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Interest and credit risk management in German banks: Evidence from a quantitative survey

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Non-technical summary

Research Question

Owing to their business model banks are exposed to the risk of abruptly changing interest levels. To some extent, banks can determine by how much they are exposed to this risk and what other risks, especially credit risk, they take. In this paper, we investigate the effects on banks of a rise in the interest level and the determinants of the banks' taking of the various risks.

Contribution

Every other year, the supervisory authorities in Germany carry out a survey among small and medium-sized banks in Germany. In this survey, these banks calculate their future profit and loss statements for a horizon of five years for different scenarios. Among these scenarios, there are the scenario of a constant term structure and the scenario of an abrupt increase in the interest level. We make use of this rich data set to address the research issues from above.

Results

In our study of the survey 2017, we find the following: i) The largest impact on banks' earnings after the first year of the rise in the interest level results from impairments in their bond portfolios, which banks mitigate by liquidating hidden reserves. ii) Banks' net interest income decreases in the first years and increases in the following years. iii) There is a positive relationship between a bank's net interest margin and its bearing of interest rate and credit risk. iv) Banks seem to set their interest rates for loans in a way that they are compensated for their expected losses and receive a risk premium. We find evidence v) that banks use their exposure to interest rate risk to hedge the risk of a change in the interest level and vi) that banks have a fixed risk budget which they allocate to interest rate and credit risk.

Nichttechnische Zusammenfassung

Fragestellung

Aufgrund ihres Geschäftsmodells sind Banken dem Risiko ausgesetzt, dass sich das Zinsniveau abrupt ändert. In gewissem Umfang können Banken bestimmen, in welchem Ausmaß sie diesem Risiko ausgesetzt sind und inwieweit sie andere Risiken eingehen, besonders Kreditrisiken. In diesem Papier untersuchen wir die Folgen eines Anstiegs des Zinsniveaus auf die Banken sowie die Faktoren, von denen es abhängt, in welchem Ausmaß die Banken verschiedene Risiken eingehen.

Beitrag

Die deutsche Aufsicht führt alle zwei Jahre eine Umfrage unter den kleinen und mittelgroßen Banken in Deutschland durch. In dieser Umfrage rechnen diese Banken über einen fünfjährigen Horizont ihre zukünftige Gewinn- und Verlustrechnung für verschiedene Szenarien der Zinsentwicklung durch. Unter den Szenarien sind auch das Szenario einer zeitlich konstanten Zinsstruktur und das Szenario eines abrupten Zinsanstiegs. Wir nutzen diesen reichen Datensatz, um die oben angesprochenen Fragestellungen zu untersuchen.

Ergebnisse

In unserer Untersuchung der Umfrage des Jahres 2017 zeigt sich Folgendes: Erstens ergibt sich im ersten Jahr nach der Erhöhung des Zinsniveau der größte Effekt auf den Jahresüberschuss aus den Abschreibungen im Anleiheportfolio, wobei die Banken diesen Effekt mildern, indem sie stille Reserven auflösen. Zweitens fällt das Nettozinseinkommen der Banken nach einem Zinsanstieg in den ersten Jahren und erhöht sich dann in den Folgejahren. Drittens gibt es einen positiven Zusammenhang zwischen der Nettozinsmarge einer Bank und deren Übernahme von Zinsänderungs- und Kreditrisiken. Viertens scheinen Banken ihre Zinssätze für Kredite so setzen, dass sie für die erwarteten Verluste entschädigt werden und eine Prämie für das Kreditrisiko erhalten. Wir finden Hinweise darauf, dass Banken – fünftens – ihr Zinsänderungsrisiko einsetzen, um ihre Nettozinsmarge zeitlich zu glätten, und dass sie – sechstens – ein festes Risikobudget haben, das sie auf Zinsänderungs- und Kreditrisiken aufteilen.

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Abstract

Using unique data of a survey among small and medium-sized German banks, we analyze various aspects of risk management over a short-term and medium-term horizon. We especially analyze the effect of a 200-bp increase in the interest level. We find that, in the first year, the impairments of banks' bond portfolios are much larger than the reductions in their net interest income, that banks attenuate the resulting write-downs by liquidating hidden reserves and that banks which use interest derivatives have lower impairments in their bond portfolios. In addition, we find that banks' exposures to interest rate risk and to credit risk are remunerated, that banks' try to stabilize the mid-term net interest margin with exposure to interest rate risk and that they act as if they have a risk budget which they allocate either to interest rate risk or credit risk.

Keywords: Net interest margin, bond portfolio, interest rate risk, credit risk

JEL classification: G21.

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1 Introduction

Strongly rising interest levels are seen as a threat to banks. Often it is argued that rising interest levels quickly lead to higher interest expenses whereas – due to the fact that fixed-interest periods are usually longer on the asset side – the interest income only slowly increases as new business alone is affected by the change in the interest level. This is especially relevant in a prolonged low-interest rate environment where the banks' net interest income is already under pressure and hidden reserves in the bond portfolio as a consequence of falling interest rates have dissipated so that diminishing net interest income cannot be easily compensated.

Using unique data from a quantitative survey among small and medium-sized banks in Germany, we empirically check this above-mentionned argument. The survey data allow us to concentrate on the direct effect of a sudden increase in the interest level. This means that we are able to extract causal relationships, not only correlations, at least when it comes to the direct effect of a sudden increase in the interest level, because we have each set of observations twice for each bank: the forecast financial statements under the assumption of an interest rate shock at the beginning of the survey horizon and those under the assumption of a constant term structure. In addition, in this paper, we analyze not only the banks' tactical measures to steer risks in the banking sector, but their long-run choices of risk exposures as well.

The survey was conducted in 2017 by the national supervisors, the Bundesbank and Bafin, among all German banks that are not directly supervised by the SSM (Single Supervisory Mechanism), i.e. the sample encompasses the small and medium-sized banks in Germany, around 1,500, most of which are universal banks.[1] The horizon of the survey extends over five years (2017-2021) and banks are requested to keep constant all their balance sheet positions.

By analyzing the survey data, we find that the above-mentionned argument is empirically backed. However, two additional aspects have to be considered. First, the huge reduction in the banks' profits in the first year after the shock is only partly due to the worsening of the net interest income. The major part of this effect results from the impairments of the banks' bond portfolios, where banks that use interest derivatives have lower impairments in their bond portfolios compared to banks without interest derivatives, even after controlling for the exposure to interest rate risk and the size of the bond portfolio. Second, banks use a special kind of hidden reserves (known as 340f-reserves) to soften the impairments on the bond portfolio resulting from rising interest levels. With the help of liquidating these hidden reserves,[2] banks attenuate, on average, these impairments by about 24%. In addition, we find that the impairments in a bank's bond portfolio are much determined by the bank's interest rate risk and by the relative size of its bond portfolio.

As to the question of strategic risk management, we find indirect evidence that banks use their exposure to interest rate risk to stabilize their mid-term net interest margin. We derive this statement from the findings that banks with a high net long-run pass-through

[1] More precisely, over 97% of the participants are universal banks.

[2] When we talk about liquidating hidden reserves, we also include the cases where banks reduce the building of hidden reserves compared to the scenario of a constant term structure (i.e. those banks still build hidden reserves in the stress scenario but the amount is smaller than in the scenario of a constant term structure).

and banks which benefit only after a long horizon from a rise in the interest level tend to be banks with large exposures to interest rate risk. We also see that the bearing of interest rate risk and the bearing of credit risk are remunerated in the form of a higher net interest margin and that banks act as if they have an internal risk budget which they allocate either to interest rate risk or to credit risk. Looking at more granular credit data, we find evidence that banks price-in components of their credit risk, for instance expected losses and – to some extent – premia for credit risk.
The paper is structured as follows: In Section 2, a brief overview of the literature in this field is given. The survey and data that are used are explained in Section 3. The empirical models and the results are given in Section 4. Section 5 concludes.

