019). Private households in Germany: Regional differences in banking. Deutsche Bank Research.

Shaffer, S. and L. Spierdijk (2020). Measuring multi-product banks' market power using the Lerner index. *Journal of Banking & Finance 117*, 1–16.

Ulate, M. (2021). Going negative at the zero lower bound: The effects of negative nominal interest rates. *American Economic Review 111*(1), 1–40.

Urbschat, F. (2018). The good, the bad, and the ugly: Impact of negative interest rates and QE on the profitability and risk-taking of 1600 German banks. CESifo Working Paper Series 7358, CESifo.

Wagner, A. (1857). *Beiträge zur Lehre von den Banken [Contributions to Banking Theory]*. Leipzig: Voss.

Yankov, V. (2014). In search of a risk-free asset. *Finance and Economics Discussion Series 2014*(108), 1–50.

8. Tables

Table 1: Overview of variables

Variable	Description	Data source
Income statement		
$IntIncLoans_{i,t}$	Interest income from lending and money market transactions, relative to total assets	Bankscope and Fitch
$IntIncSecurities_{i,t}$	Interest income from fixed-income securities and debt register claims, relative to total assets	Bankscope and Fitch
$IncomeInv_{i,t}$	Income from shares and other variable-yield securities, equity investments, and associated companies, relative to total assets	Bankscope and Fitch
$IntInc_{i,t}$	Sum of $IntIncLoans_{i,t}$, $IntIncSecurities_{i,t}$ and $IncomeInv_{i,t}$	Bankscope and Fitch, own calc.
$IntExp_{i,t}$	Total interest expenses, relative to total assets	Bankscope and Fitch
$NII_{i,t}$	Net interest income, relative to total assets, interest income minus expenses	Bankscope and Fitch, own calc.
$NonIntExp_{i,t}$	Total non-interest expenses, relative to total assets, including personnel expenses and other operating expenses	Bankscope and Fitch
$NonIntInc_{i,t}$	Total non-interest operating income, relative to total assets, including net fees & commissions, net gains/losses on loans, securities and trading & derivatives, net insurance income, other operating income	Bankscope and Fitch
$NonIntRes_{i,t}$	Total non-interest operating result (net value of $NonIntExp_{i,t}$ and $NonIntInc_{i,t}$)	Bankscope and Fitch
$ROA_{i,t}$	Total operating profit divided by total assets (return on assets)	Bankscope and Fitch, own calc.

Continued on next page

Table 1 – continued from previous page

Variable	Description	Data source
Balance sheet positions		
$Loans_{i,t}$	Total position of (net) loans to customers and banks, relative to total assets	Bankscope and Fitch
$Securities_{i,t}$	Total position of bonds (without stocks), relative to total assets	Bankscope and Fitch
$SavDep_{i,t}$	Savings deposits, relative to total assets	Bankscope and Fitch
$CustDep_{i,t}$	Total customer deposits, consisting of current, savings, and term deposits, relative to total assets	Bankscope and Fitch
$Equity_{i,t}$	Total equity (on the balance sheet), relative to total assets	Bankscope and Fitch
$TA_{i,t}$	Total assets of a bank's balance sheet	Bankscope and Fitch
$ln(TA_{i,t})$	Natural logarithm of total assets	Bankscope and Fitch, own calc.
Maturities		
$AssetMaturity_{i,t}$	Average repricing maturity of loans and securities on a bank's balance sheet	Bankscope and Fitch, own calc.
$LoanMaturity_{i,t}$	Average repricing maturity of loans	Bankscope and Fitch, own calc.
$SecMaturity_{i,t}$	Average repricing maturity of securities	Bankscope and Fitch, own calc.
$LiabMaturity_{i,t}{}^{*}$	Average repricing maturity of all interest-bearing liabilities	Bankscope and Fitch, own calc.
$DepMaturity_{i,t}{}^{*}$	Average repricing maturity of all deposits (current, savings, and term)	Bankscope and Fitch, own calc.
Interest rates and market power		
$3MEuribor_t$	Monthly time series of the three-month EURIBOR. Before 1999, we use the corresponding FIBOR	Deutsche Bundesbank
$3MEur\_rm_t$	Rolling 12-month average of three-month EURIBOR time series	Deutsche Bundesbank, own calc.

Continued on next page

Table 1 – continued from previous page

Variable	Description	Data source
$DepFac_t$	The deposit facility rate of the central bank (European Central Bank and Deutsche Bundesbank)	Deutsche Bundesbank
$DepFac\_rm_t$	Rolling 12-month average of the deposit facility rate	Deutsche Bundesbank, own calc.
$Lerner_{i,t}$	Lerner index based on total assets. For exact calculation, see Appendix B	Bankscope and Fitch, own calc.
Results from time series regressions		
$ExpBeta_i$	Sensitivity of a bank's interest expenses to variation in the market interest rate	Regression result, based on Bankscope and Fitch
$IncBeta_i$	Sensitivity of a bank's interest income to variation in the market interest rate	Regression result, based on Bankscope and Fitch
$NIMBeta_i$	Sensitivity of a bank's net interest income to variation in the market interest rate	Regression result, based on Bankscope and Fitch
$ROABeta_i$	Sensitivity of a bank's ROA to variation in the market interest rate	Regression result, based on Bankscope and Fitch
$SecBeta_i$	Sensitivity of a bank's interest income from securities to variation in the market interest rate	Regression result, based on Bankscope and Fitch
$NonIntResBeta_i$	Sensitivity of a bank's total non-interest operating profit	Regression result, based on Bankscope and Fitch

*For the repricing maturity of non-maturity deposits, we use the corresponding contractual maturities of one day (demand deposits) and three months (savings deposits).

This table presents the definitions of the variables used for our analysis and the corresponding data sources. Except for the interest rates, all variables refer to the bank level.

Table 2: Descriptive statistics of variables

Panel A: All banks							
	mean	sd	min	p25	p50	p75	max
IntInc	0.0472	0.0058	0.0273	0.0441	0.0475	0.0506	0.0676
IntExp	0.0225	0.0053	0.0071	0.0193	0.0229	0.0258	0.0410
NII	0.0247	0.0030	0.0103	0.0231	0.0249	0.0265	0.0339
NonIntInc	0.0079	0.0026	0.0003	0.0068	0.0077	0.0089	0.0434
NonIntExp	0.0226	0.0042	0.0041	0.0204	0.0227	0.0248	0.0540
ROA	0.0072	0.0019	0.0023	0.0060	0.0071	0.0082	0.0175
Loans	0.6026	0.1015	0.2312	0.5538	0.6211	0.6713	0.8275
Securities	0.1956	0.0779	0.0286	0.1398	0.1802	0.2372	0.5785
SavDep	0.3229	0.0698	0.0356	0.2787	0.3200	0.3651	0.7447
CustDep	0.7359	0.0702	0.4211	0.6937	0.7391	0.7825	0.9278
Equity	0.0654	0.0144	0.0294	0.0558	0.0637	0.0727	0.1354
log(TotalAssets)	6.4847	1.1424	2.8567	5.7673	6.4570	7.2689	10.5609
AssetMaturity	4.1278	0.4908	2.4781	3.7901	4.1290	4.4758	5.8175
LoanMaturity	3.4654	0.5521	1.8210	3.0669	3.4162	3.8465	5.1349
SecMaturity	6.5518	0.3672	5.0294	6.3369	6.5787	6.7980	7.6250
LiabMaturity	0.6031	0.1738	0.1830	0.4850	0.5941	0.7111	1.4875
DepMaturity	0.3936	0.1347	0.1485	0.2949	0.3893	0.4786	1.0720
Lerner	0.2745	0.0527	0.0318	0.2402	0.2699	0.3017	0.5397
ExpBeta	0.1781	0.0608	0.0084	0.1400	0.1752	0.2106	0.4588
IncBeta	0.1028	0.0714	-0.3032	0.0607	0.0969	0.1402	0.4495
NIMBeta	-0.0753	0.0578	-0.3846	-0.1082	-0.0747	-0.0409	0.1974
ROABeta	-0.0407	0.1012	-0.4375	-0.1023	-0.0414	0.0199	0.5098
SecBeta	-0.0102	0.0495	-0.2598	-0.0367	-0.0100	0.0156	0.2469
NonIntResBeta	0.0107	0.0501	-0.2117	-0.0181	0.0110	0.0386	0.2489
Banks	1,056						

