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What drives the short-term fluctuations of banks' exposure to interest rate risk?

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Non-technical summary

Research Question

Banks grant long-term loans and finance themselves with short-term deposits. This maturity mismatch exposes them to interest rate risk. We investigate whether banks actively manage their exposure to this risk in the short term. This is connected to the question of who predominately determines the fixed-interest period of loans, the bank as the lender or the customers as the borrowers.

Contribution

In our study of banks in Germany, we explain which factors determine their exposure to interest rate risk. As explanatory variables, we employ the remuneration of bearing interest rate risk, dummy variables describing the supervisory interest rate risk situation of a bank and its usage of interest swaps as well as the length of the fixed-interest period of its housing loans. As to the question of who predominately determine the fixed-interest period of loans, we assume that banks want to extend and customers want to shorten the fixed-interest period of the loans if the term structure becomes steeper. In our study of a sample of German banks, we investigate the relationship between the steepness of the term structure and the length of the fixed-interest period. From this, we can infer who predominantly determines the length of the fixed-interest period of loans.

Results

We find that banks actively manage their exposure to interest rate risk: They adjust it to the remuneration of this risk, they take into account their regulatory situation and they make use of interest swaps for the management of the interest rate risk exposure. In addition, it turns out that customers (and not the banks) predominantly determine the fixed-interest period of loans and that the granting of housing loans with a long fixed-interest period is found to increase not only a bank's exposure to interest rate risk resulting from housing loans, but its overall exposure as well. This last finding is not in line with active interest rate risk management.

Nichttechnische Zusammenfassung

Fragestellung

Banken vergeben langfristige Kredite und finanzieren sich durch kurzfristige Einlagen. Dieses Ungleichgewicht in den Laufzeiten führt zu Zinsänderungsrisiken. Wir untersuchen, ob Banken in der kurzen Frist aktiv ihr Zinsänderungsrisiko steuern. Damit zusammenhängend ist die Frage, wer die Länge der Zinsbindung bei Krediten vorrangig bestimmt, ob die Bank als Kreditgeber oder die Kunden als Kreditnehmer.

Beitrag

In unserer Studie für Banken in Deutschland untersuchen wir, wovon deren Zinsänderungsrisiko abhängt. Als erklärende Variablen nutzen wir die Entlohnung für das Eingehen von Zinsänderungsrisiken, Indikatorvariablen, die die regulatorische Situation einer Bank und deren Einsatz von Zinsswaps abbilden, sowie die Länge der Zinsbindung ihrer Immobilienkredite. Hinsichtlich der Frage, wer die Zinsbindungsdauer bestimmt, unterstellen wir, dass Banken bei steiler Zinsstrukturkurve eine lange Dauer der Zinsbindung der Kredite anstreben und die Kunden eine kurze Dauer der Zinsbindung wünschen. In einer Studie für eine Stichprobe deutscher Banken ermitteln wir den Zusammenhang zwischen der Steigung der Zinsstrukturkurve und der Länge der Zinsbindung von Immobilienkrediten und können daraus ableiten, wer im Gleichgewicht die Zinsbindungsdauer maßgeblich bestimmt.

Ergebnisse

Es zeigt sich, dass Banken ihr Zinsänderungsrisiko aktiv steuern: Sie richten sich nach der Entlohnung dieses Risikos, beachten ihre regulatorische Situation und steuern ihr Zinsänderungsrisiko durch den Einsatz von Zinsswaps. Auch zeigt sich, dass die Kunden (und nicht die Banken) die Zinsbindungsdauer der Kredite vorrangig bestimmen und dass die Vergabe langlaufender Immobilienkredite nicht nur dasjenige Zinsänderungsrisiko einer Bank erhöht, das auf Immobilienkrediten beruht, sondern auch deren gesamtes Zinsänderungsrisiko. Dieses zuletzt aufgeführte Ergebnis ist nicht im Einklang mit der Vorstellung, dass Banken ihr Zinsänderungsrisiko aktiv steuern.

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What drives the short-term fluctuations of banks' exposure to interest rate risk?*

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Abstract

We investigate whether banks actively manage their exposure to interest rate risk in the short run. Using bank-level data of German banks for the period 2011Q4-2017Q2, we find evidence that banks actively manage their interest rate risk exposure in their banking books: They take account of their regulatory situation and adjust their exposure to the earning opportunities of this risk. We also find that the customers' preferences predominantly determine the fixed-interest period of housing loans and that the fixed-interest period of these loans has an impact on the banks' overall exposure to interest rate risk. This last finding is not in line with active interest rate risk management.

Keywords: Interest rate risk in the banking book, fixed-interest period of housing loans, interest swaps, regulation of interest rate risk

JEL classification: G21

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1 Introduction

Usually banks grant long-term loans and finance themselves with short-term deposits. This maturity mismatch exposes the banks to interest rate risk which makes them vulnerable to sudden increases in the interest level. This issue is not only relevant for banking supervisors, but for macro-prudential supervisors as well because – unlike credit risk which has a huge bank-specific component – this risk is barely diversifiable (see Hellwig (1994)) and, therefore, affects many banks at the same time and in same way.

In this paper, we investigate the short-run changes in the exposure to this risk. In particular, we want to deal with the question of whether banks actively manage this risk in the short run. The answer to this question is not as trivial as it may sound: Instead of an active management of the exposure to interest rate risk, a bank may treat interest rate risk as a byproduct of the loan granting business and let the exposure to this risk randomly fluctuate, depending on the demand for long-term loans.

Interest rate risk is often treated as any other market risk. In this perspective, the earnings from bearing interest rate risk can primarily be seen as part of a bank's overall earnings and Busch and Memmel (2016) show that this contribution can be huge, amounting to around one third of the net interest income for the average bank in Germany. If this source of income is relevant for a bank, it is believed to adjust its exposure to this risk when its remuneration increases or decreases or when regulatory issues hinder the bank to maintain or increase its position.

There is another question which is closely related namely the question of who finally bears interest rate risk. If, for instance, banks try to keep their interest rate risk exposure at the level they consider as optimal for themselves and, at the same, fulfill their customers' wishes regarding the loans' fixed-interest periods, they will pass through possible changes in their customers' desired fixed-interest periods to the anonymous financial markets, for instance by appropriate interest swap positions. In other words, we look at the hypothesis according to which customers from the real economy predominantly determine the fixed-interest period of their loans and banks offset the resulting interest rate risk imbalances with suitable transactions at the capital market. According to Basten, Guin, and Koch (2017), this hypothesis is wide-spread. However, there is empirical evidence that market frictions make banks prefer certain fixed-interest periods of their loans. For instance, Fuster and Vickery (2015) find that banks are reluctant to grant fixed-rate mortgages if these mortgages cannot be easily securitized.