2 Literature

One central contribution of our analysis is to show that an increase in the interest level not only affects a bank's net interest income but also its valuation result by impairments on its bond portfolio where, in the first year, these impairments are much larger than the changes in the net interest income. We show that the banks in the survey make use of a special accounting rule in the German Commercial Code (Handelsgesetzbuch, HGB), known as 340f-reserves, to dampen impairments on bonds of the liquidity reserve (see Bornemann, Kick, Memmel, and Pfingsten (2012)) and that banks with interest rate derivatives have lower impairments in their bond portfolio even after controlling for the size of the bond portfolio and the exposure to interest rate risk. This contributes to the literature on how banks use interest derivatives (see, for instance, Brewer, Minton, and Moser (2000), Purnanandam (2007) and Hoffmann, Langfield, Pierobon, and Vuillemey (2018)).
In addition, we contribute to the literature on how banks strategically choose the exposure to interest rate risk. Schrand and Unal (1998) show for US banks that banks seem to have an internal risk budget that they allocate to either credit risk or interest rate risk.[3] Memmel (2018) theoretically shows and finds empirical evidence that the more a bank is exposed to the risk of a decline in the interest level, the more it is exposed to interest rate risk given its aims at stabilizing its mid-term net interest margin. Using very meaningful data on the credit risk and interest rate risk exposures of German banks, we confirm their findings. Another reason for a bank being exposed to interest rate risk is put forward by Drechsler, Savov, and Schnabl (2018). They argue that the de facto duration of customer deposits is much larger than the de jure one and that the banks are, therefore, said to be exposed to interest rate risk if they invest in long-term loans that are financed with customer deposits. They show that the net interest margin (NIM) of US banks barely reacts to changes in the interest level, which leads to the conclusion that banks are exposed to interest rate risk to hedge the actually long durations on their liability side. Having a time dimension of five years in the survey data, we show that the net interest margin (NIM) of banks in Germany in fact reacts to a (hypothetical) sudden change in the interest level and that this finding gives reason to believe that German banks are exposed to interest rate risk even if one considers the actually long durations of customer

[3] However, we do not deal with the question of how banks mix interest income, and fee and commission income as in Busch and Kick (2015).

deposits.
We also contribute to the literature on the determinants of banks' net interest margins. Wong (1997) shows, in a theoretical model, that a bank's net interest margin positively depends on its exposure to interest rate risk, its credit risk and its administrative costs. In addition, Saunders and Schumacher (2000) empirically show that a bank's administrative costs which act as a proxy for financial services that a bank provides have a huge impact on the net interest margin. This is confirmed by our empirical analysis, i.e. we find that the banks obtain a remuneration for bearing credit and interest rate risk and that a bank's net interest margin and its administrative costs are positively correlated. Our main contribution here is that we have meaningful variables to describe the exposures to interest rate and credit risk.
Busch and Memmel (2016) find in a study of German banks that a bank's net interest income and its expected losses in the credit portfolio are positively correlated, where one euro of additional net interest income is associated with approximately one euro of additional expected losses. Looking at more granular credit data, Edelberg (2006) and Magri and Pico (2011) find as well that expected losses play a role when banks set the corresponding interest rates. We confirm their finding and, taking into account that the pass-through to the corresponding interest rates is incomplete, we quantify the relationship between expected losses and bank rates for loans. We find indications of a premium for bearing credit risk.

3 Survey

3.1 General Aspects

The data used in this analysis stem from the low-interest rate environment survey conducted by the Deutsche Bundesbank and BaFin in 2017 among small and medium-sized banks in Germany, covering about 1,500 banks. This sample encompasses all universal German banks that are not directly supervised by the SSM (Single Supervisory Mechanism) and a small number of special purpose banks.
While one part of the survey investigated the banks' situation in various interest rate scenarios, the second part consisted of a stress test assessing the resilience of the banks against the risks of rising interest rates, additional credit losses and sudden adverse market changes. The shocks are assumed to take place on 31 December 2016, i.e. the first financial statement that is affected is the one of 2017. The first part of the survey, i.e. the low-interest rate environment survey in the narrow sense, has a horizon of five years (from 2017 to 2021) and banks had to quantify many positions of their financial statements for the five-year horizon and for the different scenarios. Among the positions for the yearly financial statements are the interest income and the expenses, the impairments in the credit and in the bond portfolio (where the building or liquidation of hidden reserves is to be reported separately). The survey contains data for six different scenarios. However, in this analysis we focus on two scenarios, namely the baseline scenario of a constant term structure and the stress scenario of an interest level upward shift by 200 bp at the beginning of the stress horizon.
The second part, i.e. the stress tests, contains the financial statements over a one-year horizon, i.e. 2017. Participation in the survey was compulsory and the stress test data

were cross-checked in a multiple-step quality assurance process.
These data make it possible to investigate the impact of an increase in the interest level without disturbing side effects, over a horizon of five years (2017-2021). As to the direct effects of a sudden rise in the interest level, it is possible to make causal statements because we not only have the variables in the stress scenario, but in the baseline scenario, acting as the counterfactual, as well.

3.2 Impairments of the Bond Portfolio and Reserves

Impairments and reserves are two central positions discussed in this study. Since for both positions special accounting rules apply, which affect the interpretation of the data, we want to shortly summarize these aspects in this section. Loans do not have to be written down as a consequence of an increase in the interest level; write-downs of loans are only necessary if borrowers' creditworthiness deteriorates. Keeping this in mind, it is surprising to observe the huge impairments in the first year after the interest rate shock. These impairments result from bonds which amount to about 20% of a bank's total assets (see Table 1, variable *bonds*, which gives the share of bonds relative to the bank's total assets). These bonds are mainly subject to the *strenges Niederstwertprinzip* which states that these assets have to be written down in the event that their fair value on the balance sheet day is below their book value. An example may clarify this point: Suppose a bank buys a par-yield bond (principal: 100 euro) with a maturity of 10 years at a flat term structure at 3% p.a. In the following two years, the term structure is flat at 2%, which corresponds to bond prices of 108.16 euro (at the end of year 1) and 107.33 euro (at the end of year 2), respectively.[4] Then, in year 3, the interest level increases to 4% and the bond prices go down to 94 euro. Whereas the increase in the bond price (in year 1) above the historic costs of 100 euro has not been recognized and the book value remained at 100 euro, the price decline below the historic costs has to be accounted for in the historic cost accounting, and the book value has to be written down to 94 euro. Given that the term structure remains at 4% p.a. the bond price will increase in the following years, finally reaching the par-value of 100 euro when it matures. These increases (and if other increases occur) in the bond price will lead to corresponding increases in the book value as long as the bond price is below or equal to the historic costs because of the requirement to reverse write-downs where the reasons for them no longer exist.
According to the German Commercial Code (HGB), banks are allowed to build 340f-reserves. These are hidden reserves on loans to banks and to customers and on bonds and stocks that are treated as *Umlaufvermögen* or *Liquidity Reserve* and do not count towards the trading portfolio. These reserves are limited to 4% of the asset's book value. For instance, if a bond is bought for 100 euro, banks are allowed to assign a balance sheet value of 96 euro to this bond. The expenses to build these reserves do not have to be reported separately in the profit and loss statement, but are mixed up with other expenses, for instance with impairments of the loan portfolio. The same applies when the reserves are liquidated.

[4] The decline in the bond prices from year 1 to year 2 (although the interest level is constant) is due to the *pull-to-par effect* which states that bond prices approach their redemption payment in the course of time.

3.3 Interest Rate Risk

In general, a bank's exposure to interest rate risk is mainly measured by two indicators, namely by the change in the net present value of its assets and liabilities due to an interest rate shock and by the change in the earnings due to an interest rate shock (see Sierra and Yeager (2004)). Under certain conditions (for instance, equal volumes and pass-throughs of the interest-bearing assets and liabilities), these two indicators point in the same direction, as the change in the net present value should be equal to the sum of the change in the present value of the future earnings (see Memmel (2014)). However, these conditions are often not met in our sample of small and medium banks:

- The banks' pass-through on the asset side is much larger than on the liability side. Think of a simplified central bank as the extreme case: On the asset side, there are loans, tied to the (short-term) interest rate, and on the liability side, there are banknotes, not remunerated at all irrespective of the interest level. A change in the interest level does not affect the present value of this bank's assets (as their maturity is extremely low) nor the present value of its liabilities (as their remuneration is always zero), but the net interest margin (equal to the (short-term) interest rate) is heavily affected.

- Balance sheet positions are treated differently if the interest level changes. This is due to the application of the German Commercial Code (HGB), which the banks in our sample use: If the interest level rises, bonds (that are treated as *Umlaufvermögen*) have to be written down (see Section 3.2), but not positions on the liability side. This differential treatment of the positions on the asset and liability side leads to effects on the profit and loss account (and the empirical effects are huge, as can be seen in Figure 1), but not necessarily with respect to the net present value.

There are good reasons to measure a bank's exposure to interest rate risk with respect to the impact on its earnings, especially as our sample is composed of small and medium banks for which the two arguments from above are relevant. Nevertheless, we define a bank's exposure to interest rate risk with respect to possible changes in the net present value of its assets and liabilities. We do so for the following reasons:

- In the literature, a bank's exposure to interest rate risk is often defined as maturity mismatches between assets and liabilities (see, for instance, Angbazo (1997), Sierra and Yeager (2004), Purnanandam (2007) and Hoffmann et al. (2018)), which is close to the concept of a change in the net present value.

- The change in a bank's net present value seems to be more economically relevant than the earnings perspective, which may be distorted by impairments due to accounting issues (see Section 3.2 and above).

- For the banks in our sample, we have at our disposal a comprehensive measure of the change in the net present value, namely the Basel interest rate coefficient (IRR).

3.4 Summary Statistics

In Table 1 and Figure 1, summary statistics are given. Variables with a $C.$-operator give the differences of the respective variables in the scenario with the upward shift of the term structure relative to the scenario with the assumption of a constant term structure.