Continued on next page

Table 2 – continued from previous page

Panel B: Top 10% banks							
	mean	sd	min	p25	p50	p75	max
IntInc	0.0474	0.0053	0.0341	0.0450	0.0478	0.0509	0.0650
IntExp	0.0254	0.0040	0.0145	0.0228	0.0253	0.0281	0.0399
NII	0.0220	0.0034	0.0103	0.0207	0.0224	0.0240	0.0279
NonIntInc	0.0065	0.0018	0.0011	0.0057	0.0068	0.0075	0.0097
NonIntExp	0.0188	0.0039	0.0041	0.0172	0.0196	0.0212	0.0262
ROA	0.0071	0.0018	0.0031	0.0060	0.0070	0.0082	0.0133
Loans	0.5953	0.1162	0.2533	0.5619	0.6236	0.6747	0.7628
Securities	0.1916	0.0765	0.0709	0.1427	0.1767	0.2207	0.5038
SavDep	0.2925	0.0750	0.0356	0.2464	0.2874	0.3434	0.4882
CustDep	0.7078	0.0792	0.5312	0.6627	0.7067	0.7609	0.9278
Equity	0.0588	0.0123	0.0312	0.0516	0.0581	0.0657	0.0929
log(TotalAssets)	8.4843	0.5044	7.9283	8.1110	8.3604	8.7627	10.5609
AssetMaturity	4.2883	0.4436	2.9955	3.9791	4.3667	4.5661	5.2966
LoanMaturity	3.5495	0.5595	1.8919	3.2206	3.6164	3.9410	4.5782
SecMaturity	6.5151	0.3470	5.2430	6.3219	6.5388	6.7749	7.1684
LiabMaturity	0.6606	0.1759	0.2445	0.5281	0.6335	0.7734	1.1131
DepMaturity	0.4462	0.1404	0.1918	0.3459	0.4344	0.5237	0.9099
Lerner	0.2745	0.0533	0.1815	0.2336	0.2723	0.3011	0.5316
ExpBeta	0.2148	0.0813	0.0103	0.1601	0.2075	0.2667	0.4425
IncBeta	0.1553	0.0902	-0.1299	0.1000	0.1445	0.1972	0.4495
NIMBeta	-0.0595	0.0537	-0.3846	-0.0857	-0.0537	-0.0271	0.0552
ROABeta	-0.0278	0.0848	-0.2726	-0.0724	-0.0295	0.0229	0.2180
SecBeta	0.0074	0.0545	-0.1754	-0.0207	0.0044	0.0396	0.1780
NonIntResBeta	0.0041	0.0362	-0.1684	-0.0171	0.0049	0.0237	0.0835
Banks	106						

This table presents summary statistics for the variables described in Table 1 for the total sample in Panel A, and for the largest 10% of the banks in Panel B.

Table 3: Descriptive statistics: Additional t-tests

	(1) LowBeta mean	(2) HighBeta mean	(3) Low-High MeanDiff	(4) LowDiff mean	(5) HighDiff mean	(6) Low-High MeanDiff	(7) Small-Big MeanDiff
IntInc	0.0470	0.0474	-0.0004	0.0475	0.0469	0.0007*	-0.0002
IntExp	0.0221	0.0229	-0.0008**	0.0230	0.0219	0.0011***	-0.0033***
NII	0.0249	0.0246	0.0004*	0.0245	0.0249	-0.0004**	0.0031***
NonIntInc	0.0079	0.0080	0.0000	0.0078	0.0081	-0.0003*	0.0016***
NonIntExp	0.0228	0.0224	0.0004*	0.0225	0.0227	-0.0002	0.0043***
ROA	0.0072	0.0071	0.0001	0.0069	0.0074	-0.0005***	0.0001
Loans	0.6058	0.5994	0.0065	0.6008	0.6044	-0.0035	0.0081
Securities	0.1944	0.1969	-0.0025	0.1893	0.2020	-0.0127***	0.0045
SavDep	0.3346	0.3111	0.0235***	0.3293	0.3165	0.0128***	0.0338***
CustDep	0.7380	0.7338	0.0042	0.7391	0.7327	0.0063	0.0312***
Equity	0.0673	0.0634	0.0039***	0.0643	0.0664	-0.0021**	0.0073***
log(TotalAssets)	6.3287	6.6407	-0.3120***	6.6299	6.3395	0.2904***	-2.2227***
AssetMaturity	4.1506	4.1050	0.0456	4.1107	4.1449	-0.0341	-0.1784***
LoanMaturity	3.5087	3.4222	0.0866**	3.4522	3.4787	-0.0264	-0.0934
SecMaturity	6.5513	6.5523	-0.0010	6.5512	6.5524	-0.0011	0.0408
LiabMaturity	0.5867	0.6195	-0.0328***	0.6080	0.5982	0.0099	-0.0639***
DepMaturity	0.3729	0.4143	-0.0414***	0.4017	0.3855	0.0162*	-0.0585***
Lerner	0.2735	0.2756	-0.0021	0.2696	0.2796	-0.0101***	-0.0000
ExpBeta	0.1325	0.2238	-0.0913***	0.1654	0.1908	-0.0254***	-0.0408***
IncBeta	0.0721	0.1336	-0.0616***	0.1293	0.0763	0.0530***	-0.0583***
NIMBeta	-0.0604	-0.0902	0.0297***	-0.0361	-0.1145	0.0784***	-0.0175***
ROABeta	-0.0367	-0.0448	0.0081	-0.0308	-0.0507	0.0199***	-0.0144
SecBeta	-0.0186	-0.0019	-0.0168***	-0.0007	-0.0198	0.0191***	-0.0196***
NonIntResBeta	0.0107	0.0107	0.0000	0.0015	0.0199	-0.0184***	0.0074*
Banks	528	528	1,056	528	528	1,056	1,056

This table presents summary statistics for the variables described in Table 1, differentiated by low/high expense beta and low/high beta difference banks. To split the sample of all banks into low and high, we use the respective median values for the expense beta and the difference between expense and income beta. We test the subsample means for significant differences. Columns (3) and (6) show the difference in the means. The last column (7) presents the mean difference between all banks and the largest 10% of banks in the sample and the respective significance. Significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 4: IncBeta on ExpBeta regression

Panel A - IncBeta on ExpBeta

	(1) All Banks	(2) LowGap	(3) HighGap	(4) Top 10%
ExpBeta	0.737***	0.913***	0.809***	0.897***
	(0.037)	(0.026)	(0.053)	(0.105)
Constant	-0.029***	-0.022***	-0.078***	-0.037*
	(0.007)	(0.005)	(0.011)	(0.021)
Banks	1,056	528	528	106
R^2	0.395	0.777	0.452	0.655

Panel B - NIMBeta on ExpBeta

	(1) All Banks	(2) LowGap	(3) HighGap	(4) Top 10%
ExpBeta	-0.263***	-0.087***	-0.191***	-0.103
	(0.037)	(0.026)	(0.053)	(0.105)
Constant	-0.029***	-0.022***	-0.078***	-0.037*
	(0.007)	(0.005)	(0.011)	(0.021)
Banks	1,056	528	528	106
R^2	0.076	0.031	0.044	0.024

Panel A of this table presents the results for the regression according to Equation (2). Panel B shows the result of the cross-sectional regression according to Equation (2) with the NIM beta as dependent variable. Low- and high-gap banks are banks with an absolute difference in income and expense beta below or above the median of the sample. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 5: ROABeta on NIMBeta regression

	(1) All Banks	(2) LowGap	(3) HighGap	(4) Top 10%
NIMBeta	0.363***	0.212*	0.544***	0.407*
	(0.056)	(0.120)	(0.097)	(0.217)
Constant	-0.013***	-0.023***	0.012	-0.004
	(0.005)	(0.006)	(0.012)	(0.014)
Banks	1,056	528	528	106
R^2	0.043	0.005	0.068	0.066