We investigate the hypothesis from above, because it would be solid evidence for the banks' active management of their interest rate risk exposure if this hypothesis were backed. This hypothesis is checked using housing loans to private households. We believe that housing loans are the most suitable bank product from which to infer the preferences of fixed-interest periods for the following reasons. First, changes in market interest rates are nearly completely passed through to the corresponding bank rates (see Schlueter, Busch, Hartmann-Wendels, and Sievers (2016)). That means that the fixed-interest periods of housing loans mirrors the actual length of the fixed-interest period, unlike, for instance, customer deposits where the juristic and actual maturities and thereby the fixed-interest periods largely differ. Second, housing loans represent a huge part of banks' loans to non-banks, so that their fixed-interest periods have a significant impact on banks' interest rate risk position.[1] If the hypothesis from above holds, then changes in these loans' fixed-interest period will not have any impact on the banks' overall exposure to this risk.

In our empirical study of German banks for the period 2011Q4 - 2017Q2, we find evidence that banks actively manage the exposure to interest rate risk in the short run. For instance, banks take account of their regulatory situation when they adjust their interest rate risk exposure. Other evidence for the active management is that banks adjust the interest rate risk exposure to the remuneration of this risk. We also find that the fixed-interest period of housing loans are predominantly determined by the customers and that the overall exposure of a bank to interest rate risk increases when the fixed-interest period of its new housing loans increases. The last result – in combination with the finding that primarily the customers (and not the banks) determine the fixed interest period of housing loans – is evidence against active interest rate risk management and indicates that there is still a connection between the granting of housing loans and a bank's overall exposure to interest rate risk. Our results suggest that, within one quarter, banks offset only 11.4% of those changes in interest rate risk exposure that result from the housing loan business.

The paper is structured as follows: In Section 2, a brief overview of the literature in this field is given. The empirical models are described in Section 3. In Section 4, the data that is used is explained and, in Section 5, the empirical results are given. Section 6 concludes.

2 Literature

This paper contributes to the literature on how the customers' preferences concerning interest rate risk determines the banks' exposure to this risk. Basten et al. (2017) analyse the customers' choice of fixed versus variable interest rate mortgages in Switzerland where their data allows them to distinguish between demand and supply. They find that the customers' demand for a certain fixed-interest period is largely determined by the steepness of the term structure: The higher the steepness, the lower is the fixed-interest period the customers demand. We as well explore this question by investigating the fixed-interest periods of housing loans and we look whether their fixed-interest periods become smaller or larger when the steepness of the term structure increases. As we do not have separate data on demand and supply as they have, but only data on the market outcome, we develop a model that makes it possible to derive statements on the relationship of the fixed-interest periods of loans and the steepness of the term structure, using only this limited information. In this context, we make use of the character of bank loans: For a bank, they are an asset and, for the customers, they are a liability, meaning a development of the term structure that is beneficial for the banks is detrimental to their customers and vice versa. What we see is that there is a strongly negative relationship between the steepness of the term structure and the fixed-interest period of new German housing loans, meaning that the determination of the fixed-interest periods seems to be mainly demand-driven. This need not be in contrast with the finding in the literature that some market imperfections

[1] In June 2017, the volume of book credits of banks in Germany to domestic firms and private households amounted to € 2,559.7 billion of which € 1,143.6 billion (share: 44.7%) were housing loans to private households (see Deutsche Bundesbank (2017)).

make also banks have an impact on the market outcome of fixed-interest periods. We do not claim that banks have no influence at all, but that the influence of the customers is stronger. By contrast, Kirti (2017) theoretically and empirically shows that the firms' decisions for floating interest rate loans are dominantly driven by the banks' supply of these loans. In our empirical study, we further show that the customers' fixed-interest period preferences are not only a determinant of banks' on-balance sheet interest rate risk exposure, but that they have an impact on the banks' overall interest rate risk exposure as well. We quantify the part of the change in interest rate risk exposure resulting from housing loans that is closed by appropriate on- and off-balance sheet positions.

Another contribution of this paper to the literature is to explore the question of whether and how firms tactically manage their interest rate risk (see for banks, e.g., Brewer, Jackson, and Moser (2001); Brewer, Minton, and Moser (2000) and for non-financial firms, e.g., Oberoi (2018)). Purnanandam (2007) and Memmel and Schertler (2013) show that US and German banks, respectively, use interest rate swaps, on average, for hedging purposes. As to this risk, Memmel (2011) finds that the exceedance of a regulatory threshold leads to a reduction of the exposure in the future. In our study, we provide additional evidence that banks use swaps to hedge their on-balance-sheet interest rate risk and that the exceedance of this regulatory threshold has the expected impact on the exposure to the overall interest rate risk of a bank.

Finally, this paper contributes to question of what the determinants of the banks' net interest margins are (see, for instance, Maudos and de Guevara (2004)) where the earnings from bearing interest rate risk represent a substantial part; for instance, Busch and Memmel (2016) find that these earnings account for around one third of the average German banks net interest margin in 2012 and 2013. Memmel (2011) and Chaudron (2018) find that a bank's interest rate risk exposure moves in sync with the earning opportunities from interest rate risk. We also find evidence that the banks' exposure to interest rate risk depends on the earning opportunities from bearing interest rate risk.

In this paper, we look at interest rate risk. This risk can be, but need not be bundled together with the risk from maturity transformation (see, for instance, Allen and Gale (1997)). For instance a 10-year bond with a floating interest rate, i.e. a coupon that is linked to a short-term interest rate like the 3-month Euribor, has zero or little interest rate risk. However, due to its long period of capital commitment, it bears much risk from term transformation.

3 Empirical Modeling

3.1 Managing Interest Rate Risk

In our empirical study, we explain the change in a bank's exposure to interest rate risk, where we quantiy the exposure to this risk using a measure irr close to the Basel interest rate coefficient. This measure can be seen as a bank's present value losses due to a standardized interest rate shock, normalized with the bank's equity (see Section 4 for a detailed description). It can also be interpreted as a multiple of the duration of the banking book (normalized with the bank's equity), meaning that the exposure to interest rate risk is separated from the volatility of the interest level. This can be compared to the risk of a stock position: Its risk is the risk of the stock times the position in the stock. In this analogy, our measure irr corresponds to the position in interest bearing assets and liabilities.