The impairments Imp used in our study come from two sources: (i) write-downs of bonds of the liquidity reserve and (ii) write-downs of bonds that are treated as *Anlagevermögen*. The variable Res refers to 340f-reserves, which are a special feature of the German Commercial Code (HGB). These hidden reserves can be built and liquidated at the will of bank management for all balance sheet items that are treated as *Umlaufvermögen*, for instance book loans and bonds of the liquidity reserve; the maximum amount of these reserves is 4% of the underlying instrument.

In this survey, we find that the largest group of banks does not use any interest derivatives (788 banks out of 1414, or 55.7%). If interest derivatives are used (626 banks, or 44.3%), then in most cases (573 banks, or 91.5%), the cash flow in the event of an increase in the interest level is positive. This finding is in line with Purnanandam (2007) and Hoffmann et al. (2018) who find that banks mainly use interest derivatives for hedging purposes. However, the magnitude of the additional cash flows are not huge (less than 4 bp relative to total assets on average; even if solely the non-zero values are considered, the mean is only about 8 bp), especially when compared to the impairment losses (almost 70 bp).

IRR refers to the Basel interest rate coefficient, i.e. the change in the net present value of a bank's assets and liabilities due to an instantaneous parallel upward shift of the term structure by 200 bp, standardized with the bank's own funds.

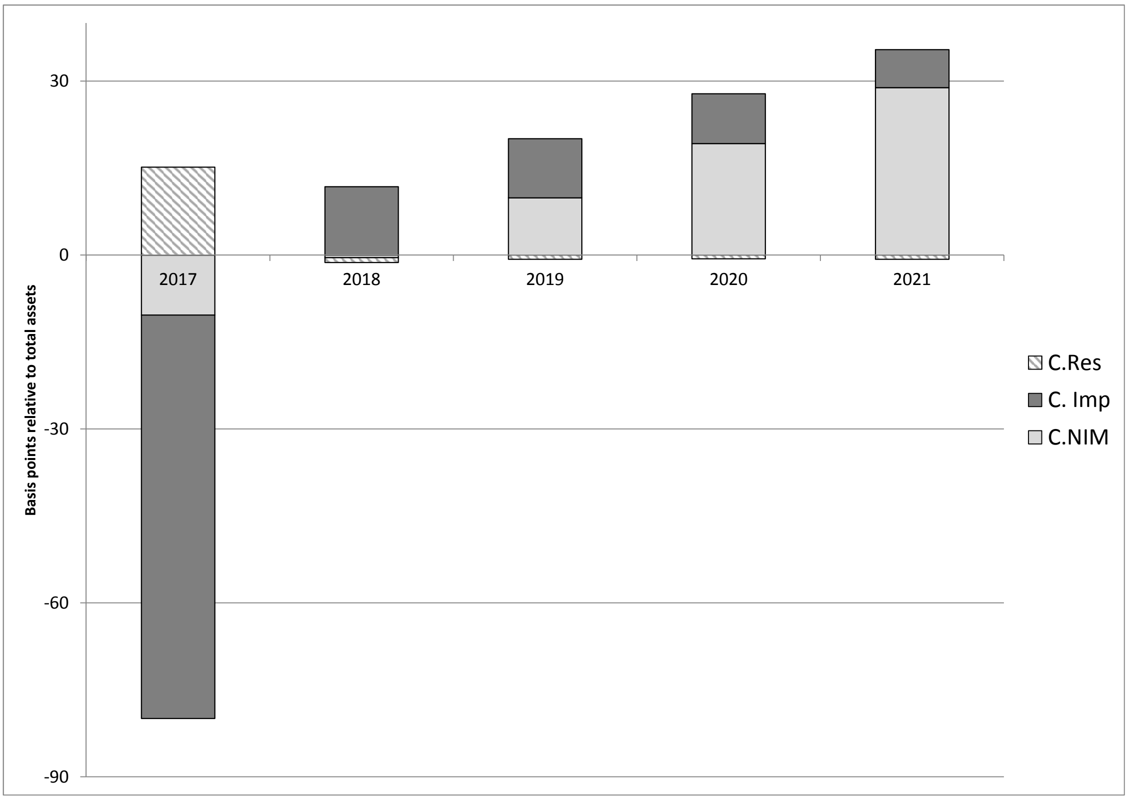
θ and θ_1 give estimates for a bank's long-term net pass-through, i.e. the long-term change in the bank's net inter margin (NIM) as a consequence of a permanent parallel shift of the term structure. They are defined later in the paper (see Equations (6) and (7)).

We make use of two different credit risk measures – one referring to expected loss in the baseline and the other to the loss due to the credit stress test. The expected loss for each euro of risk volume is measured by the impairment rate $ImpR_{EL}$, which is defined as the product between the PD and LGD where PDs and LGDs are approximated by their historical counterparts. New defaults within the reporting year in relation to the exposure at default operationalize PDs, while LGDs are measured as the ratio between credit risk adjustments for the new defaults divided by new defaults. On average, banks' credit risk adjustments were about 18 cents for 100 euro exposure at default for exposure related to retail, while only 4 cents were made for 100 euro exposure at default secured by residential mortgages. The difference mainly reflects the difference in the historical LGD (appr. 40 versus 10 euro of credit risk adjustment for 100 euro of new defaults) driven by the securitized amount.

The other credit risk measure is $ImpR_{CST}$ which is based on the concept of credit losses due to the credit stress test. Specifically, we measure $ImpR_{CST}$ as the difference between the expected credit losses in the adverse scenario versus the expected loss on the historical reporting date. The adverse scenario consists of an assumed increase in the loans' probabilities of default (PD) by 155% and an increase in the loss given default (LGD) by 20%.

The *size* of a bank is measured as the logarithm of its total assets (in 1000 euro). Hence, a value of 13.44 corresponds to total assets of EUR 687 mio.

Figure 1: Change in Income due to an Interest Rate Shock



This figure shows the change in the banks' income components (means) due to a parallel interest rate shock of 200 basis points at the end of 2016. $C.NIM$ is the difference of the net interest margin (NIM) in the stress scenario (a 200-bp upward shift of the term structure) relative to the baseline scenario of a constant term structure. $C.Imp$ and $C.Res$ are the respective differences for the impairments of the bond portfolio and the liquidation of 340f-reserves. All variables are standardized with the bank's total assets.

Table 1: Summary Statistics and Descriptive Analysis

Variable	Obs.	Mean	Standard dev.	Share of neg. values (%)
$C.NIM2017$	1414	-10.34	27.57	74.40
$C.NIM2018$	1414	-0.45	27.93	53.04
$C.NIM2019$	1414	9.87	28.00	32.74
$C.NIM2020$	1414	19.25	28.27	17.61
$C.NIM2021$	1414	28.91	29.43	9.19
$C.Imp2017$	1414	-69.59	56.97	93.21
$C.Imp2018$	1414	11.80	12.16	2.33
$C.Imp2019$	1414	10.22	10.39	1.98
$C.Imp2020$	1414	8.58	9.29	2.55
$C.Imp2021$	1414	6.54	7.93	2.83
$C.Res2017$	1414	15.19	33.95	0.28
$C.Res2018$	1414	-0.81	5.47	4.60
$C.Res2019$	1414	-0.71	4.51	4.17
$C.Res2020$	1414	-0.64	4.27	4.31
$C.Res2021$	1414	-0.71	4.47	4.46
IRR	1414	18.83	8.78	3.04
θ	1414	24.99	11.78	2.69
θ_1	1414	34.64	18.01	3.32
NIM	1414	184.83	80.99	0.57
$Cost$	1414	207.47	300.03	0.00
$ImpR_{CST}$	1414	46.74	42.49	0.00
$ImpR_{ELRetail}$	1369	0.18	0.10	0.07
$ImpR_{ELResM}$	1267	0.04	0.01	0.08
$C.Der$	1414	3.56	9.35	3.75
CR	1414	19.25	10.81	0.00
$bonds$	1414	19.69	12.40	0.00
$size$	1414	13.44	1.34	0.00

This table shows summary statistics. The variables $C.NIM...$, $C.Imp...$ and $C.Res...$ are given in basis points (relative to the time-constant balance sheet sum), where $C.NIM...$ is the difference of the NIM in the stress scenario (a 200-bp upward shift of the term structure) relative to the baseline scenario of a constant term structure. $C.Imp...$ and $C.Res...$ are the respective differences for the impairments of the bond portfolio and the liquidation of 340f-reserves. IRR denotes the Basel interest rate coefficient, i.e. the change in the net present value of a bank's assets and liabilities due to an instantaneous parallel upward shift of the term structure by 200 bp, standardized with the bank's own funds. θ stands for the long-term net pass-through, while θ_1 stands for the net pass-through over a one-year horizon. NIM stands for the net interest margin in 2016 (net interest income divided by total assets, in bp), $Cost$ for administrative costs in 2016 divided by total assets (in bp), $ImpR_{CST}$ is the credit risk as the difference between the expected loss in the stress and in the baseline scenario (in bp over total assets), $C.Der$ is the difference of the cash flows of interest derivatives in the two scenarios, CR for the capital ratio at the end of 2016 (in %), and $bonds$ is the share of bonds (in % of total assets at the end of 2016). The variable $size$ is the natural logarithm of total assets (in 1000 euro) at the end of 2016. $ImpR_{ELRetail}$ and $ImpR_{ELResM}$ denote the expected losses of the retail loans and mortgage loans; they are given in percentages of the respective credit exposures.