This table shows the result of the cross-sectional regression according to Equation (2), with the ROA beta as dependent and the NIM beta as independent variable. Low- and high-gap banks are banks with an absolute difference in income and expense beta below or above the median of the sample. Top 10% represent the largest 10% of banks in the sample. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 6: NIMBeta on NonIntResBeta regression

	(1) All Banks	(2) LowGap	(3) HighGap	(4) Top 10%
NonIntResBeta	-0.269***	-0.049	-0.209***	-0.390**
	(0.042)	(0.030)	(0.060)	(0.156)
Constant	-0.072***	-0.036***	-0.110***	-0.058***
	(0.002)	(0.001)	(0.003)	(0.005)
Banks	1,056	528	528	106
R^2	0.055	0.006	0.040	0.069

This table shows the result of the cross-sectional regression according to Equation (2), with the NIM beta as dependent and the non-interest operating income beta (balance of non-interest expenses and non-interest operating income) as independent variable. Low- and high-gap banks are banks with an absolute difference in income and expense beta below or above the median of the sample. Top 10% represent the largest 10% of banks in the sample. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 7: Market power and sensitivity matching

	(1) Stage 1	(2) Stage 2	(3) Stage 1	(4) Stage 2
Lerner	-0.009***		-0.016***	
	(0.0002)		(0.0054)	
δ		0.584***		0.774***
		(0.0169)		(0.0152)
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	No	Yes	Yes
Obs	24,236	24,236	24,236	24,236
R^2	0.467	0.165	0.646	0.279

This table presents the results for the panel estimation of the relationship between a bank's market power, approximated by the Lerner index (see Appendix B) and its interest expense sensitivity, and the subsequent matching of income and expense sensitivities based on the first stage regression as outlined in Equation (3). Columns (1) and (3) represent the first stage regression, columns (2) and (4) the subsequent second stage. Bank-fixed effects are implemented in columns (1) and (2), bank and time-fixed effects in columns (3) and (4). Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 8: Repricing maturity of assets

Panel A - All banks

	(1)	(2)	(3)	(4)	(5)
ExpBeta	-0.454*	-0.168	-0.807***	-1.029***	-0.821***
	(0.268)	(0.295)	(0.260)	(0.265)	(0.282)
SavDep		0.983***			1.195***
		(0.291)			(0.269)
Equity			-7.994***		-4.144***
			(1.116)		(1.157)
log(TotalAssets)				0.141***	0.130***
				(0.012)	(0.014)
Constant	4.209***	3.840***	4.794***	3.396***	3.314***
	(0.049)	(0.125)	(0.092)	(0.089)	(0.185)
Banks	1,056	1,056	1,056	1,056	1,056
R^2	0.003	0.021	0.056	0.106	0.148

Panel B - Top 10% banks

	(1)	(2)	(3)	(4)	(5)
ExpBeta	-0.748	-0.282	-0.738	-0.619	-0.213
	(0.619)	(0.617)	(0.622)	(0.635)	(0.627)
SavDep		1.170*			1.124*
		(0.646)			(0.664)
Equity			0.392		-0.172
			(3.702)		(3.778)
log(TotalAssets)				-0.069	-0.049
				(0.077)	(0.077)
Constant	4.449***	4.007***	4.424***	5.006***	4.430***
	(0.122)	(0.247)	(0.254)	(0.630)	(0.758)
Banks	106	106	106	106	106
R^2	0.019	0.051	0.019	0.024	0.053

This table presents the results for the regression according to Equation (5). Panel A includes all banks in the sample, Panel B the largest 10% of the banks. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 9: Repricing maturity of loans and securities

Panel A - All banks

	(1) All Assets	(2) Loans	(3) Securities
ExpBeta	-0.821***	-1.877***	0.502**
	(0.282)	(0.296)	(0.204)
SavDep	1.195***	0.339	0.369**
	(0.269)	(0.252)	(0.183)
Equity	-4.144***	-4.195***	-1.061
	(1.157)	(1.220)	(0.915)
log(TotalAssets)	0.130***	0.164***	-0.055***
	(0.014)	(0.015)	(0.011)
Constant	3.314***	2.903***	6.771***
	(0.185)	(0.188)	(0.140)
Banks	1,056	1,056	1,056
R^2	0.148	0.161	0.034

Panel B - Top 10% banks

	(1) All Assets	(2) Loans	(3) Securities
ExpBeta	-0.213	-3.600***	1.284***
	(0.627)	(0.605)	(0.473)
SavDep	1.124*	-1.230*	0.465
	(0.664)	(0.695)	(0.444)
Equity	-0.172	7.465	-1.997
	(3.778)	(4.841)	(2.660)
log(TotalAssets)	-0.049	0.028	-0.204*
	(0.077)	(0.109)	(0.112)
Constant	4.430***	4.004***	7.950***
	(0.758)	(1.035)	(1.018)
Banks	106	106	106
R^2	0.053	0.270	0.122

This table presents the results for the regression according to Equation (5), differentiated for the repricing maturity of loans and securities. Panel A includes all banks in the sample, Panel B the largest 10% of the banks. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 10: Repricing maturity of loans and securities separated for low/high beta difference banks

	(1)	(2)	(3)	(4)	(5)	(6)
	All assets		Loans		Securities	
	LowGap	HighGap	LowGap	HighGap	LowGap	HighGap
ExpBeta	-1.686***	-0.342	-2.869***	-1.356***	0.782***	0.277
	(0.423)	(0.403)	(0.430)	(0.434)	(0.278)	(0.322)
SavDep	1.081***	1.308***	0.007	0.654**	0.346	0.405
	(0.362)	(0.367)	(0.351)	(0.326)	(0.257)	(0.269)
Equity	-7.673***	-0.954	-6.101***	-2.918*	-2.363*	0.264
	(1.457)	(1.679)	(1.613)	(1.739)	(1.221)	(1.330)
log(TotalAssets)	0.127***	0.151***	0.146***	0.208***	-0.058***	-0.061***
	(0.019)	(0.021)	(0.021)	(0.021)	(0.015)	(0.019)
Constant	3.685***	2.901***	3.347***	2.408***	6.847***	6.742***
	(0.258)	(0.250)	(0.257)	(0.261)	(0.188)	(0.205)
Banks	528	528	528	528	528	528
R^2	0.206	0.140	0.186	0.188	0.043	0.037

This table presents the results for the regression according to Equation (5), differentiated for the repricing maturity of loans and securities and for banks with low and high differences in their expense and income betas. We use the median difference to split the sample into low and high banks. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 11: Share of securities

Panel A - All banks

	(1)	(2)	(3)	(4)	(5)
ExpBeta	0.047	0.115***	0.051	0.074	0.133***
	(0.045)	(0.045)	(0.046)	(0.045)	(0.045)
SavDep		0.236***			0.227***
		(0.047)			(0.048)
Equity			0.099		-0.016
			(0.187)		(0.195)
log(TotalAssets)				-0.007***	-0.005**
				(0.002)	(0.002)
Constant	0.187***	0.099***	0.180***	0.226***	0.133***
	(0.008)	(0.018)	(0.016)	(0.016)	(0.033)
Banks	1,056	1,056	1,056	1,056	1,056
R^2	0.001	0.043	0.002	0.010	0.049

Panel B - Top 10% banks

	(1)	(2)	(3)	(4)	(5)
ExpBeta	0.246*	0.390***	0.221*	0.316**	0.416***
	(0.125)	(0.112)	(0.124)	(0.125)	(0.116)
SavDep		0.362**			0.326**
		(0.142)			(0.138)
Equity			-1.003		-1.429**
			(0.637)		(0.669)
log(TotalAssets)				-0.038**	-0.040**
				(0.015)	(0.017)
Constant	0.139***	0.002	0.203***	0.442***	0.434**
	(0.024)	(0.047)	(0.047)	(0.116)	(0.176)
Banks	106	106	106	106	106
R^2	0.069	0.171	0.094	0.124	0.257

This table presents the results for the regression according to Equation (6). Panel A includes all banks in the sample, Panel B the largest 10% of the banks. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 12: Share of securities separated for low/high beta difference banks