Concretely, we run the following panel regression, where the indexes t and i stand for the point in time and the bank, respectively.

$$\triangle irr_{t,i} = \alpha + \beta_1 \cdot \triangle \mu_t + \beta_2 \cdot \triangle reg_{t,i} + \beta_3 \cdot \triangle swap_{t,i} + \beta_4 \cdot \triangle fip_{t,i} + \gamma_1 \cdot \triangle CR_{t,i} + \varepsilon_{t,i} \quad (1)$$

In the following, the explanatory variables are described.[2] Interest rate risk is sometimes interpreted as a market risk like any of the others that banks are exposed to. In this case, we would expect the exposure to this risk to increase as the remuneration of bearing this risk increases (see, for instance, Fishburn and Porter (1976)).[3] Therefore, we include the earning opportunities from interest rate risk in Equation (1) where the variable $\triangle\mu_t$ denotes the change in the earnings from a passive trading strategy in German government bonds that is only subject to interest rate risk (see Section 4 for a description and Memmel (2011) for an application of this trading strategy in this context).

A bank may be prevented from extending or maintaining its exposure to interest rate risk for regulatory reasons. As done in Memmel (2011), we introduce the dummy variable $reg_{t,i}$ which takes the value 1 if bank i's interest rate risk exposure in time $t-1$, i.e. in the previous quarter, was above 20%, a regulatory threshold above which a bank counts among the banks with elevated interest rate risk exposure.

One central question of this paper is whether banks actively manage their interest rate risk or whether their interest rate risk randomly fluctuates in response to their customers' demand for long-term loans. Above, we explored the banks' reaction to changes in the risk remuneration and to regulatory requirements. Another issue in this context is whether banks use derivatives to manage their interest rate risk exposure, i.e. the issue of how banks adjust their exposure. To shed light on this issue, we include the dummy variable $\triangle swap_{t,i}$ in the regression (1). The dummy variable $swap_{t,i}$ takes the value of 1 if bank i in time t has a strictly positive notional amount of interest rate swaps, i.e. a bank reports either zero (if it has no interest swaps at all) or a strictly positive number if it uses swaps irrespective of how the present value of its swap position reacts to changes in the interest level. If the coefficient in front of the variable $\triangle swap_{t,i}$ is different from zero, there is evidence that banks use interest swaps to steer their interest rate risk exposure; if it is negative, this suggest that they use it – on average – to hedge this risk. Note that, in the panel regression (1), we make use of the time serial variation in this variable, i.e. the change from 0 to 1 and vice versa. By contrast, if a bank has never used interest swaps during the sample period or has used those swaps in every quarter, there is no change in the variable $swap_{t,i}$ and the first difference of this variable is always zero.

In addition, we introduce the variable $\triangle fip_{t,i}$ in regression (1), where $fip_{t,i}$ is the average fixed-interest period of new housing loans that bank i grants in time t. The idea behind it is as follows: We hypothesize that the customers get their wishes concerning the fixed-interest periods of the housing loans fulfilled. This part of the hypothesis is checked

[2] The operator $\triangle$ gives the difference between the variable in time t and its value in the previuos quarter (time $t-1$).

[3] If, however, a bank's market value is maximised as in the framework of Froot and Stein (1998), its exposures to any risks that can be completely hedged are irrelevant because they do not change the market value.

in a study described below. The checking of this part of the hypothesis is important as it may be that banks manage their exposure to interest rate risk by promoting mortgage loans with fixed-interest periods that fit to their exposure wishes. In this case, the fixed-interest period of housing loans would be an instrument of the banks to manage their exposure to interest rate risk and we would expect a positive relationship between the fixed-interest period of new housing loans and the banks' overall exposure to interest rate risk.

We further hypothesize that the banks offset possible open unwanted interest rate risk positions by suitable transactions at the capital market. If this part of the hypothesis holds (and the housing loans' fixed-interest period is not an instrument of the banks to manage their interest rate risk), we don't expect to find any impact of changes in a bank's loans fixed-interest period on its overall exposure to interest rate risk. In case, there is a (positively) significant relationship in the data, a bank's overall interest rate risk exposure depends on the loan granting of housing loans and the bank does not offset the whole change in interest rate risk exposure by appropriate on and off balance sheet transactions on the capital market.

The fixed-interest period of housing loans $fip_{t,i}$ has a close connection to these loans' duration $D_{t,i}$ (see Appendix 2). In an additional specification, we replace the measure $\triangle fip_{t,i}$ in regression (1) with the standardized duration $\triangle D^s_{t,i}$ where the standardization is done in the same way as with the overall bank's interest rate risk irr in the banking book. Thus, the coefficient can be interpreted as the share of the interest rate risk resulting from housing loans that is not hedged in a given quarter.

As a control variable, we introduce the change in a bank's capital ratio $\triangle CR_{t,i}$.

3.2 Fixed-Interest Periods of Housing Loans

As stated above, we investigate in this paper whether a bank or whether its customers predominantly determine the fixed-interest period profile of the bank's assets and liabilities. In a model for a bank's loans, we show that the loans' fixed-interest periods in equilibrium depend on the importance which the bank and its customers attach to the fixed-interest periods. This model makes it possible to derive statements on the strength of demand and supply effects using only data on the market outcome and not separate data on supply and demand. As the empirical identification, we look at the relationship between the fixed-interest period of new housing loans and the steepness of the term structure. We make use of the fact that a loan is an asset for a bank, but a liability for the borrower that means that a development of the term structure that is positive for the bank is detrimental for the customers and vice versa.

In the model, we assume that the customers' wish for the length of the fixed-interest period fip_D of the loans depends on the steepness st of the term structure in a negative way, which is modeled as a linear relationship for reasons of parsimony and analytical tractability:

$$fip_D = -b \cdot st \tag{2}$$

where b is a positive parameter. Without loss of generality and for ease of exposition, we treat the variables fip and st as demeaned variables.

We reason as follows: The steeper the term structure, the less inclined are the customers as the borrowers to have loans with a long fixed-interest period, because they believe that they will lock in the (relative to the short-term) high interest rates for a long time. Note that this reasoning is in contrast to the expectation hypothesis according to which long-term interest rates are, on average, a weighted average of future short-term interest rates. However, empirical results concerning this hypothesis are – at best – mixed (see, for instance, Dai and Singleton (2002)). In addition, Basten et al. (2017) find in their empirical study that the customers' demand for mortgage loans with long a fixed-interest period depends on the steepness of the term structure in a negative way.[4]

For the banks as the lenders, it should be the other way around, because the loans are on the asset side of their balance sheets, whereas – as stated above – they are on the liability side of the borrowers' balance sheets. The corresponding equation for the fixed-interest period of the loan supply is

$$fip_S = b \cdot st, \tag{3}$$

where, without loss of generality, we do not distinguish between the sensitivities of demand and supply; their absolute value is in both cases equal to the parameter b. Memmel (2011) and Chaudron (2018) find empirical evidence that banks' exposure to interest rate risk increases when the earning opportunities from bearing this risk (here: the steepness of the term structure) rise.