3.5 Descriptive Analysis

In a first step, we look at descriptive analyses of the interest rate shock, especially at the variables with the $C.$-operator because, for these variables, we know for sure that the effect of the increase in the interest level – directly (NIM, Imp, Der) or indirectly (Res) – is the cause for their change as we have the counterfactual of an unchanged interest level.
The change in net interest income is the effect that first comes to mind when thinking about changes in the interest level. However, we see in the summary statistics in Table 1 and in Figure 1 that the largest effect by far – at least in the first year after the shock – comes from impairments in the bond portfolio, amounting to almost 70 bp (relative to total assets) on average in 2017. In the subsequent years (2018-2021), there are write-ups. The net effect due to the impairments in the first year is still negative after five years (32 bp, or 46.7% relative to the impairments in the first year). The impairments in the first year are to some degree attenuated by liquidating hidden reserves. This liquidation softens the effect by – on average – a bit more than 15 bp (relative to total assets), which gives a net effect of the impairments of 55 bp (relative to total assets).
Looking at the mean of the difference in the net interest margins $C.NIM...$ for the different years, we see an upward trend from around -10 bp to 29 bp (relative to total assets), meaning that an increase in the interest level is – after some time – beneficial for the banks. The average difference in the net interest margins is negative in 2017 and slightly negative in 2018, but strongly positive in 2019 and thereafter, i.e. between 2018 and 2019 the effect turns from negative to positive. This is in line with Busch, Drescher, and Memmel (2017), who analyzed the data of the corresponding survey of 2015 as to the question of dynamic versus constant balance sheets, and with Table 2, where – for the median bank – the last year without improvement in the net interest margin is 2018. In Busch and Memmel (2017), the time span during which rising interest levels have a negative impact on the net interest margin is 1.5 years, compared to more than 2 years in this survey. The different time spans may result from different assumptions as to bank management's reactions: Whereas the time span in Busch and Memmel (2017) is estimated under the assumption that banks can also adjust their balance sheet, the assumption in this survey is a constant balance sheet. The sum over the period of five years of the difference in the net interest margins is 47 bp. Hence, as to the net interest margin, the overall effect of an increase in the interest rate level is positive (for the average bank).
Table 2 states the last year (in Appendix A, this horizon is denoted as t^*) where a bank's net interest margin in the scenario of an upward shift of the term structure relative to the baseline scenario of a constant term structure is negative or zero (and consequently positive in previous years). It only encompasses banks for which the net interest margin (relative to the scenario of a constant term structure) monotonically increases in the period 2017-2021, i.e. the net interest margin (relative to the baseline scenario of a constant term structure) of 2017 is less than or equal to the one of 2018 and so forth. The monotonicity is given for 1183 banks out of 1414 banks (share of 83.6%). For instance in the case where 2018 is the "[l]ast year without improvement", there are 271 banks where the net interest margin (relative to the baseline scenario) in 2018 is negative (or zero) and positive (or zero) from 2019 on. The highest number of banks (299, or 25.27%) experience a deterioration of their net interest margin only in 2017 and, from 2018 on,

Table 2: Dynamics of Net Interest Margins

Year	Last year without improvement		IRR
	Number of banks	Share (in %)	(average)
2016	258	21.81	15.36
2017	299	25.27	18.72
2018	271	22.91	20.39
2019	192	16.23	22.49
2020	101	8.54	23.36
2021+	62	5.24	23.13
sum	1183	100.00	19.61

This table shows the last year, in the scenario of a 200-bp upward shift of term structure, in which no improvement of a bank's net interest margin manifests (compared to the scenario of a constant term structure). Only banks whose net interest margin dynamics in the period 2017-2021 are monotonically increasing are considered (1183 out of 1414, which equals 83.6%).

an improvement of their net interest margin relative to the baseline scenario. However, there are banks that have lower net interest margins (relative to the baseline scenario) even after five years (62 banks).

The year with the turning point, i.e. the last year without improvement and the following year with the improvement, shows considerable variation, reaching from immediate improvement to five years or more after the interest shock took place. Moreover, when looking at the third column of Table 2, where the mean exposure to interest rate risk (measured by the Basel interest rate risk coefficient at the end of 2016) of the respective group of banks is given, it seems as if the exposure to interest rate risk (IRR) is related to the speed of improvement: The exposure to interest rate risk (IRR) is positively associated with the length of the time span (t^*) with no improvement concerning the net interest margin. This is in line with the rather mechanical model in Appendix A (see Equations (22) and (23)).

4 Risk Management

4.1 Tactical Risk Exposure

In the short run, when faced with valuation losses in the bond portfolio, banks can take different measures to attenuate the impact on the profit and loss statement, for instance they can liquidate a special kind of hidden reserves (340f-reserves) or they can reclassify their bonds from *Umlaufvermögen* (current assets) to *Anlagevermögen* (fixed assets) (see Subsection 3.2). However, we employ data which were generated applying the assumption of a static balance sheet and, therefore, reclassification is not permitted. Besides, as the interest rate shock in this survey is assumed to be permanent, the reclassification of the bonds is not an option because, in the event of a permanent shock, bonds classified as *Anlagevermögen* also have to be written down.

To investigate the relationship between the liquidation of reserves and the impairment

Table 3: Change in Reserves

Variables	C.Res2017	C.Res2018	C.Res2019	C.Res2020	C.Res2021
C.Imp	-0.245***	-0.079***	-0.075***	-0.067***	-0.049**
	(0.027)	(0.023)	(0.021)	(0.021)	(0.022)
size	0.316	-0.119	-0.076	-0.064	0.086
	(0.621)	(0.090)	(0.071)	(0.075)	(0.090)
CR	0.109**	-0.009	-0.007	-0.006	-0.004
	(0.052)	(0.007)	(0.006)	(0.006)	(0.005)
const.	-8.207	1.893	1.208	0.916	-1.468
	(9.067)	(1.306)	(1.053)	(1.121)	(1.314)
R-sq	0.169	0.031	0.030	0.021	0.009
Nobs	1414	1414	1414	1414	1414

This table shows the estimation results of Equation (1) for different years; robust standard deviations in brackets; *** and ** denote significance levels of 1% and 5%. $R-sq$ is the coefficient of determination R^2 and $Nobs$ is the number of observations.

losses in the bond portfolio, we run the following regression:

$$C.Res_{t,i} = \alpha_t + \beta_t \cdot C.Imp_{t,i} + \gamma_t' X_i + \varepsilon_{t,i}, \tag{1}$$

where $Imp_{t,i}$ is bank i's impairment of the values of bonds (divided by the bank's total assets) in year t, $Res_{t,i}$ is the amount of liquidated hidden reserves on bonds (divided by the bank's total assets) in year $t = 2017, ..., 2021$, where the $C.$ operator states that we use the difference of the respective variables in the shock scenario (a sudden rise in the interest level) and the baseline scenario (constant term structure). This allows us to exclusively look at the effect due to an increase in the interest level. X_i is a vector that contains the control variables $size_i$ and capital ratio (CR_i). β_{2017} can be interpreted as the euro amount of immediately liquidated hidden reserves as a consequence of an interest rate shock that leads to one euro of impairments in the bond portfolio.

As stated above, we expect that the negative impact on the P&L through higher impairments after a positive shock in the interest rate will be attenuated by the liquidation of reserves. Thereby, we expect that a reduction in the difference for impairments in the +200-bp scenario versus the scenario with the constant term structure (higher negative effect on P&L) will be associated with an increase in the difference in reserve flows in the +200-bp scenario versus the scenario with the constant term structure. Hence, we expect a negative β_t in Equation (1) where we show the results of this equation in Table 3. Especially in the first year, we observe a highly significant and negative estimate with a coefficient of determination of almost 17%. This estimate can be interpreted such that an impairment of one euro leads to 24.5 cents of immediate liquidation of 340f-reserves. As to credit risk, banks are allowed to use these hidden reserves as well. However, our data do not make it possible to quantify the usage in this case.

Note that from 2018 on, the banks on average build reserves (instead of liquidating them). The sign of the respective coefficients remains negative although the change in reserves alters its sign (see Table 1). This is so because, from 2018 on, there are on average no longer write-downs in the bond portfolio, but write-ups due the pull-to-par effect.

Table 4: Impairments

Variables	C.Imp2017	C.Imp2018	C.Imp2019	C.Imp2020	C.Imp2021
IRR	-1.224***	0.223***	0.204***	0.197***	0.149***
	(0.171)	(0.048)	(0.043)	(0.042)	(0.038)
bonds	-2.546***	0.462***	0.404***	0.331***	0.274***
	(0.139)	(0.039)	(0.034)	(0.032)	(0.027)
size	4.900***	0.114	0.007	-0.092	-0.114
	(0.981)	(0.200)	(0.171)	(0.158)	(0.131)
CR	-0.157*	0.011	0.001	-0.003	-0.012
	(0.085)	(0.040)	(0.040)	(0.040)	(0.041)
const.	-59.253***	-3.237	-1.709	-0.340	0.115
	(13.647)	(2.872)	(2.496)	(2.299)	(1.912)
R-sq	0.443	0.297	0.318	0.285	0.261
Nobs	1414	1414	1414	1414	1414

This table shows the estimation results of Equation (2) for different years; robust standard deviations in brackets; *** and * denote significance levels of 1% and 10%. $R-sq$ is the coefficient of determination R^2 and $Nobs$ is the number of observations.