	(1) LowGap	(2) HighGap
ExpBeta	0.063	0.168**
	(0.061)	(0.071)
SavDep	0.256***	0.204***
	(0.058)	(0.078)
Equity	-0.396	0.371
	(0.254)	(0.284)
log(TotalAssets)	-0.002	-0.007*
	(0.003)	(0.004)
Constant	0.134***	0.127***
	(0.042)	(0.049)
Banks	528	528
R^2	0.060	0.053

This table presents the results for the regression according to Equation (6), differentiated for banks with low and high differences in their expense and income betas. We use the median difference to split the sample into low and high banks. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 13: SecBeta on ExpBeta regression

	(1) All banks	(2) LowGap	(3) HighGap	(4) Top 10%
ExpBeta	0.188***	0.223***	0.240***	0.123*
	(0.028)	(0.036)	(0.043)	(0.073)
Constant	-0.044***	-0.038***	-0.066***	-0.019
	(0.005)	(0.006)	(0.008)	(0.015)
Banks	1,056	528	528	106
R^2	0.053	0.088	0.073	0.034

This table shows the result of the cross-sectional regression according to Equation (2), with the estimated securities beta as dependent variable. Low and high gap banks are banks with an absolute difference in income and expense beta below or above the median of the sample. Top 10% represent the largest 10% of banks in the sample. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 14: Robustness: Overview of main results

	(1)	(2)	(3)	(4)	(5)	(6)
Interest rate	DepFac			3MEURIBOR		
Calculation method		Rolling mean			Time series difference	
Number of lags/difference	0, 12m	3, 3m	0, 12m	0, 12m	3, 3m	1, 6m
Min. years per bank	15	15	7	15	15	15
Mean over all banks in sample						
ExpBeta	0.2093	0.3579	0.1804	0.0880	0.3188	0.1541
IncBeta	0.1110	0.2411	0.1068	0.0457	0.2153	0.0764
NIMBeta	-0.0983	-0.1168	-0.0736	-0.0423	-0.1035	-0.0777
ROABeta	-0.0781	0.0816	-0.0420	-0.0112	0.0716	-0.0173
SecBeta	-0.0084	0.0184	-0.0136	-0.0097	0.0112	-0.0194
Market power - ExpBeta und Lerner index						
Lerner^{BFE}	-0.0036***	-0.4210***	-0.0037***	-0.0035***	-0.4800***	-0.144***
Matching^{BFE}	0.576***	0.666***	0.584***	0.579***	0.680***	0.668***
Lerner^{BTFE}	-0.0095***	-0.1220**	-0.0112***	-0.0094***	-0.0770**	-0.0270***
Matching^{BTFE}	0.776***	0.624***	0.755***	0.785***	0.608***	0.639***
Matching						
IncBeta - ExpBeta						
cross-section	0.658***	0.718***	0.609***	0.708***	0.691***	0.740***
panel^{BFE}	0.574***	0.820***	0.612***	-0.238***	0.734***	0.814***
panel^{BTFE}	0.668***	0.729***	0.499***	0.587***	0.702***	0.710***
ROABeta - NIMBeta						
cross-section	0.284***	0.203	0.318***	0.307***	0.272**	0.308***
panel^{BFE}	0.680***	0.318***	0.192***	-0.004	0.297***	0.276***
panel^{BTFE}	0.312***	0.316***	0.204***	0.347***	0.303***	0.300***
ROABeta - NonIntResultBeta						
cross-section	0.229***	0.495***	0.306***	0.235***	0.523***	0.262***
panel^{BFE}	0.110	0.334***	0.233***	0.318***	0.335***	0.245***
panel^{BTFE}	0.179***	0.264***	0.161***	0.202***	0.276***	0.224***

Continued on next page

Table 14 – continued from previous page

	(1)	(2)	(3)	(4)	(5)	(6)
Interest rate	DepFac	3MEURIBOR				
Calculation method	Rolling mean			Time series difference		
Number of lags/difference	0, 12m	3, 3m	0, 12m	0, 12m	3, 3m	1, 6m
Min. years per bank	15	15	7	15	15	15
Implementation of matching						
Repricing maturities						
All assets	-0.572**	-0.180***	-0.519**	-0.831**	-0.195**	-0.440***
Loans	-1.235***	-0.338***	-1.260***	-2.208***	-0.403***	-1.134***
Securities	0.225	0.167***	0.449***	0.311	0.130**	0.203
Share of securities and loans						
Securities	0.119***	0.004	0.092***	0.142**	0.016	0.056**
Loans	-0.189***	-0.023	-0.171***	-0.268***	-0.043**	-0.116***
Matching securities portfolio						
SecBeta - ExpBeta	-0.176***	0.118***	0.076***	0.148***	0.112***	0.166***
Number of banks	1,054	1,056	1,532	1,015	1,015	1,026

^{BFE}bank fixed effects
^{BTFE}bank and time fixed effects

This table gives an overview of the major results for our analysis for varying settings. We first replace the three-month EURIBOR by the deposit facility of the European Central Bank (before the start of European Central Bank in 1999, we use the corresponding rate from the Deutsche Bundesbank). We also change the time period of interest rate changes and use quarterly changes with three additional lags or semiannual changes and one additional lag to match our yearly changes from the balance sheet data. Lastly, we replace the rolling mean by the respective difference of the three-month EURIBOR time series. The difference in the number of banks with the same number of minimum years in a bank's time series comes from different numbers of negative expense betas, which we exclude for further analysis as outlined in Section 6.1. Additionally, we winsorize the data with at least seven years of observations in column (3) on a 5% level to account for an increased number of extreme values. Significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 15: Overview of results: Sensitivities for use of derivatives

	(1)	(2)
Mean	use: no	use: yes
ExpBeta	0.1756	0.1802
IncBeta	0.0913	0.1101
NIMBeta	-0.0844	-0.0701
ROABeta	-0.0595	-0.0287
NonIntResBeta	0.0076	0.0112
SecBeta	-0.0197	-0.0061
Banks	222	599

This table shows the means of beta values as results of the time series regressions according to Equation (1), differentiated for the use of derivatives. Banks with no information on derivatives use accessible are excluded from this analysis.

Table 16: Overview of results: Matching coefficients for use of derivatives

	(1)	(2)	(3)	(4)	(5)	(6)
	IncBeta		ROABeta		ROABeta	
	use: no	use: yes	use: no	use: yes	use: no	use: yes
ExpBeta	0.493***	0.823***				
	(0.067)	(0.050)				
NIMBeta			0.182	0.392***		
			(0.137)	(0.070)		
DiffBeta					-0.112	-0.454***
					(0.169)	(0.076)
Constant	0.005	-0.038***	-0.044***	-0.001	-0.050***	0.005
	(0.012)	(0.009)	(0.013)	(0.006)	(0.016)	(0.007)
Banks	222	599	222	599	222	599
R^2	0.211	0.493	0.009	0.051	0.002	0.054

This table shows the regression coefficients for the cross-sectional relationship between the income and expense beta, and the ROA and the (absolute) difference in income and expense beta, according to Equation (2), differentiated for the use of derivatives. Banks with no information on derivatives use accessible are excluded from this analysis. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 17: Overview of results: Asset maturity differentiated for use of derivatives

	(1)	(2)	(3)	(4)	(5)	(6)
	All assets		Loans		Securities	
	use: no	use: yes	use: no	use: yes	use: no	use: yes
ExpBeta	0.353	-0.994***	-0.184	-2.568***	0.486	0.446*
	(0.673)	(0.333)	(0.790)	(0.366)	(0.387)	(0.251)
Constant	3.455***	3.279***	2.985***	3.079***	5.956***	6.492***
	(0.335)	(0.240)	(0.384)	(0.262)	(0.248)	(0.206)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Banks	222	599	222	599	222	599
R^2	0.072	0.141	0.085	0.126	0.044	0.016

This table shows the result of the cross-sectional regression according to Equation (5) for the overall mean repricing maturity of a bank's assset, a bank's loans and a bank's securities, differentiated for the use of derivatives. Banks with no information on derivatives use accessible are excluded from this analysis. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 18: Overview of results: Share of loans and securities differentiated for use of derivatives