The steepness of the term structure st is treated as exogenous and not as an endogenous variable that balances out demand and supply at the housing loan market. The market clearing is done by the variable fip, the length of the fixed-interest period of housing loans. We assume that the loan volume V_D that is demanded depends on the actual fixed-interest period fip and the fixed-interest period that the borrowers prefer fip_D (see Equation (2)):

$$V_D(fip) = c - \beta_D \cdot (fip - fip_D)^2 \tag{4}$$

where β_D is a positive parameter, that gives the importance the customers attach to the fixed-interest period. The modeling of the demand function is such that the demand for loans is the lower, the more the actual fixed-interest period fip deviates in both directions from the one that the borrowers prefer fip_D. The same assumption is applied to the loan supply V_S (again β_S is a positive parameter):

$$V_S(fip) = c - \beta_S \cdot (fip - fip_S)^2 \tag{5}$$

In the market equilibrium, we have the following condition fulfilled:

$$V_D(fip) = V_S(fip).$$

From this equilibrium condition and the Equations (2) to (5), we obtain

$$0 = (a-1) \cdot fip^2 + 2 \cdot (a+1) \cdot b \cdot st \cdot fip + (a-1) \cdot b^2 \cdot st^2, \tag{6}$$

[4] Koijen, Hemert, and Nieuwerburgh (2009) theoretically show and empirically find that (what they call) the long-term bond risk premium (the premium earned on investing long in a long-term bond and rolling over a short position in short-term bonds) best explains the customers' fixed-interest period choice. The steepness of the term structure is related to this premium, but may deviate.

where $a = \beta_D/\beta_S$. Ignoring the case of $a = 1$ [5], applying the formula to solve quadratic equations and using only the one of the two roots that is economically sensible, we obtain (see Appendix 3)

$$fip = -\frac{(\sqrt{a}-1)^2}{a-1} \cdot b \cdot st. \tag{7}$$

It can be shown that the relationship in Equation (7) between the actual fixed-interest period fip, i.e. the observed fixed-interest period in the data, and the steepness of the term structure st is positive or negative, depending on the importance of the fixed-interest periods of loans for banks (β_S) and for customers (β_D), i.e.

$$-\frac{(\sqrt{a}-1)^2}{a-1} \cdot b \begin{matrix} > \\ = \\ < \end{matrix} 0 \iff \beta_S \begin{matrix} > \\ = \\ < \end{matrix} \beta_D \tag{8}$$

with $a = \beta_D/\beta_S$.

To empirically determine how the average fixed-interest period is influenced by the steepness of the term structure of interest rate, we run the following regression

$$\triangle fip_t = \alpha + \beta \cdot \triangle st_t + \gamma \cdot \triangle r_{10y,t} + \varepsilon_t \tag{9}$$

where $\triangle fip_t$ is (again, but this time the cross-sectional weighted average over the banks in Germany) the change in the average of the fixed-interest period of new housing loans granted in t and the variable $\triangle st_t$ is the change in the steepness of the term structure, measured as the difference of the German government bond yields (zero-coupon bonds) of 10 years and of 1 year. We estimate this relationship in first differences because the levels of the variables do not seem to be stationary (see Table 4 in Appendix 1). In addition, we include the variable $\triangle r_{10y,t}$ which is the change in the yield of the German government bond with a 10-year maturity. We expect the coefficient β to be negative, if the customers' demand (and not the banks' loan supply) predominantly determines the loans' fixed-interest periods, i.e if $\beta_S < \beta_D$.

Another empirical implication of Equation (7) concerns the individual banks: When the steepness of bank i's term structure of rates for housing loans $\triangle st^b_{t,i}$ increases, we expect that there will be a change in the fixed-interest period of the housing loans this bank grants:

$$\triangle fip_{t,i} = \tilde{\alpha} + \tilde{\beta} \cdot \triangle st^b_{t,i} + \tilde{\gamma} \cdot \triangle r^b_{lg,t,i} + \varepsilon_{t,i} \tag{10}$$

where i stands for the banks, t for the respective quarter and $r^b_{lg,t,i}$ is the rate that bank i charges in quarter t for housing loans with a long fixed-interest period. Again, depending on the relative importance of supply and demand, we expect a positive or negative sign of $\tilde{\beta}$. The steepness of the bank-specific term structure can be split into a part that is common to all banks st^b_t and a deviation from this average, i.e. $st^b_{t,i} \equiv st^b_t + \left(st^b_{t,i} - st^b_t\right)$; correspondingly, that can be done for the long-term bank rate: $r^b_{lg,t,i} \equiv r^b_{lg,t} + \left(r^b_{lg,t,i} - r^b_{lg,t}\right)$. This split makes it possible to see whether the general economic conditions or whether bank-specific factors drive the results. With these replacements, Equation (10) becomes

[5] In this case, $fip = 0$ would be a solution (see Appendix 3).

Table 1: Summary Statistics

Variable	Period	Observations	Mean	Std.
$irr_{t,i}$	2011Q4-2017Q2	34,724	18.844	7.970
μ_t	2011Q4-2017Q2	23	3.044	0.220
red_t	2011Q4-2017Q2	23	2.563	0.403
$swap_{t,i}$	2011Q4-2017Q2	34,724	0.460	0.498
$CR_{t,i}$	2011Q4-2017Q2	34,724	14.637	5.043
fip_t	2003Q1-2017Q2	58	7.547	0.616
$fip_{t,i}$	2003Q1-2017Q2	9,253	7.331	1.801
st_t	2003Q1-2017Q2	58	1.408	0.787
$st^b_{t,i}$	2003Q1-2017Q2	9,253	0.238	0.470
$r_{10y,t}$	2003Q1-2017Q2	58	2.677	1.508
$r^b_{lg,t,i}$	2003Q1-2017Q2	9,253	3.689	1.240