The amount of impairments as a consequence of the interest rate shock $C.Imp_{t,i}$ in a bank's bond portfolio is likely to depend on this bank's exposure (IRR_i) to interest rate risk and the size ($bonds_i$) of its bond portfolio:

$$C.Imp_{t,i} = \alpha_t + \beta_{1,t} \cdot IRR_i + \beta_{2,t} \cdot bonds_i + \gamma_t' X_i + \varepsilon_{t,i} \tag{2}$$

As said above, the variable IRR_i denotes the Basel interest rate coefficient under a +200 basis points shock, that is, the present value loss in the valuation of fixed assets given a sudden parallel increase in the yield curve by 200 bp, divided by the regulatory own funds of the bank. As stated in Subsection 3.3, we use this as a proxy for the bank's exposure to interest rate risk, which is a common assumption (see, for instance, Deutsche Bundesbank (2015)).

As to the explanation of the impairments of the bond portfolios, we show the results of estimating Equation (2) in Table 4. These results are important for top-down stress testing, because, as explanatory variables, only information is used that is available before the stress tests and that is part of the normal supervisory reporting. According to these results, a bank's exposure to interest rate risk (IRR) and the size of its bond portfolio ($bonds$) are important determinants for its write-downs in the bond portfolio. Not only are the coefficients highly significant, but the explained variation, especially in the first year, is remarkably high at more than 44%.

In principle, a bank could be exposed to interest rate risk without many bond holdings. For instance, a bank could invest into loans with a long fixed-interest period (instead of: into corresponding bonds). This would reduce the impairments resulting from a rise in the interest level because a loan only has to be written down if the creditworthiness of the borrower deteriorates, but not (unlike a bond) if the risk-free interest rate increases (see Subsection 3.2). Not to use bonds as a liquidity reserve requires elaborate risk management, which, we hypothesize, could consist in the holding of derivatives to manage the exposure to interest rate risk. To investigate whether banks with more instruments to adjust their risk profile have different impairments in their bond portfolio, we run the following regression (for 2017):

$$C.Imp_i = \alpha + \alpha_D \cdot D_i + \beta_1 \cdot IRR_i + \beta_{1,D} \cdot IRR_i \cdot D_i + \beta_2 \cdot bonds_i + \beta_{2,D} \cdot bonds_i \cdot D_i + \gamma' X_i + \varepsilon_i \quad (3)$$

where D_i is a dummy variable that takes the value of one if bank i uses interest derivatives.

Questions as to the usage of interest derivatives (Equation (3)) are treated in this subsection with the short-term measures, although, for about 80% of the banks (507 out of 626 banks), their on-balance sheet net interest income and the cash flows of their interest derivatives move in opposite directions in the event of an interest rate shock. If the usage of interest derivatives were solely a means of fine-tuning risk exposures, we would observe that about 50% of the cash flows of the derivative position move in sync and about 50% of the cash flows move in opposite directions. Nevertheless, we count the usage of the interest derivatives among the short-term measures because – once the decision to use derivatives has been made – the exact position of the derivatives can be adjusted in next to no time.

In Table 5, the results of Equation (3) are shown. This equation makes it possible to investigate whether the relationship between the impairments Imp in a bank's bond portfolio and its exposure to interest rate risk and the size of its bond portfolio depends on the usage of interest derivatives. As can be seen from the $F-test$, which tests whether the three coefficients β_D, γ_D and α_D in Equation (3) are jointly zero, this relationship is highly significantly different. When calculated at the respective means of the exposure to interest rate risk (IRR), of the relative size of the bond portfolio ($bonds$) and of the control variables (see Table 1), the expected impairment after the shock in the interest level by 200 bp is 81 bp (relative to the bank's total assets) and 55.2 bp (relative to the bank's total assets) for banks without derivatives and with derivatives, i.e. banks with interest derivatives have on average 25.8 bp lower impairments in their bond portfolio, of which 15.3 bp are due to bank characteristics (other than the usage of derivatives) and 10.5 bp are due to the usage of derivatives.

A possible explanation of this latter result is that banks with interest derivatives can better steer their interest rate risk and liquidity risk so that they can invest a larger part of their assets into illiquid loans (that are not written down in the event of an interest rate shock, but only in the event of deteriorating creditworthiness of the borrowers (see Subsection 3.2)). This estimate is backed up when we look at the results of a regression that explains the loan share $loans$:[5]

$$\begin{array}{rcl} loans & = & 41.851 + 5.937 \cdot D + 0.060 \cdot NIM - 0.001 \cdot IRR + 0.865 \cdot size - 0.369 \cdot CR + \varepsilon \\ & & (11.139)\ (0.940) \qquad (0.029) \qquad\qquad (0.068) \qquad\qquad (0.475) \qquad\qquad (0.127) \end{array} \quad (4)$$

The loan share $loans$ (relative to the bank's total assets) is significantly larger for banks which use interest derivatives (dummy variable D), almost 6 percentage points. By contrast, the exposure to interest rate risk IRR does not seem to be related to the size of

[5]Robust standard errors in brackets; R^2 of the cross-sectional regression amounts to 22.61%.

Table 5: Impairments and Derivatives

Variables	C.Imp2017	C.Imp2017	C.Imp2017
IRR	-1.311*** (0.241)		-1.314*** (0.241)
D IRR		-1.007*** 0.235	0.301 0.336
bonds	-2.691*** (0.177)		-2.691*** (0.177)
D bonds		-1.981*** (0.239)	0.687** (0.291)
size	1.050 (1.541)		1.047 (1.541)
D size		6.945*** (1.463)	5.946*** (2.126)
D const		-93.465*** (21.911)	-91.399*** (29.155)
CR	-0.135 (0.086)	-0.467 (0.452)	-0.147* (0.087)
const	-8.067 (19.977)		-7.726 (19.982)
R-sq	0.468	0.322	0.456
Nobs	788	626	1414
F-test p-val.			5.451*** 0.001

This table shows the estimation results of Equation (3) for different years; robust standard deviations in brackets; ***, ** and * denote significance levels of 1%, 5% and 10%. The F-test tests whether the three coefficients $DIRR$, *Dbonds* and *Dconst* are jointly equal to zero. The samples in the first and second columns consist of banks without and with interest derivatives.

the customer loan portfolio, suggesting that customer loans do not have a different interest rate exposure than the rest of the assets. Note that these results are not necessarily based on causal effects, but are derived from a correlation analysis. An example may illustrate this point: for the variable NIM, the net interest margin, we observe a significantly positive relationship to the loan share *loans*. From an economic point of view, it is unclear whether the higher net interest margin NIM is due to better earning opportunities from granting customer loans *loans* or whether an unobservable third factor, for instance a prosperous economic environment in the region where the bank operates, is responsible for a high net interest margin NIM and – at the same time – for a large portfolio of customer loans.

The result according to which banks with usage of interest derivatives have lower impairment losses in their bond portfolio indicates that the hedging of interest rate risk is not a pure redistribution of this risk from one bank to another bank (if both contractuayl parties are banks). Instead, the result suggests that there are banks that are better suited (for instance banks that use interest derivatives) than others.

4.2 Strategic Risk Exposure

In the long-run perspective, banks can adjust their business environment to some extent. Some parameters can be adjusted more easily than others. One parameter that is presumably difficult to adjust is a bank's long-term net pass-through (the long-term effect of a change in the interest level on a bank's net interest margin; in our study denoted as θ) because it depends on the bank's business model and this cannot be easily changed. For instance, a bank with a traditional business model, i.e. of granting customers loans and taking in deposits, is likely to have a significantly positive long-term net pass-through θ, i.e. in the event of an increase in the interest level, this bank's net interest margin largely improves. By contrast, an investment bank that buys and issues bonds is likely to have a net pass-through in the long term that is close to zero.