	(1)	(2)	(3)	(4)
	Share of loans		Share of securities	
	use: no	use: yes	use: no	use: yes
ExpBeta	-0.130	-0.344***	0.169	0.239***
	(0.135)	(0.077)	(0.110)	(0.058)
Constant	0.760***	0.682***	0.129*	0.128**
	(0.083)	(0.066)	(0.069)	(0.050)
Controls	Yes	Yes	Yes	Yes
Banks	222	599	222	599
R^2	0.105	0.114	0.060	0.088

This table shows the result of the cross-sectional regression according to Equation (5) for the overall mean repricing maturity of a bank's assset, a bank's loans and a bank's securities, differentiated for the use of derivatives. Banks with no information on derivatives use accessible are excluded from this analysis. Robust standard errors are reported in parentheses, significance levels are indicated by indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

9. Figures

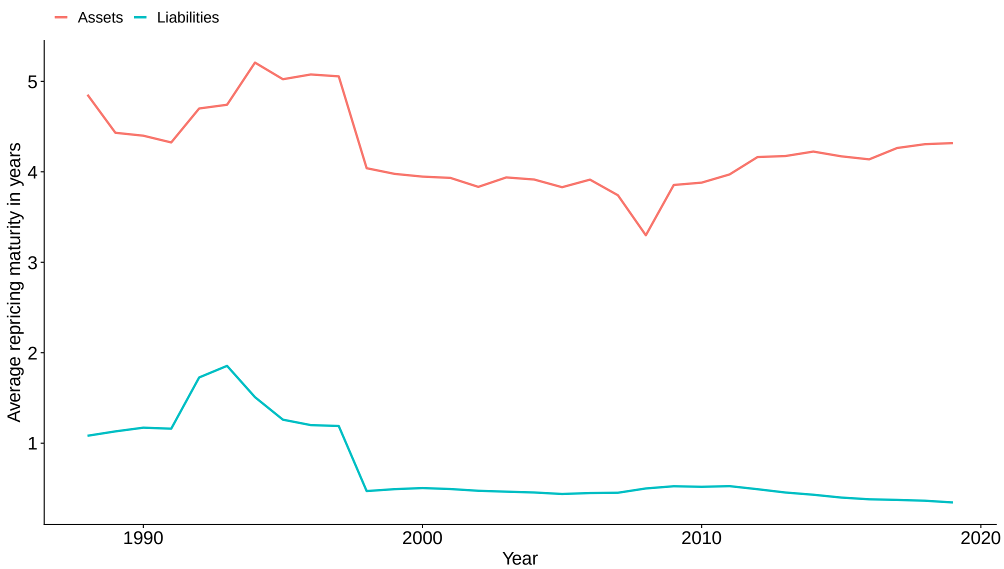


Figure 1: Aggregated repricing maturities of bank assets and liabilities

This figure displays the average repricing maturities for the savings banks and credit cooperatives in our sample from 1999 until 2018. The repricing maturities are calculated in years. The maturities of the banks' liabilities are calculated using the contractual maturity, including demand and savings deposits.

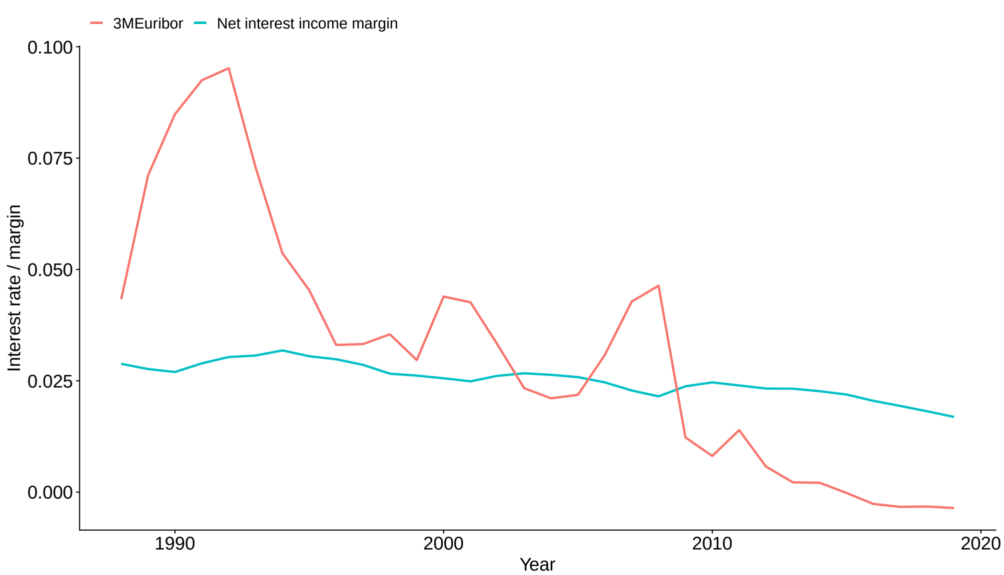


Figure 2: Aggregated net interest income margin of savings banks and credit cooperatives

This figure displays the average net interest income margin (net interest income relative to a bank's total assets) for the savings banks and credit cooperatives in our sample and the three-month EURIBOR from 1999 until 2018. Before 1999, we use the three-month FIBOR.

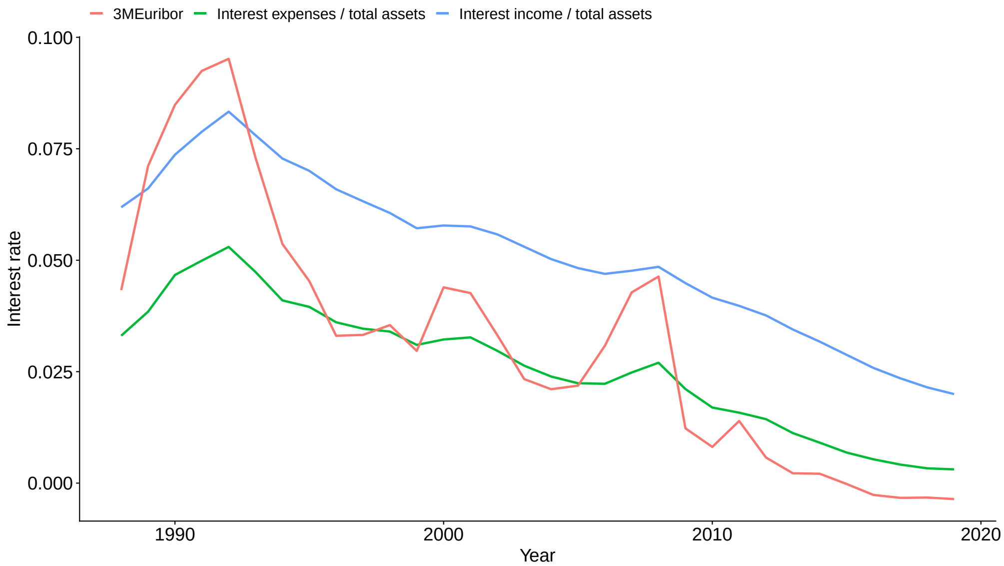


Figure 3: Aggregated interest income and expenses of savings banks and credit cooperatives

This figure displays the average interest income and interest expenses (relative to a bank's total assets) for the savings banks and credit cooperatives in our sample and the three-month EURIBOR from 1999 until 2018. Before 1999, we use the three-month FIBOR.