This table shows summary statistics: $irr_{t,i}$ is a bank's exposure to interest rate risk, μ_t is the earnings of a passive trading strategy in government bonds (in % p.a.), red_t is the average initial amortization of housing loans (in % p.a.), $swap_{t,i}$ is a dummy variable indicating that a bank has a strictly positive notional amount of interest rate swaps, $CR_{t,i}$ is the capital ratio (in %), fip_{ti} and $fip_{t,i}$(in years) are the fixed-interest period of newly granted German housing loans (weighted average in the cross-section of banks (index t) and bank-specific (index t, i)), st_t (in % p.a.) is the steepness of the German term structure (10 years - 1 year), $st^b_{t,i}$ is the steepness of the term structure of housing loans (fixed-interest periods of more than 10 years - fixed-interest periods of 1-5 years), the $r_{10y,t}$ (in % p.a.), is the return of German ten-year government bonds and $r^b_{lg,t,i}$is the interest level of housing loans with a fixed-interest period of 5 to 10 years; quarterly data

$$\triangle fip_{t,i} = \alpha + \tilde{\beta}_1 \cdot \triangle st^b_t + \tilde{\beta}_2 \cdot \left(\triangle st^b_{t,i} - \triangle st^b_t\right) + \tilde{\gamma}_1 \cdot \triangle r^b_{lg,t} + \tilde{\gamma}_2 \cdot \left(\triangle r^b_{lg,t,i} - \triangle r^b_{lg,t}\right) + \varepsilon_{t,i}. \quad (11)$$

Note that if $\tilde{\beta}_1 = \tilde{\beta}_2$ and $\tilde{\gamma}_1 = \tilde{\gamma}_2$, i.e. if the nationwide effects ($\tilde{\beta}_1$ and $\tilde{\gamma}_1$) are equal to the bank-specific effects ($\tilde{\beta}_2$ and $\tilde{\gamma}_2$), specification (11) becomes specification (10).

4 Data

All data (except for the housing loans' initial redemption rate red_t[6]) in the paper is provided by Deutsche Bundesbank. It comes from regular supervisory reports and periodic estimates of the term structure for German government bonds. Additionally for some banks and sometimes aggregated to the nation-wide level, data of the German contribution to the MFI statistics is used. The data at bank level is confidential, whereas the time series aggregates and the data on interest rates is publicly available. In Table 1, we show summary statistics of the various variables.

In every quarter since end-2011, each bank in Germany has had to report its exposure

[6]The duration $D_{t,i}$ of the housing loans depends on the annual installment $a_{t,i}$ (see Equation (14)), which we calculate as the sum of the initial redemption rate and the bank rate (see Equation (15)), where the initial redemption rate red_t is not loan- or bank-specific, but constant in the cross-section of banks and has only a time-series variation (source: Dr. Klein Trendindikator Baufinanzierung (DTB)).

to interest rate risk in its banking book. In doing so, the bank has to determine the changes in present values of the asset and liabilities in its banking book as a consequence of interest rate shocks. The shocks consist of parallel overnight shifts of the entire term structure by +200 basis points and by -200 basis points, respectively. The more adverse of the two outcomes is chosen and normalized with the bank's regulatory capital, known as the Basel interest rate coefficient. As the standardized present value change in the scenario with the increasing interest level is nearly proportional to the bank's modified duration of its equity, we resort to this scenario in the paper and use it as our measure irr.[7] We also keep those observations where a bank gains in present value as a consequence of an increase in interest rates.[8] In other words, our measure irr can be interpreted as a bank's exposure to interest rate risk, separated from the dynamics of the term structure. For some positions, especially for the customer deposits where actual and juristic maturity and thereby fixed-interest periods largely differ, the duration cannot be easily determined. In these cases, the reliance on the banks' internal models is crucial. Only the interest rate risk in the banking book is covered. By contrast, the banks' trading activities in the trading books are not included. Our dependent variable in the panel regression, $irr_{t,i}$, determines the sample period (2011Q4-2017Q2) and the frequency (quarterly). According to Table 1, the mean value of this exposure measure was around 18.8% in the sample period.

A bank is said to have elevated interest rate risk if the net change in present values exceeds 20 per cent of its regulatory capital, which we capture with the dummy variable $reg_{t,i}$ that takes on the value of 1 in case bank i in time $t-1$ exceeds this regulatory threshold. Since the end of 2016, banks have had to back their exposure to interest rate risk in the banking book with regulatory capital. In Subsection 5.2, we analyse the implications of this change in the regulation.

The banks' earnings from holding interest rate risk are measured by the variable μ_t. This variable gives the earnings of a passive investment strategy which consists in investing in German 10-year government par-yield bonds on a revolving basis and financing this investment by constantly issuing one-year par-yield bonds, which we assume to have the yield of corresponding German government bonds.[9] In the sample period, the average earning of this strategy was 3% p.a. relative to the book value of the long position. Note that this variable has no cross-sectional variation.

Concerning interest rate derivatives, only the nominal amount of swaps a bank is holding in a given quarter (interest rate, currency and combined swaps) is available. As the notional amount says little about the swaps' net effect, we only make use of the information whether or not a bank holds swaps at all in a given quarter. We construct the dummy variable $swap_{t,i}$ which takes on the value 1 if bank i in time t has a strictly positive nominal amount of interest rate and/or currency swaps. This was the case for 46% of the observations in our sample. In around 1.2% of the observations, there is a change in this variable compared to the status in the previous quarter, meaning that in

[7] Internal analysis of supervisory data showed that the present value changes of different shock sizes had a nearly linear relationship.

[8] Only few banks gain in present value if the interest level goes up. Due to the outlier correction of this study (removal of the first and 99th percentiles), the share of banks with present value gains in our final sample is even less.

[9] It is common in the literature to measure the steepness of the term structure by the difference of the yield of a 10-year-government bonds to a short-term interest rate, for instance the yield of 1-year-government bonds (see, for instance, Campbell and Cocco (2003)).

the current quarter, there is positive swap position where in the previous quarter there was no swap position or vice versa.

We measure the outcome of the length of the fixed-interest period of housing loans by the variable $fip_{t,i}$ which is the average fixed-interest period of newly granted housing loans. For each bank contributing data to the German part of the MFI statistics and for every month, we have data on the amount of newly granted housing loans in four buckets of fixed-interest periods: up to 1 year, 1 year to 5 years, 5 years to 10 years and over 10 years, where we assume fixed-interest periods of the four different buckets of 0.5, 3, 7.5 and 13 years. To obtain quarterly data, we sum up the volumes in the three months belonging to the respective quarters. In the sample period, the average fixed-interest period was 7.33 years.

The average capital ratio, measured as a bank's Tier 1 capital over its risk weighted assets amounts to 14.6%.

We apply a mild outlier treatment by removing observations below the first percentile and above the 99th percentile (for the non-dummy variables).