Memmel (2018) derives the following relationship between a bank's difference in its net interest margin ($NIM_{t,i}$) in the scenario with a upward shift of the term structure relative to the scenario with a constant term structure, the net long-run pass-through (θ_i) of assets and liabilities and its exposure to interest rate risk (IRR_i) (see also Appendix A, Equation (17)):

$$C.NIM_{t,i} = \beta_{1,t} \cdot \theta_i + \beta_{2,t} \cdot IRR_i + \varepsilon_i \tag{5}$$

where $\beta_{1,t}$ and $\beta_{2,t}$ are positive and negative parameters, respectively. The intuition behind this relationship is that a bank's net interest margin (NIM) usually benefits from a higher interest level (see Busch and Memmel (2017) and Claessens, Coleman, and Donnelly (2018)). This is so because the long-run pass-through on the asset side is usually greater than on the liability side, where the extent of the net effect is measured by the variable θ. Again, we refer to the extreme case of a simplified central bank where its assets – loans to banks – are closely tied to the (short-term) interest level and its liabilities – mostly banknotes – are not remunerated at all, irrespective of the interest level. In this case, the long-run net pass-through θ would be one, meaning that an increase in the interest level by 100 bp leads to an increase in the net interest margin by 100 bp as well. As to the exposure to interest rate risk IRR, it can be seen as a measure of the difference in the fixed-interest periods on the asset and on the liability side. If this difference is large, i.e. the exposure to interest rate risk IRR is high, there is a significantly smaller share of new business (which is adjusted to the new interest level) on the asset side than on the liability side so that it takes longer until a rise in the interest level leads to an improvement in the net interest margin NIM (see Appendix A for a model), which explains that the coefficients $\beta_{2,t}$ are negative.

In this study, having at hand a unique data set on interest rates for a large sample of banks, we are able to further analyze the variable θ. More precisely, for each bank i, we can distinguish between a short-run pass-through in the first year, based on the (non-) repricing of maturing (and existing) business ($\theta_{1,i}$), and a long-term pass-through (θ_i). Basically, the definitions of both variables are

$$\theta_i = \sum_j sgn_j pt_j w_{ij} \,, \tag{6}$$

$$\theta_{1,i} = \sum_j sgn_j pt_{ij} w_{ij} \,, \tag{7}$$

where the sum goes over all interest-bearing asset and liability positions j, $sgn_j = 1$ if position j is on the asset side and $sgn_j = -1$ if position j is on the liability side, and w_{ij} denotes the weight of position j in the respective bank. The difference between the two definitions lies in the variable pt: While pt_j is an average pass-through per balance sheet position as derived in Memmel (2018), in this study, we have the possibility of extracting the bank-individual pass-through in a one-year horizon pt_{ij}. Thus, any variation in θ_1 does not only stem from different balance sheet compositions, but also from different (bank-individual) pass-throughs. It is interesting (but not unexpected) that the standard deviation of θ_1 is much larger than that of θ, however, a different dataset was used for calculating both variables. When testing whether the variability of θ_1 is mainly driven by w_{ij} or pt_{ij}, it turns out that for a given balance sheet position j, the variation of pt_{ij} is much larger than for w_{ij}. This means that the variation of the pass-through is much greater than the variation of the balance sheet composition – this result may be considered surprising. As to the origin of the variation, as noted above, one key may lie in the level of competition in the market in which a bank operates (see Heckmann-Draisbach and Moertel (2019)). There is empirical evidence that the bank-individual pass-through depends on the degree of competition a bank experiences (see Heckmann-Draisbach and Moertel (2019)). However, this question is not in the focus of the current analysis. In all analyses, we use both definitions of θ and are able to shed some light onto the variation of this variable.

In Tables 6 and 7, the results of Equation (5) are displayed, where the control variables CR and $size$ have been additionally included (consistent with the previous section) and the two different versions of θ and θ_1 are used in the respective tables.

It turns out that for both definitions of θ, both variables of interest, i.e. θ or θ_1, the net pass-through, and IRR, the bank's exposure to interest rate risk, are highly significant with the predicted sign. Whereas the coefficient for IRR is around -1 for all horizons, we observe an increase for the variables θ and θ_1, which is in line with the derivation in Memmel (2018) where the coefficient for θ is equal to the share of liabilities that have already matured by the year t. The coefficient of determination, R^2, amounts to about 17% for all horizons, when using θ. For θ_1, however, the value of R^2 increases with an

Table 6: Difference of Net Interest Margins in the Scenarios

Variables	C.NIM2017	C.NIM2018	C.NIM2019	C.NIM2020	C.NIM2021
θ	0.220***	0.499***	0.666***	0.806***	0.947***
	(0.076)	(0.077)	(0.081)	(0.082)	(0.085)
IRR	-1.289**	-1.286***	-1.193***	-1.050***	-0.890***
	(0.164)	(0.159)	(0.154)	(0.152)	(0.152)
size	0.460	1.115*	1.389**	1.475**	1.304
	(0.683)	(0.669)	(0.662)	(0.662)	(0.684)
CR	0.145	0.114	0.094	0.071	0.064
	(0.142)	(0.132)	(0.128)	(0.126)	(0.125)
const.	-0.543	-5.876	-4.801	-2.321	3.238
	(12.040)	(11.745)	(11.521)	(11.482)	(11.787)
R-sq	0.169	0.176	0.175	0.171	0.167
Nobs	1414	1414	1414	1414	1414

This table shows the estimation results of Equation (5) for different years when using θ as defined in Equation (6); robust standard errors; ***, ** and * denote significance levels of 1%, 5% and 10%. $R-sq$ is the coefficient of determination R^2 and $Nobs$ is the number of observations, respectively.

Table 7: Difference of Net Interest Margins in the Scenarios

Variables	C.NIM2017	C.NIM2018	C.NIM2019	C.NIM2020	C.NIM2021
θ_1	0.257***	0.411***	0.525***	0.619***	0.723***
	(0.077)	(0.076)	(0.075)	(0.075)	(0.077)
IRR	-1.322***	-1.290***	-1.188***	-1.037***	-0.874***
	(0.142)	(0.138)	(0.134)	(0.132)	(0.133)
size	-0.146	-0.014	-0.085	-0.285	-0.757
	(0.667)	(0.653)	(0.653)	(0.645)	(0.658)
CR	0.153	0.146	0.140	0.127	0.131
	(0.133)	(0.121)	(0.112)	(0.106)	(0.101)
const.	4.664	6.975	12.507	18.721	27.963**
	(12.832)	(12.508)	(12.272)	(12.040)	(12.075)
R-sq	0.187	0.203	0.213	0.216	0.224
Nobs	1414	1414	1414	1414	1414

This table shows the estimation results of Equation (5) for different years when using the one-year net pass-through θ_1 as defined in Equation (7). Robust standard errors; ***, ** and * denote significance levels of 1%, 5% and 10%. $R - sq$ is the coefficient of determination R^2 and $Nobs$ is the number of observations, respectively.

increasing horizon.

Given some assumptions (not necessarily those in Appendix A), the relationship in Equation (5) should be valid. However, without data about the difference in the NIM in different scenarios, this relationship cannot be tested, at least not in a direct way. For instance, as Memmel (2018) had no data about the differences in the banks' net interest margins in the different scenarios ($C.NIM_{t,i}$), he could only indirectly test this relationship. He further assumes that banks try to stabilize their future net interest income, i.e. to minimize the variance of $C.NIM_{t,i}$,

$$\min_{IRR_i} var\left(C.NIM_{t,i}\right) = \left(\beta_{1,t} \cdot \theta_i + \beta_{2,t} \cdot IRR_i\right)^2 var(\Delta R) + \sigma_\varepsilon^2 \tag{8}$$

Taking θ_i as given and only being able to vary the exposure IRR_i to interest rate risk, he obtains a relationship between θ_i and IRR_i, namely that these two variables are associated in a positive way. In other words: If we further assume that bank management tries to stabilize the net interest margin in the mid-term by optimizing the exposure to interest rate risk (IRR), we will observe a positive relationship between a bank's interest rate risk exposure IRR and its long-term net pass-through θ, i.e. that β_1 in Equation (9) is positive.

As a further focus of our study, we analyze the interdependence of interest rate risk and credit risk. It is empirically documented that banks have an internal risk budget which they allocate to interest rate risk (IRR_i) and credit risk ($ImpR_{CST,i}$) (see Schrand and Unal (1998) and Memmel (2018)).

To test the validity of the behavioural assumptions, i.e. variance minimization of future net interest margins as in Equation (8) and a joint risk budget, we run the following regression:

$$IRR_i = \alpha + \beta_1 \cdot \theta_i + \beta_2 \cdot ImpR_{CST,i} + \gamma' X_i + \varepsilon_i. \tag{9}$$

As a measure for credit risk $ImpR_{CST,i}$, we use in this case the expected loss for 2017 under the stress scenario and substract the expected loss without stress. We think this is a good measure for credit risk in this context because this measure gives the additional credit losses in the stress test. We expect β_1 and β_2 to be positive and negative, respectively. Although the relationship in Equation (9) is rather mechanical and involves little economic reasoning, it is not always the case that it empirically holds: Banca d'Italia (2013) finds for a sample of 11 Italian banks that there is only a weak link between a bank's exposure to interest rate risk and the change in its net interest income given an interest rate shock, which may be due to relatively low interest rate risk exposure of the banks in the sample.