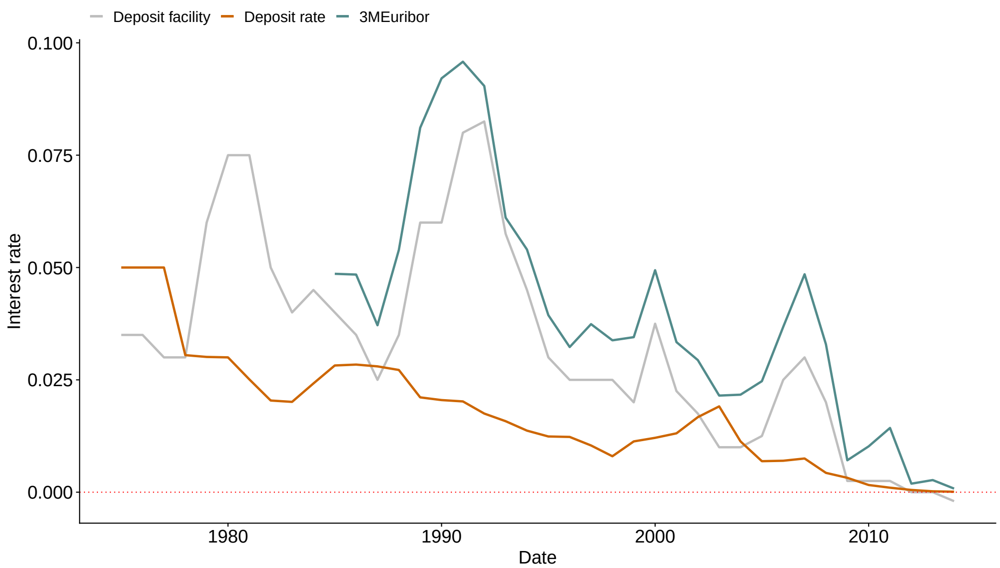
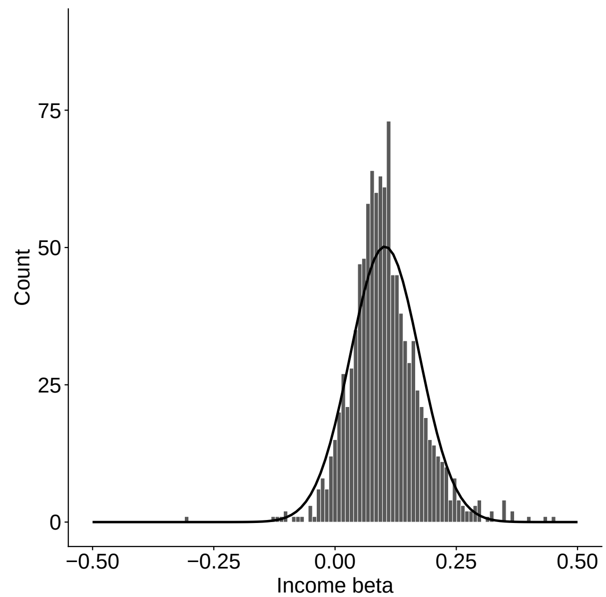
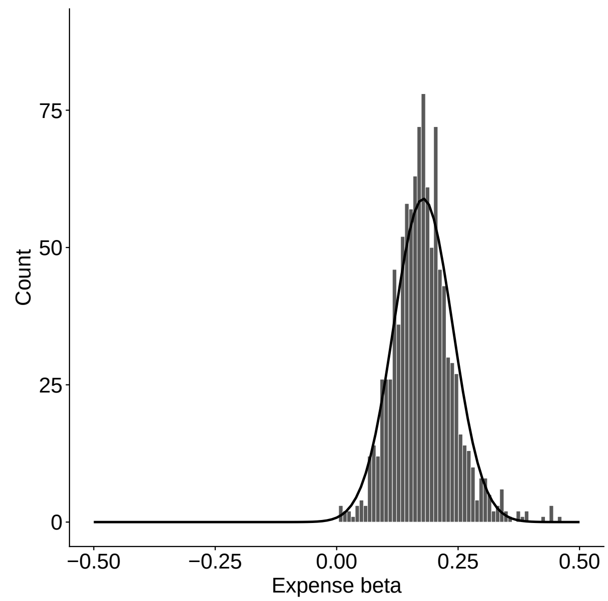


Figure 4: Comparison of the deposit rate, deposit facility and market interest rate in Germany since 1975

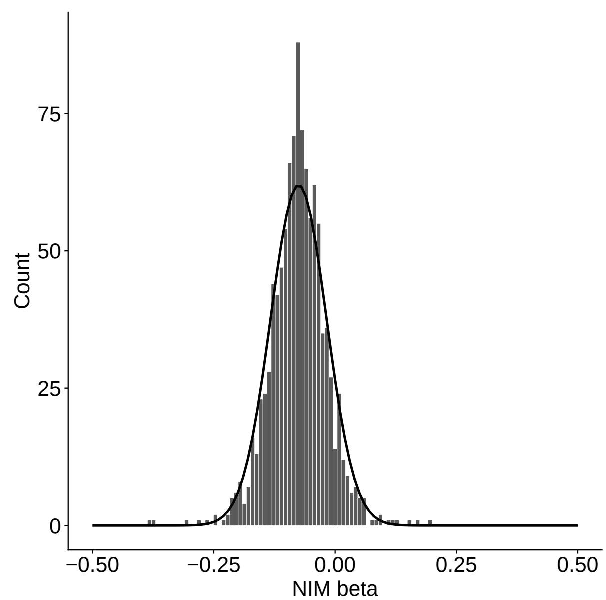
This figure displays the European Central Bank deposit facility (before the start of the European Central Bank in 1999, we use the corresponding interest rate of the Deutsche Bundesbank), a consolidated interest rate for deposits in Germany and the three-month EURIBOR. The deposit rate stems from Deutsche Bundesbank and reflects the average rate for all banks in Germany. It represents the most frequently agreed interest rates for deposits with agreed minimum rates of return (without premium or bonus program) and notice of three months—referred to as savings deposits "at statutory notice". The reported mean values concern nominal interest rates most commonly realized in new contracts or extensions of existing agreements. Since 2003, interest rate statistics have been harmonized across European member states, and due to technical changes in reporting standards, the subsequent time series for the same product category is not comparable. For this reason, this figure plots the mean values for agreed conditions regarding overnight deposits from households for 2003 onward. The aggregated means are now volume-weighted average interest rates, covering all types of daily deposits whether interest-bearing or not (Deutsche Bundesbank, 2015). The dotted line represents the interest rate of zero percent. The three-month EURIBOR and the corresponding FIBOR before 1999, which we use in the primary analysis, show a development very similar to the deposit facility.



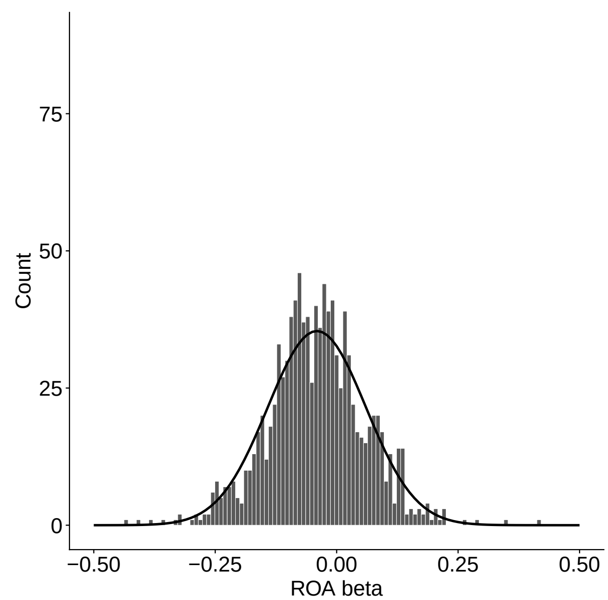
(a) Histogram of interest income betas



(b) Histogram of interest expense betas



(c) Histogram of NIM betas



(d) Histogram of ROA betas

Figure 5: Histograms of estimated interest rate sensitivities

This figure displays the distributions of the estimated betas of banks' interest income, interest expenses, NIM, and ROA according to Equation (1) in (a), (b), (c), and (d) respectively. The NIM beta reflects the difference between a bank's expense and income beta. For all four histograms, the scales of the x-axis and the y-axis are identical. The dark line represents a normal distribution based on each beta's mean and standard deviation.