For the regression (9), we use variables that have only variation in the time dimension, but not in the cross-sectional dimension. The variable fip_t, the fixed-interest period of newly granted housing loans, is here – unlike above – the nation-wide average where Deutsche Bundesbank determines the weights of the aggregation (see Deutsche Bundesbank (2004) and Deutsche Bundesbank (2011)); in the period 2003Q1-2017Q2, this average was 7.55 years. Concerning the steepness of the term structure st_t, measured as the difference between the zero-coupon bond return of a ten-year and a one-year German government bonds, it was 1.41% p.a. and the return of the ten-year government zero-bond was 2.68% p.a. For the regressions (10) and (11), we use corresponding data at bank-level (for the German banks that report to the MFI statistics). Please note that the steepness of the term structure at bank-level ($st_{t,i}^b$) is measured as the difference between the rate of the respective bank for housing loans with a fixed-interest period of more than 10 years relative to the corresponding bank rate for housing loans with a fixed-interest period of 1 to 5 years. The interest level is measured as the rate of the respective for housing loans with a fixed-interest period between 5 to 10 years ($r_{lg,t,i}^b$).

5 Results

5.1 Baseline Results

Table 2 shows the results of the panel analysis from regression (1) where the change in a bank's exposure to interest rate risk $\triangle irr_{t,i}$ in its banking book is explained. The change in the earning opportunities from interest rate risk $\triangle \mu_t$ has the expected positive sign and is highly significant (at least in the sample with all banks), i.e. when the earning opportunities become better, the exposure to interest rate risk increases. In the sample period 2011Q4-2017Q2, there was no major shift in this variable compared to the ones in the periods before, and yet we find a significant impact like Memmel (2011) and Chaudron (2018). In line with previous analyses, we find that the regulatory threshold of 20% has a strong influence: If a bank has an interest rate risk exposure exceeding this threshold in the previous quarter, the bank – on average – reduces its exposure in the following quarter. In accordance with Purnanandam (2007) and Memmel and Schertler (2013),

Table 2: Results: Change in Interest Rate Risk Exposure

Variables	$\triangle irr_{t,i}$	$\triangle irr_{t,i}$	$\triangle irr_{t,i}$
$\triangle \mu_t$	0.786***	0.863	0.647
	(0.151)	(0.507)	(0.501)
$\triangle reg_{t,i}$	-0.647***	-0.652***	-0.671***
	(0.041)	(0.137)	(0.131)
$\triangle swap_{t,i}$	-0.257*	0.162	0.208
	(0.147)	(0.137)	(0.584)
$\triangle fip_{t,i}$		0.136*	
		(0.082)	
$\triangle D^s_{t,i}$			0.886***
			(0.124)
$\triangle CR_{t,i}$	-0.593***	-0.575***	-0.503***
	(0.021)	(0.069)	(0.069)
constant	0.212***	0.175***	0.158***
	(0.005)	(0.018)	(0.017)
Observations	34,724	3,502	3,502
Banks	1,773	185	185
R-squared (within)	0.051	0.044	0.073
Sample	All banks	Only banks contrib. to the MFI statistics	

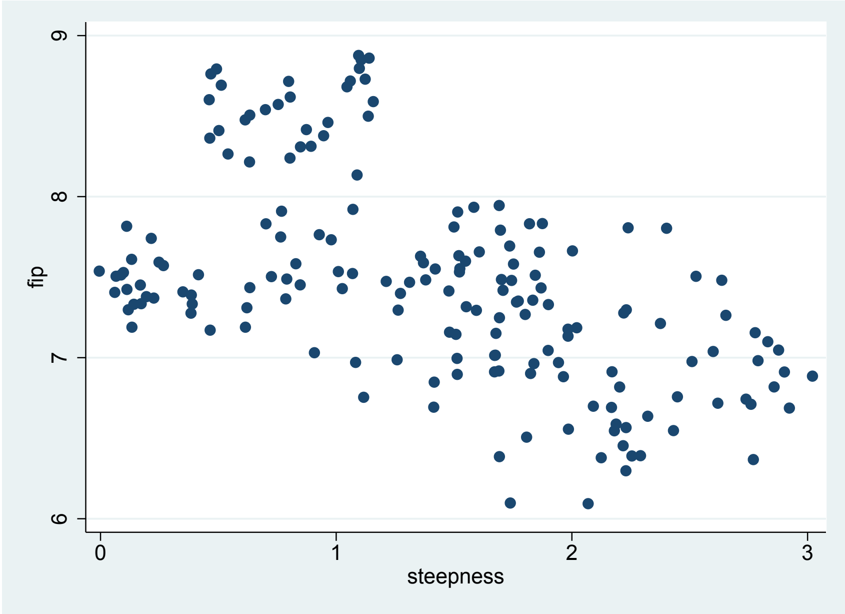
This table shows the results of the panel regression (1). $\triangle irr_{t,i}$ is the change in a bank's exposure to interest rate risk, $\triangle \mu_t$ is the change of the earnings of a passive trading strategy in government bonds, $\triangle reg_{t,i}$ is the change in a dummy variable, indicating whether a bank's exposure to interest rate risk $irr_{t-1,i}$ exceeded 20% in the previous quarter, $\triangle swap_{t,i}$ is the change in a dummy variable indicating that a bank has a strictly positive notional amount of interest rate swaps, $\triangle fip_{t,i}$ is the change in the fixed-interest period of housing loans, $\triangle D^s_{t,i}$ is the change in the standardized duration of the housing loans and $\triangle CR_{t,i}$ is the change in the capital ratio; period 2011Q4-2017Q2, quarterly data. Robust standard errors in brackets. *** and * denote significance at 1% and 10% level, respectively.

we find evidence that banks use, on average, interest rate swaps to hedge, and not to speculate on interest rate risk, as can be seen from the (at least in the sample with all banks) significantly negative coefficient for the variable $\triangle swap_{t,i}$. All these results are in line with the idea that banks actively manage their exposure to interest rate risk in the short run, thereby considering the earning opportunities of this risk and regulatory issues.

As stated above, one central issue in this paper is to test the hypothesis according to which customers' fixed-interest period preferences shape a large part of the on-balance sheet interest rate risk exposure and the banks use off-balance sheet instruments or interbank loans to adjust their overall exposure to their wishes.[10] To test the first part of the hypothesis from above, we investigate the relationship between the customers' fixed-interest period preferences and the banks' on-balance sheet interest rate risk exposure. Looking at the Germany-wide aggregate data from January 2003 to June 2017, we find, in line with Banca d'Italia (2016), a strongly negative relationship between the average

[10]For managing interest rate risk with exposures at the interbank market see Bluhm, Georg, and Krahnen (2016).