In Table 8, first column, we find evidence for the reasoning according to which banks try to stabilize their net interest margin: The coefficient in front of θ is highly positively significant. More specifically, the coefficient for θ is larger (by nearly a factor of 2) than the coefficient for θ_1. This means that the long-term net pass-through is a stronger determinant of the exposure to interest rate risk than the short-term (one-year) pass-through. In addition, we see that the exposure to credit risk and to interest rate risk are negatively associated, where the coefficients vary slightly in the two different specifications, from -0.026 to -0.023. This suggests that banks have a risk budget which they allocate either to credit risk or to interest rate risk. These findings are in line with Schrand and Unal (1998) and Memmel (2018). Note that the exposures to interest rate risk and the exposure

Table 8: Determinants of IRR and NIM

Variables	IRR	IRR	NIM
IRR			0.187*** (0.049)
θ	0.174*** (0.027)		
θ_1		0.089*** (0.016)	
ImpR-CST	-0.023*** (0.005)	-0.026*** (0.005)	0.969*** (0.177)
Cost			0.292*** (0.048)
CR	-0.124*** (0.031)	-0.111*** (0.025)	-0.743*** (0.193)
size	-0.302 (0.197)	-0.625*** (0.194)	-8.761*** (1.099)
const.	22.018*** (2.943)	27.524*** (2.763)	236.096*** (22.756)
R-sq	0.093	0.074	0.352
Nobs	1414	1414	1380

This table shows the estimation results of Equations (9) and (10). Robust standard errors in brackets; *** denotes a significance level of 1%. $R - sq$ is the coefficient of determination R^2 and $Nobs$ is the number of observations. Observations of the variable $Cost$ that are larger than the median plus five times the interquartile range are removed.

to credit risk are measured relative to the shock sizes of different stress tests so that the size of the coefficient cannot be interpreted, only its sign.

As to the level of the net interest margin NIM (and not the differences in the scenarios as above), we hypothesize that banks with high exposure to interest rate risk IRR and high credit risk $ImpR_{CST}$ have a high net interest margin NIM, i.e. $\beta_1 > 0$ and $\beta_2 > 0$, because interest rate risk and credit risk should be remunerated in the form of a higher net interest margin.

$$NIM_i = \alpha + \beta_1 \cdot IRR_i + \beta_2 \cdot ImpR_{CST,i} + \beta_3 \cdot Cost_i + \gamma' X_i + \varepsilon_i, \tag{10}$$

In Equation (10), we additionally include the variable $Cost$, which gives the bank's administrative costs. We do so because these variables are found in the literature to impact the net interest margin (see, for instance, Saunders and Schumacher (2000) and Busch and Memmel (2016)).
In Table 8, third column, the results of the corresponding regression (10) are displayed. We see that banks with more interest rate risk IRR and more credit risk have a significantly higher net interest margin NIM. However, as to the credit risk, it is unclear from this result whether the increase in the banks' net interest margin (NIM) only covers the expected losses or (additionally) a risk premium. Below, we will come back to this issue. In addition, the variable $Cost$ as a proxy for the services a bank provides is positively

significant: Banks with one euro more of administrative costs have – ceteris paribus – about 30 cents more of net interest income, when comparing institutions with the same balance sheet sum.

Above, we looked at the risk from the whole credit portfolio. In the following, we employ the richness of our data set and look at more granular data, i.e. at different types of loans and the corresponding expected losses. Especially, we are interested in the issue of how banks deal with their expected losses in the credit portfolio as to the setting of bank rates. Expected losses are a cost component of loan granting and this component should be reflected in the level of the corresponding bank rates if banks price credit risk (see, for instance, Edelberg (2006) and Magri and Pico (2011)). In order to empirically check the hypothesis of a positive relation between bank rates and credit risk, we estimate the following relation between the bank rates and the expected loss per exposure amount, i.e. the impairment rate ($ImpR_{EL,i,j} = LGD_{i,j} \cdot PD_{i,j}$), at the exposure class level (j) with bank individual data (i):

$$IR_{i,j} = \alpha + \beta_1 \cdot ImpR_{EL,i,j} + \beta_2 \cdot Cost_i + \gamma' X_i + \varepsilon_{i,j}, \tag{11}$$

In addition, we estimate the equation above with fixed effects for each bank. Thereby, we control for unobservable bank characteristics. Note that in this analysis, we can include as control variables in the vector Y only variables that vary across banks' balance sheet positions and not only across banks.

$$IR_{i,j} = \alpha_i + \beta \cdot ImpR_{EL,i,j} + \gamma' Y_{i,j} + \delta_i + \varepsilon_{i,j}, \tag{12}$$

Estimating Equation (11) for the two exposure classes *retail* and *loans secured by residential mortgages*, we find that our hypothesis is confirmed (see Table 9, first and second columns). Expected credit losses are significantly positively related to bank rates controlling for the bank's administrative costs $Cost$, its capital ratio CR, its total assets $size$, its interest rate risk IRR and the loans' residual fixed-interest period *(fixed-interest period)*. This is especially true for retail loans where additionally the R^2 is almost 3 percentage points higher than for mortgage loans. It seems as if the low expected losses of mortgage loans (see Table 1) were not a decisive cost component. In the third column of Table 9, we report the results of the fixed effects panel regression (12) and find that the positive relation between expected losses and bank rates is even more significantly supported.

Turning to the control variables, we find that the capital ratio CR is positively – but insignificantly – related to the bank rate. One possible explanation for this finding is that, from a bank's perspective, capital is relatively costly and the bank will price in these costs which are reflected in higher bank rates. The finding of an often negative relation between the loans' residual *fixed-interest period* and the bank rate could be due to the fact that loans with a long fixed-interest period lead to additional income so that profit-maximising banks find it optimal to lower the bank rates. This is just the opposite reasoning as with the administrative costs where we observe a positive relation.

As the relationship between an increase in the marginal costs and the corresponding

price is not trivial (see Appendix B),[6] we generate a new regressor which is equal to $pt_{i,j}$ times $ImpR_{EL,i,j}$ (instead of $ImpR_{EL,i,j}$ alone). The variable $pt_{i,j}$ gives the pass-through of another cost component, namely the interest level r_f, and we assume that the pass-through for all cost components is the same for each type of loan a bank offers. For instance, if Bank A increases its rates for mortgage loans ($j = 1$) by 180 bp after a shock of 200 bp to the risk-free rate, our assumption states that the pass-through $pt_{A,1}$=90%=180/200 is the same for each cost component of Bank A's mortgage loans (expected losses, refinancing, proceeds of bearing interest rate risk, ...).
Controlling for the bank's administrative costs, its capital ratio, its size, its interest rate risk and the residual fixed-interest period of the loans, we expect that the corresponding coefficient is one (see Appendix B) if the banks treat all cost components in the same way, irrespective of their nature (here: expected credit losses and interest level). In order to test our hypothesis, we estimate the following two equations:

$$IR_{i,j} = \alpha + \beta_1 \cdot pt_{i,j} \cdot ImpR_{EL,i,j} + \beta_2 \cdot Cost_i + \gamma' X_i + \varepsilon_{i,j}, \tag{13}$$

$$IR_{i,j} = \alpha_i + \beta \cdot pt_{i,j} \cdot ImpR_{EL,i,j} + \gamma' Y_{i,j} + \varepsilon_{i,j}, \tag{14}$$

When we introduce the variable $pt * ImpREL$ consisting of the pass-through times expected losses as an explanatory variable (instead of the expected losses alone), as suggested in Equations (13) and (14), (see Table 9, columns four to six), we can quantitatively interpret the coefficient in front of this variable (see Appendix B). A coefficient of 1 means that expected losses are priced-in in the bank rate in the same way as the risk-free interest rate. If, however, the banks not only price in the expected losses, but a risk premium for the credit risk as well, then the coefficient β_1 in Equation (13) and β in Equation (14) are larger than one. We see that the coefficient in the panel specification (column 6) is significantly larger than one, hinting that a risk premium is included in the bank rate.

5 Conclusion

In this paper, we use data from a quantitative survey among small and medium-sized German banks to learn about banks' interest and credit risk management. In the case of an upward shift of the interest level, we find that most of the reduction in earnings in the first year after this shock results from write-downs in the bond portfolio. We also see that banks tend to dampen these write-downs by liquidating hidden reserves (about 24 cent for each euro of write-downs) and that banks which use interest derivatives are less exposed to the risk of write-downs in the bond portfolio. Moreover, we find that interest rate risk and credit risk are remunerated in the sense that banks with more exposure to these risks (ceteris paribus) have higher net interest margins. Looking at more granular data of the credit portfolio, we see that banks seem to be compensated for the expected losses. We even find hints of a risk premium that banks include in their loan rates. In addition, banks seem to stabilize their mid-term net interest margins by exposing themselves to

[6] Bulow and Pfleiderer (1983) theoretically show that producers pass through less or even more than the change in the variable costs and that the extent of the pass-through strongly depends on the functional form of the demand function.