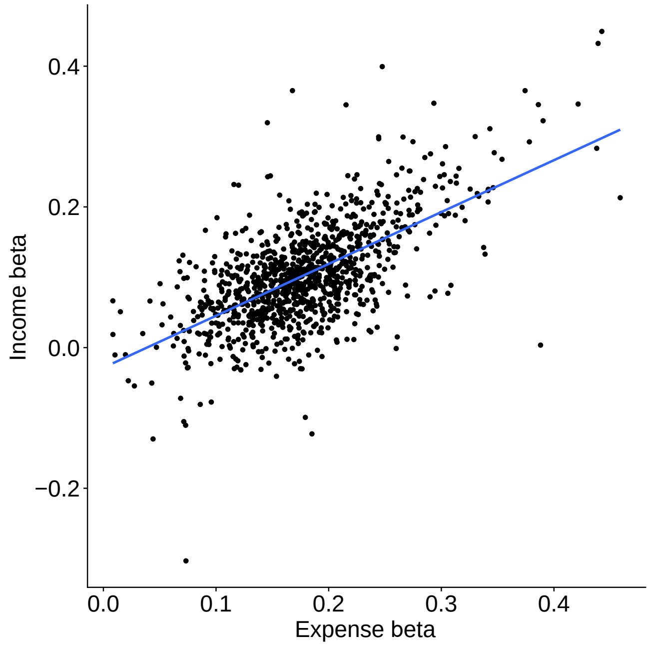


Figure 6: Relationship between income and expense betas

This figure shows a scatter plot of banks' income and expense betas estimated according to Equation (1). The blue line represents the regression line estimated analogous to Equation (2).

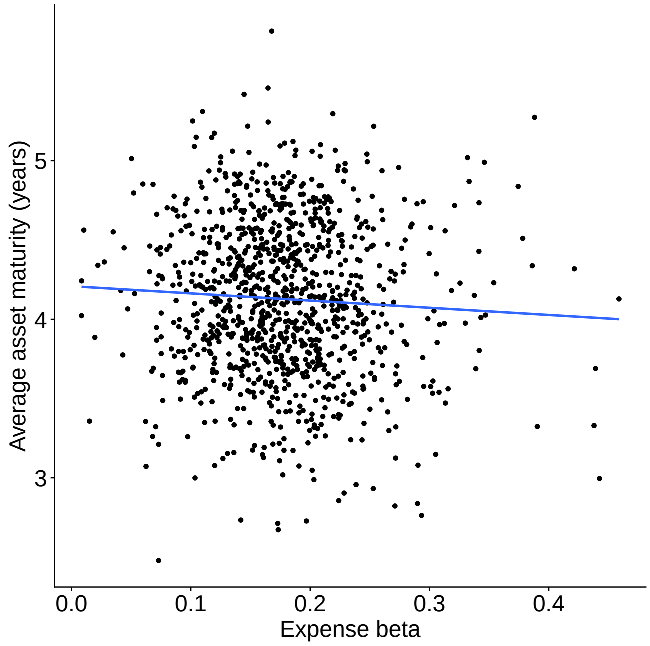


Figure 7: Relationship between asset maturity and expense betas

This figure shows a scatter plot of banks' average asset repricing maturities and expense betas estimated according to Equation (1). The blue line represents the regression line estimated analogous to Equation (2).

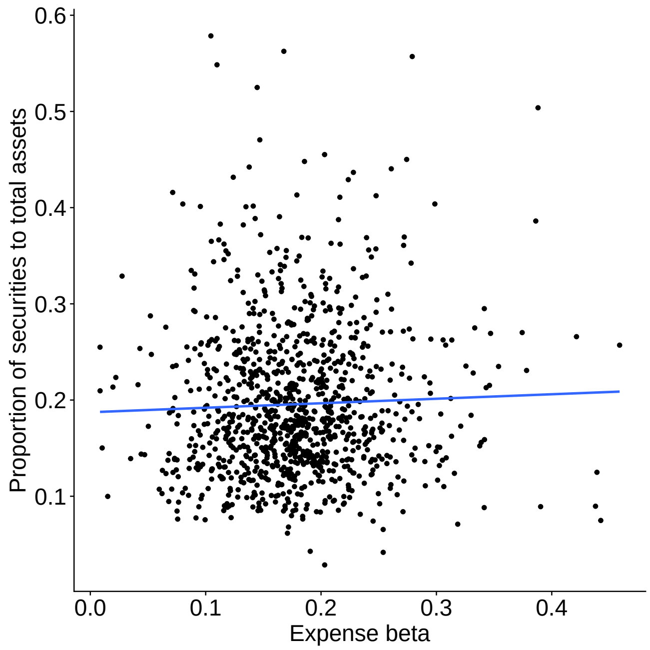


Figure 8: Relationship between shares of securities and expense betas

This figure shows a scatter plot of banks' average proportion of securities and expense betas estimated according to Equation (1). The blue line represents the regression line estimated analogous to Equation (2).

Appendix A. Additional tables

Table A.1: Sample selection process

	Number of banks	
	Savings banks	Credit cooperatives
Banks from Fitch Connect and Bankscope (1988–2019)	640	1,892
Keep only banks in the sample		
with no missing data on key balance sheet positions	640	1,884
with at least 15 time series observations	460	966
with at most one break in the consecutive time series	408	662
with information on market power (Lerner index)	408	662
with information on repricing maturities	407	656
After the time-series regression		
keep only banks with non-negative expense betas	403	653
Corresponding time series observations of these banks	10,515	14,803

This table presents the selection process of the sample. Relevant balance sheet positions are loans, securities, current and savings deposits, equity, and total assets. Relevant positions from the profit and loss statement are interest income on loans, interest expenses, operating profit, and personnel expenses. The banks in the final sample sum up to 1,056, and the corresponding time series observations sum up to 25,318.

Table A.2: ROABeta on absolute NIM beta regression

	(1) All banks	(2) LowGap	(3) HighGap	(4) Top 10%
DiffBeta	-0.360***	-0.305	-0.566***	-0.441***
	(0.062)	(0.191)	(0.116)	(0.160)
Constant	-0.012**	-0.018*	0.017	0.000
	(0.006)	(0.009)	(0.015)	(0.013)
Banks	1,056	528	528	106
R^2	0.031	0.005	0.043	0.069

This table shows the result of the cross-sectional regression according to Equation (2), with the ROA beta as dependent and the absolute NIM beta (absolute difference between expense and income beta) as independent variable. Low- and high-gap banks are banks with an absolute difference in income and expense beta below or above the median of the sample. Top 10% represent the largest 10% of banks in the sample. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table A.3: ROABeta on ExpBeta regression

	(1) All banks	(2) LowGap	(3) HighGap	(4) Top 10%
ExpBeta	-0.053	0.013	-0.059	-0.196*
	(0.050)	(0.062)	(0.084)	(0.099)
Constant	-0.031***	-0.033***	-0.040**	0.014
	(0.010)	(0.011)	(0.017)	(0.022)
Banks	1,056	528	528	106
R^2	0.001	0.000	0.001	0.035

This table shows the result of the cross-sectional regression according to Equation (2) with the ROA beta as dependent and the expense beta as independent variable. Low- and high-gap banks are banks with an absolute difference in income and expense beta below or above the median of the sample. Top 10% represent the largest 10% of banks in the sample. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table A.4: Share of Loans

Panel A - All banks

	(1)	(2)	(3)	(4)	(5)
ExpBeta	-0.126**	-0.239***	-0.109*	-0.135**	-0.227***
	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)
SavDep		-0.390***			-0.385***
		(0.055)			(0.057)
Equity			0.396*		0.378
			(0.240)		(0.241)
log(TotalAssets)				0.002	0.001
				(0.003)	(0.003)
Constant	0.625***	0.771***	0.596***	0.613***	0.734***
	(0.010)	(0.022)	(0.021)	(0.020)	(0.041)
Banks	1,056	1,056	1,056	1,056	1,056
R^2	0.006	0.073	0.009	0.006	0.075

Panel B - Top 10% banks

	(1)	(2)	(3)	(4)	(5)
ExpBeta	-0.421***	-0.608***	-0.381**	-0.490***	-0.621***
	(0.150)	(0.150)	(0.153)	(0.151)	(0.158)
SavDep		-0.471**			-0.436**
		(0.202)			(0.202)
Equity			1.597		2.043
			(1.280)		(1.339)
log(TotalAssets)				0.037*	0.042*
				(0.020)	(0.024)
Constant	0.686***	0.864***	0.583***	0.387**	0.382
	(0.032)	(0.073)	(0.091)	(0.162)	(0.271)
Banks	106	106	106	106	106
R^2	0.087	0.162	0.115	0.110	0.219