Figure 1: Fixed-Interest Period and Steepness of the Term Structure



In this figure, the nation-wide average fixed-interest period ('fip', in years) of newly granted housing loans is plotted against the steepness (in per cent) of the German term structure (German government zero-coupon bonds, 10 years vs. 1 year); monthly data; period January 2003 - June 2017.

fixed-interest period of new housing loans to private households and the steepness of the term structure (see Figure 1 and for the dynamics of the single variables Figure 2 and 3 in Appendix 4).[11] These results suggest that the expectation hypothesis in its simple form does not hold and that the customers see the steepness of the term structure as the relative advantage of loans with different fixed-interest periods: If the term structure gets steeper, the customers will shift their demand to loans with shorter fixed-interest periods. The negative relationship between the fixed-interest period and the steepness of the term structure is confirmed when we look at the corresponding regression (see Equation (9) and Table 3, column 1): The steepness of the term structure has a highly significantly negative impact on the average fixed-interest period of new housing loans.[12] Similar results are found when we investigate the issue at bank level (see Table 3, columns 2 and 3). These results shed some light on the question of who determines the housing loans' fixed-interest period, the banks or the customers. According to these results, it seems that the customers predominantly determine the fixed-interest period because otherwise, i.e. if the banks were the decisive determinants, we would observe a rising and not a falling relationship.[13] We would observe a rising relationship because during periods when the term structure is very steep banks tend to increase their overall exposure to interest rate

[11] However, Campbell and Cocco (2003) find little correlation between the share of fixed rate mortgage loans and the steepness of the term structure for the US (period: 1985-2001). Instead, they find a strong a strong negative correlation between the long-term interest rate and the share of fixed rate mortgages.

[12] For the variables fip_t, st_t and $r_{10y,t}$, the hypothesis of a unit-root process cannot be rejected. Therefore, the relationship is estimated in first differences which seem to be stationary; see Table 4 in Appendix 1.

[13] Based on a different reasoning, Koijen et al. (2009) also argue that banks do not predominantly determine the loans' fixed-interest periods.

risk (as the results in Table 2 suggest).

In Table 3, we found that the customers (and not the banks) primarily determine the fixed-interest period of housing loans. Yet it may be possible that some banks manage their exposure to this risk by setting the bank rates for the various fixed-interest periods of their housing loans in a way that their customers choose the length of the fixed-interest periods the bank wants them to choose. In this case, we would observe – at least for those banks – a positive relationship between $\triangle fip_{t,i}$ and the $\triangle irr_{t,i}$. Therefore, we split the changes in the steepness and in the level of the bank rates up as done in Equation (11). According to the Table 3, column 3, this steering is not done by deviating from the average steepness of term structure of bank rates, $\triangle st^b_{t,i} - \triangle st^b_t$, but by deviating from the average long-term bank rate $\triangle r^b_{lg,t,i} - \triangle r^b_{lg,t}$. We test whether the impact of the general economic conditions and the bank-specific factors, i.e. the models in columns (2) and (3) of Table 3, are statistically the same, and clearly reject this hypothesis.[14] The change in the long-term bank rate is negatively associated with the change in the length of fixed-interest period. One possible explanation is that low bank rates for housing loans attract customers who prefer long-fixed-interest periods and who could not afford to buy a house in normal circumstances. However, we do not find a significant relationship with the change in the new business of housing loans which cast some doubts on this interpretation. To sum up: We find that the customers largely determine the fixed-interest period of housing loans. We cannot rule out that banks use their rates for housing loans as an instrument to manage interest rate risk. However, we find no empirical evidence that this is done by setting a bank-specific steepness of the bank rates, rather by setting the deviation from the long-term average bank rate.

Having established the demand for housing loans as the primary determinant of the fixed-interest period, we turn to the second part of the hypotheses from above, i.e. the irrelevance of the customers' fixed-interest rate preferences for the banks' (short-term) overall interest rate exposure. To do so, we introduce the variable $\triangle fip_{t,i}$ in regression (1), i.e. the change in the fixed-interest period of newly granted housing loans (see column 2 in Table 2). We observe a significantly positive impact, meaning that the banks' overall interest rate risk exposure increases when the exposure of this part of its balance sheet goes up. This finding refutes the second part of the hypothesis and indicates that there is still some connection between the granting of long-term loans and the banks' total interest rate risk exposure. It seems as if banks are unable or unwilling to completely offset the customers' fixed-interest period choices without delay by suitable transactions at the capital market or at the interbank market. From column 3 in Table 2, we can obtain an estimate of the extent of this hedging: The coefficient in front of $\triangle D^s_{t,i}$ is highly significant and amounts to 0.886, meaning that 88.6% of the change in the exposure to interest rate risk that results from housing loans is not, on average, offset, but impacts a bank's overall exposure. It seems as if in a quarter only 11.4% (=100%-88.6%) of this change in exposure is hedged.

The economic significance of the variables differs a lot, where we define this significance

[14]As to the choice of the length of the fixed-interest period of mortgage loans, Foà, Gambacorta, Guiso, and Mistrulli (2015) find for Italy that not only the long term bond risk premium (a measure related to the steepness of the term structure; see also Footnote 4) is relevant but the advice given by the banks to the customers. In this study, we also look at bank-specific effects, however not in the form of advice that gives a bank to its customers, but in the form of deviation from the average slope and level of bank rates.

Table 3: Results: Fixed-Interest Period

Variables	$\triangle fip_t$	$\triangle fip_{t,i}$	$\triangle fip_{t,i}$
$\triangle st_t$	-0.207***		
	(0.067)		
$\triangle st^b_{t,i}$		-0.132***	
		(0.040)	
$\triangle st^b_t$			-0.745***
			(0.063)
$\triangle st^b_{t,i} - \triangle st^b_t$			-0.065
			(0.042)
$\triangle r_{10y,t}$	-0.116		
	(0.094)		
$\triangle r^b_{lg,t,i}$		-0.433***	
		(0.059)	
$\triangle r^b_{lg,t}$			-0.374***
			(0.044)
$\triangle r^b_{lg,t,i} - \triangle r^b_{lg,t}$			-0.492***
			(0.119)
constant	0.023	0.008**	0.006**
	(0.022)	(0.004)	(0.003)
R-squared	0.154	0.023	0.036
Observations	57	9,002	9,002
Banks		206	206