Table 9: Bank Rates and Credit Risk

Variables	Bank rate Retail	Bank rate Mortgages	Bank rate	Bank rate Retail	Bank rate Mortgages	Bank rate
ImpREL	0.586*** (0.204)	0.483* (0.270)	1.277*** (0.185)			
pt*ImpREL				0.658** (0.274)	0.489 (0.390)	1.785*** (0.268)
Cost	0.123** (0.045)	0.059 (0.045)		0.122** (0.045)	0.059 (0.046)	
CR	0.000 (0.000)	0.000 (0.000)		0.000 (0.000)	0.000 (0.000)	
size	-0.002*** (0.000)	0.000 (0.000)		-0.002*** (0.000)	0.000 (0.000)	
IRR	0.000* (0.000)	-0.000*** (0.000)		0.000 (0.000)	-0.000*** (0.000)	
fixed-interest period	-0.000** (0.000)	-0.000* (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000* (0.000)	0.000 (0.000)
Constant	0.056*** (0.006)	0.027*** (0.002)	0.031*** (0.000)	0.057*** (0.006)	0.027*** (0.002)	0.031 (0.000)
Bank FE	no	no	yes	no	no	yes
F-test p-val.				1.56 0.212	1.72 0.190	8.55*** 0.004
R-sq	0.067	0.039	0.043	0.065	0.035	0.040
Nobs	1240	1242	2482	1240	1242	2482
Banks	1240	1242	1338	1240	1242	1338

This table shows the estimation results of Equations (11) to (14). Robust standard errors in brackets; ***, ** and * denote significance levels of 1%, 5% and 10%. $R-sq$ is the coefficient of determination R^2 (in columns 3 and 6: within R^2) and $Nobs$ ($banks$) is the number of observations (banks). Observations of the variables pt and $Cost$ that are larger than the median plus five times the interquartile range are removed; the F-test tests whether the coefficient in front of $pt * ImpREL$ is equal to one.

interest rate risk and they act as if they have a risk budget which they either allocate to credit risk or to interest rate risk.

A Appendix: Exposure to Interest Rate Risk and the Dynamics of the Net Interest Margin

In this section, we formulate and formalize our expectations concerning the dynamics of the net interest margin. We assume a bank with a stylized balance sheet (the assumptions are similar to Busch and Memmel (2017) and Memmel (2018)): On the asset side, there are default-free loans (share: θ_A) that are granted in a revolving manner, i.e. whenever a loan matures, it is replaced by a new one. These loans have a maturity M_A and a coupon c equal to the then prevailing interest level. The other assets are cash (share: $1-\theta_A$). On the liability side, there are default-free loans (share: θ_L) with maturity M_L that the banks issues in a revolving manner; the rest of the liabilities consist of non-remunerated current accounts (share: $1-\theta_L$). Please note that θ_A (and θ_L) can also be interpreted differently: Instead of the share of assets that have a pass-through of 100%, it can also be interpreted as the average pass-through on the asset side. This interpretation is more in line with the use of the variable $\theta := \theta_A - \theta_L$ in the main sections of this paper.
Given these assumptions and a parallel shift ΔR of the term structure in $t=0$, the difference of the net interest margin (NIM) to the case of no interest rate shock is:

$$C.NIM = (\phi_A\theta_A - \phi_L\theta_L)\cdot\Delta R \tag{15}$$

where ϕ_A and ϕ_L denote the share of loans and bonds that have already matured by time t. The interest rate risk (IRR) of such a bank is:

$$IRR = \frac{1}{2}\left(M_A\theta_A - M_L\theta_L\right) \tag{16}$$

Combining Equations (15) and (16) and setting $t=1$ such that $\phi_A = 1/(2\cdot M_A)$ and $\phi_L = 1/(2\cdot M_L)$ (see Busch and Memmel (2017)), we obtain

$$\frac{C.NIM}{\Delta R} = \left(\phi_L + \frac{1}{2\cdot M_A}\right)\theta - \frac{1}{M_A\cdot M_L}IRR. \tag{17}$$

More generally, we have for $M_k > 1$ with $k = A, L$:

$$\phi_k(t) = \begin{cases} \frac{t/2}{M_k} & if \quad t \leq 1 \\ \frac{t-1/2}{M_k} & if \quad 1 < t < M_k + 1/2 \\ 1 & if \quad t \geq M_k + 1/2 \end{cases} \tag{18}$$

We thus expect that the temporal development of the net interest margin in the shock scenario, compared to the case of no shock, depends in a characteristic way on the average maturities of the asset and liability side, respectively. Of course, we do not expect a real bank to have a business model and a balance sheet as simple as in our assumptions. However, since the data contains information on the average maturity, we check whether the prediction of our model is in line with this information. Indeed, when evaluating the temporal evolution of $C.NIM$ for groups of banks with different average maturities, we observe that the higher M_L, the smaller is the increase of $C.NIM$ from 2017 to 2021. For banks with $0.5y < M_L < 1.5y$, the increase 42.7 basis points (relative to the balance sheet sum), while it is only 23.7 bp for banks with $M_L > 4.5y$. For different buckets of M_A, we observe that the increase of $C.NIM$ is higher with increasing M_A. These results indicate that, despite the simplicity of the model, our formulation of the temporal development of $C.NIM$ captures some important features of the real dynamics of the net interest margin.

For $1 < M_L < t - 1/2 < M_A$, Equation (15) becomes

$$\frac{C.NIM}{\Delta R} = \frac{t - 1/2}{M_A}\theta_A - \theta_L. \tag{19}$$

Equation (16) can be transformed to

$$M_A = \frac{2 \cdot IRR + M_L\theta_L}{\theta_A}. \tag{20}$$

Combining Equations (19) and (20), we obtain

$$\frac{C.NIM}{\Delta R} = \left(t - \frac{1}{2}\right)\frac{\theta_A^2}{2 \cdot IRR + M_L\theta_L} - \theta_L. \tag{21}$$

Let t^* be the horizon, for which $C.NIM = 0$ in Equation (21), i.e. the horizon where the negative effect of an increase in the interest level ends and the positive effect starts:

$$0 = \left(t^* - \frac{1}{2}\right)\frac{\theta_A^2}{2 \cdot IRR + M_L\theta_L} - \theta_L. \tag{22}$$

One can show (applying the theorem about implicit functions) that this horizon increases if the interest rate risk goes up:

$$\frac{\partial t^*}{\partial IRR} = \frac{2}{2 \cdot IRR + M_L\theta_L} > 0 \tag{23}$$

This is line with the results shown in Table 2.

B Appendix: Loan Rate and Expected Losses

In this appendix, we want to outline our idea of how to establish a relationship between the bank rate and the expected losses. We start with three examples that show that banks maximising their profits choose the extent of the pass-through depending on the market situation and that, however, the relationship between market power and the pass-through is not monotone (see Bulow and Pfleiderer (1983) on whom our examples are based). In the first example, we assume a bank that faces demand D for loans according to the demand function $D(IR) = a - b \cdot IR$, where IR is its loan rate and a and b are (positive) parameters. Concerning loan granting, the bank has variable costs c. Maximising its profits $\Pi = D(IR) \cdot (IR - c)$, it sets its loan rate IR_M^* to

$$IR_1^* = \frac{a}{2b} + \frac{c}{2} \tag{24}$$

In the second example, we assume a bank that faces a demand curve with constant elasticity $-\eta > 1$: $D(IR) = b \cdot IR^\eta$. Profit maximization implies

$$IR_2^* = c \cdot \frac{\eta}{\eta + 1} \tag{25}$$

By contrast (third example), a bank facing perfect competition will set its loan rate IR_3^* equal to the variable costs c:

$$IR_3^* = c \tag{26}$$

These three examples show that banks with market power may pass on less ($\partial IR_1^*/\partial c = 1/2$) or more ($\partial IR_2^*/\partial c = \eta/(\eta+1) > 1$) than the actual change in the marginal costs and that banks without market power ($\partial IR_3^*/\partial c = 1$) pass on the entire change in marginal costs.

To circumvent the problem of the differing (and non-monotonic) pass-throughs, we make use of our rich data set: We know the pass-through for the loan rate IR_i^* with respect to one cost component, namely with respect to changes in the risk-free interest rate r_f, denoted by $pt_i = \partial IR_i^*/\partial r_f$. We assume that the pass-through for other cost components is the same for the same bank i, for instance for the expected losses $ImpR_{EL,i}$:

$$pt_i := \frac{\partial IR_i^*}{\partial r_f} = \frac{\partial IR_i^*}{\partial ImpR_{EL,i}} \tag{27}$$

Under this assumption, we can express the change in bank i's loan rate as

$$\Delta IR_i^* = pt_i \cdot \Delta ImpR_{EL,i}. \tag{28}$$

In our data, there are the bank rates $IR_{i,j}$ for different asset classes j, the corresponding pass-throughs $pt_{i,j}$ for a change in the interest level and the expected rate of losses $impR_{EL,i,j}$. This may lead to the following empirical relationship:

$$IR_{i,j} = \alpha + \beta \cdot (pt_{i,j} \cdot ImpR_{EL,i,j}) + \varepsilon_{i,j} \tag{29}$$

which corresponds to Equations (13) and (14) in the main text. If the assumptions from above hold, we expect the variable β to equal one. If not only the expected losses, but also a risk premium is priced-in, then β is larger than one. Note that the pass-through $pt_{i,j}$ is derived from the observations for the same bank in two different scenarios, whereas we use the cross-sectional variation for the estimation of regression (29).

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