This table presents the results for the regression according to Equation (6), with the proportion of loans as dependent variable. Panel A includes all banks in the sample, Panel B the largest 10% of the banks. We find almost identical regression coefficients if we split the sample for low and high gap banks. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table A.5: Overview of results: Non-interest income components, differentiated for use of derivatives

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ROA beta		NonIntInc beta		NonIntExp beta		NonIntResult beta	
	use: no	use: yes	use: no	use: yes	use: no	use: yes	use: no	use: yes
ExpBeta	0.132	-0.130**	0.033	0.008	-0.067	0.029	0.100*	-0.021
	(0.158)	(0.058)	(0.043)	(0.020)	(0.053)	(0.028)	(0.056)	(0.031)
Banks	222	599	222	599	222	599	222	599
R^2	0.004	0.008	0.003	0.000	0.007	0.002	0.014	0.001

This table shows the result of the cross-sectional regression according to Equation (1) with the ROA beta in Columns (1) and (2), NonIntInc beta in Columns (3) and (4), NonIntExp beta in Columns (5) and (6), or NonIntResult beta in Columns (7) and (8), and the expense beta as independent variable, differentiated for the use of derivatives. This table complements the corresponding Table 16 for the analysis of derivative usage. Banks with no information on derivatives use accessible are excluded from this analysis. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Appendix B. Calculation of the Lerner index

To proxy the competitive structure of the market we estimate the Lerner index which has been extensively used in the literature as an indicator for the degree of competition for the specific case of banks. In general, the index quantifies the ability to set prices above marginal cost on the bank-level and it is calculated as the price set by each bank less the estimated marginal costs, in relation to the price. Therefore values equal to zero indicate perfect competition and in case of monopoly power, it becomes 1 (Maudos and Fernández de Guevara, 2004). There are numerous variants to estimate the index, the differences are not only in the mathematical estimation method but also in the choice of input and output factors of the cost function. For a good theoretical overview and discussion of different approaches to estimate Lerner indices see Shaffer and Spierdijk (2020). Our empirical approach is based on Maudos and Fernández de Guevara (2004), who examine factors explaining the net interest margin for several European countries. Following Maudos and Fernández de Guevara (2004), we calculate the Lerner index as

$$LernerIndex_{i,t} = \frac{p_{i,t} - mc_{i,t}}{p_{i,t}} \tag{B.1}$$

where $mc_{i,t}$ is bank *i's* marginal cost of producing one more unit of output (= *total assets*) at time t and $p_{i,t}$ are bank *i's* total revenue (interest income plus other operating income, divided by total assets) at t.

To estimate marginal costs within our banking sample, we use a trans-logarithmic cost function with fixed effects to capture variation between banks and include time trends. We use banks' total operating costs as dependent variable and total assets as a single output factor. We employ the three price factors as input factors for production, the price of labor (personnel expenses divided by total assets), price of physical capital (total operating costs without personal expenses divided by fixed assets), and the price of deposits (total interest expenses divided by total customer deposits).[27]

[27] For estimation purpose, variables used to calculate the price set by banks and used for estimation of marginal costs for each bank in every year are winsorized at the 1% level.

Appendix C. Matching of sensitivities in the panel data

We test the findings regarding the banks' interest expenses, income, and ROA in the panel structure of our data set and again follow the approach of Drechsler et al. (2021). Within the panel approach, the number of observations of each bank enters the regression, whereas, in the cross-section, we have one observation for each bank, regardless of the length of the respective time series.[28]

We use the same sample as described in Section 5.2 that we used for the cross-sectional analysis. We build on the estimated bank-individual betas from Equation (1) in the first stage and use the predictions from this regression equation for the following panel regression. Specifically, we estimate the following panel regression:

$$\Delta IntInc_{i,t} = \gamma_i + \delta \Delta 3MEur\_rm_t + \lambda \Delta \widehat{IntExp}_{i,t} + \epsilon_{i,t}\,, \tag{C.1}$$

where $\Delta IntInc_{i,t}$ is bank *i's* change of interest income at time t, $\Delta 3MEur\_rm_t$ is the corresponding change of the rolling mean of the three-month EURIBOR and $\lambda\Delta\widehat{IntExp}_{i,t}$ is the predicted change of bank *i's* interest expenses, based on the estimated β_i^{Exp} from Equation (1). γ_i are bank-fixed effects. The coefficient of interest is λ which corresponds to the matching coefficient of the cross-sectional regression and should indicate the extent to which the sensitivities of interest income and expenses are matched.

The results for the panel regression are presented in Table C.1. Columns (1) and (2) refer to the total sample of banks, (3) and (4) to the largest banks. The overall coefficient of 0.789 in column (1) is very similar to our result from the cross-section regression of 0.737. For the largest banks in the sample, the coefficient is 0.938 in column (3). Both coefficients are highly significant and confirm our findings of the cross-sectional analysis. If we include time-fixed effects in columns (2) and (4), the coefficients decline to 0.673 (full data set) and 0.880 (largest banks). Again, the coefficients are highly significant and indicate a substantial matching of sensitivities, but again, we find no evidence for complete matching. We also

[28] The panel regression is also an approach to estimate the average beta values for our data set. If we do so and estimate Equation (1) as panel regression, we get results very similar to the average betas presented in Table 2.

analyze the relationship between the banks' ROA and their NIM based on the panel data. Therefore, we re-run Equation (C.1). The modified regression equation can be written as

$$\Delta ROA_{i,t} = \gamma_i + \delta\Delta \mathit{3MEur\_rm}_t + \lambda\Delta \widehat{NetIntInc}_{i,t} + \epsilon_{i,t}\ , \tag{C.2}$$

where $\Delta ROA_{i,t}$ is bank *i's* change of ROA at time t, $\Delta \mathit{3MEur\_rm}_t$ is the corresponding change of the rolling mean of the three-month EURIBOR and $\Delta \widehat{NetIntInc}_{i,t}$ is the predicted change of bank *i's* net interest income, based on the estimated β_i^{NIM} from Equation (1). γ_i are bank-fixed effects. Regression results are shown in Table C.2. Again, columns (1) and (2) refer to the total sample of banks, and (3) and (4) to the largest banks. The results are similar to the cross-sectional regression: The coefficient of interest in column (1) is 0.372. The largest banks show a coefficient of 0.441 in column (3). Both estimates are highly significant. Including time-fixed effects in columns (2) and (4) confirms the results in general. Further regression results similar to the cross-section analysis are available from the authors upon request.

Table C.1: IncBeta on ExpBeta panel regression

	(1) All banks	(2) All banks	(3) Top 10%	(4) Top 10%
δ	0.789***	0.673***	0.938***	0.880***
	(0.039)	(0.035)	(0.114)	(0.116)
$\Delta 3MEur\_rm$	-0.035***		-0.057**	
	(0.007)		(0.026)	
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	No	Yes	Yes
Observations	24,262	24,262	2,495	2,495
R^2	0.193	0.372	0.250	0.398

This table presents the results for the panel estimation of sensitivity matching according to Equation (C.1). Columns (1) and (2) refer to the total sample of banks, (3) and (4) to the largest 10% banks. Columns (1) and (3) include bank-fixed effects, while (2) and (4) include bank and time-fixed effects. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table C.2: ROABeta on NIMBeta panel regression

	(1) All banks	(2) All banks	(3) Top 10%	(4) Top 10%
δ	0.372***	0.367***	0.441***	0.501***
	(0.051)	(0.052)	(0.146)	(0.152)
$\Delta 3MEur\_rm$	-0.010**		0.003	
	(0.005)		(0.010)	
Bank FE	Yes	Yes	Yes	Yes
Time FE	No	No	Yes	Yes
Observations	24,262	24,262	2,495	2,495
R^2	0.007	0.138	0.004	0.258

This table presents the results for the panel estimation of sensitivity matching according to Equation (C.1) based on the predicted changes of banks' ROA based on the NIM betas according to Equation (1). Columns (1) and (2) refer to the total sample of banks, (3) and (4) to the largest 10% banks. Columns (1) and (3) include bank-fixed effects, while (2) and (4) include bank and time-fixed effects. Robust standard errors are reported in parentheses, significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.