This table shows the results of the regressions (9), (10) and (11). $\triangle fip_{t,i}$ and $\triangle fip_t$ are the changes in the fixed-interest periods of new housing loans (bank-specific (index t, i) and weighted average in the cross-section of banks (index t)); $\triangle st_t$ is the change in the steepness of the term structure (German government zero-coupon bond yields, 10 years - 1 year), $\triangle st^b_{t,i}$ and $\triangle st^b_t$ are the changes in the steepness of the term structure of housing loans (fixed-interest periods of more than 10 years - fixed-interest periods of 1-5 years; bank-specific (index t, i) and weighted average in the cross-section of banks (index t)); $\triangle r_{10,ty}$ is the change in the German government ten-year bond yield and $\triangle r^b_{lg,t,i}$ and $\triangle r^b_{lg,t}$ are the changes in the interest level of housing loans with a fixed-interest period of 5 to 10 years (bank-specific (index lg, t, i) and weighted average in the cross-section of banks (index lg, t)); in column 1: Newey-West standard errors in brackets (4 as maximum lag order of autocorrelation); in columns 2 in 3: within R-squared; quarterly data; period 2003Q1 - 2017Q2; *** and ** denote significance at 1% and 5% level, respectively.

as the expected change in the dependent variable $\triangle irr_{t,i}$ if the respective variable changes by one standard deviation (concerning its time series dimension). It turns out that (for the first column) the change in the regulatory situation $\Delta reg_{t,i}$ is nearly four times as high as the change in the earning opportunities from term transformation $\Delta\mu_t$ and nearly nine times as high as the change in the swap usage $\Delta swap_{t,i}$. In the third column, the economic significance of the variable $\triangle D^s_{t,i}$ is twice as high as that of the regulatory situation $\Delta reg_{t,i}$.

5.2 Robustness Checks

Recently, the regulation of the interest rate risk in the banking book changed. Germany's national supervisory agency BaFin issued in December 2016 a general administrative measure (*Allgemeinverfügung*, see BaFin (2016)) saying that interest rate risk in the banking book has to be backed with regulatory capital, depending on the bank's present value losses standardized with the bank's risk weighted assets (RWA) that result from the scenarios assumed for the Basel interest coefficient, i.e. parallel shifts of the term structure of +/-200 bp. Therefore, for the last three quarters in our sample (2016Q4-2017Q2), we replace the variable $reg_{t,i}$ by the variable $sur_{t,i}$ which gives the capital charge (relative to the bank's risk weighted assets, RWA) due to interest rate risk in the banking book (in the previous period). This variable turns out to be negatively significant. As the variables $reg_{t,i}$ and $sur_{t,i}$ are highly correlated, it is not surprising to obtain similar results when replacing the variable $reg_{t,i}$ by the variable $sur_{t,i}$.[15] To see whether banks have reacted to the new regulatory regime, we make use of the design of this new regime, namely that the capital charge $sur_{t,i}$ does not linearly increase in the exposure to interest rate risk, but in steps depending on the exceedance of certain thresholds. We investigate whether we find more observations of interest rate risk exposure just below than above these thresholds and we notice that there is no significant difference. However, we find that the share of exposure observations that are close to the thresholds (no matter of whether the exposures are below or above the thresholds) have significantly reduced in the new regulatory regime. A possible explanation of this finding is that banks trade the risk of breaching the different thresholds (which calls for a large distance to the next higher threshold) off against the earning opportunities from increasing the exposure to the maximum level just below the different thresholds.

Banks with already high exposure to interest rate risk may be more likely to hedge additional exposure resulting from new housing loans (see Basten et al. (2017)). To test this hypothesis, we introduce an additional explaining variable in Equation (1), namely the interaction term of the variables reg and D^s. This variable is to indicate whether banks that exceeded the regulatory exposure threshold of 20 per cent in the previous quarter differ in their reaction to changes in the fixed-interest periods of their housing loans compared to the remaining banks. The first difference of this interaction term turns out to be insignificant, meaning that we do not find any significant difference concerning this reaction between banks with low exposure and banks with high exposure to interest rate risk.

Low bank rates (yields) for housing loans may attract borrowers who cannot afford

[15] For the three quarters (2016Q4 to 2017Q2), the correlation between these variables in levels is 0.7358 and 0.3940 for the first differences of this variables.

to buy houses in normal circumstances. As the monthly installment for housing loans consists of the sum of the yield and the initial redemption rate (see Equation (15)), the monthly installment does not go down to the same extent as the bank rates (yields), if the dynamics of the initial redemption rate is in the opposite direction compared to the one of the bank rates (which is the case). This mitigates the effect from above.

If the steepness of the term structure is not calculated as the difference to the yield of one-year government bonds, but to the yield of three-month government bonds, this variable is no longer significant in the first differences, but only in the levels.

As a further robustness check, we replace the variable $\triangle st_t$, the change in the steepness of the term structure in Equation (9) by $\triangle \mu_t$, the change in the earning opportunities from interest rate risk. In the specification with the earning opportunities from interest rate risk, the relationship is no longer significant. One reason for this finding may be that the earning opportunities from interest rate risk, the variable μ_t, are based on a continuous business model where the investment and financing is done in a revolving manner, whereas the households' decisions about the length of the fixed-interest periods are made in a concrete point in time (which is better captured by the steepness of the term structure).[16] Moreover, again in Equation (9), we replace $\triangle st_t$ and $\triangle r_{10y,t}$ by (the change in) the nation-wide averages of the steepness of the term structure and of the interest level of mortgage loans, i.e. by $\triangle st_t^b$ and $\triangle r_{lg,t}^b$. Both variables are significant and have the economically expected sign. However, the coefficient of determination, R^2, is higher (15.4% vs. 14.9%) in the original specification with the variables $\triangle st_t$ and $\triangle r_{10y,t}$. Therefore, we decided to use these variables in the baseline specification, although knowing that private households are charged the bank rates, not the interest rates at the capital market. Another reason for using the capital market variables $\triangle st_t$ and $\triangle r_{10y,t}$ is that they can be seen as exogenous with respect to the real estate market. Additionally, we split the sample in two halves (2003Q1-2010Q1 and 2010Q2-2017Q2). We find that the impact of the steepness of the yield curve is more pronounced in the second subsample.

6 Conclusion

This paper analyzes the short-term fluctuations in banks' exposure to interest rate risk. We carry out an empirical study of German banks for the period 2011Q4-2017Q2. We find evidence that banks actively manage their interest rate risk exposure, for instance with interest rate swaps, and that they increase their exposure to interest rate risk when its remuneration increases. We also find evidence that banks whose exposure to interest rate risk in the banking book exceeds a regulatory threshold tend to decrease their risk exposure in the subsequent quarter.

In addition, we find that the fixed-interest period of housing loans is largely determined by the customers, not by the banks and that the fixed-interest period of housing loans has an impact on the overall interest rate risk exposure of a bank. This finding is not in line with the idea of banks' active management of their exposure to interest rate risk and indicates that there is still a connection between loan granting and banks' interest rate risk exposure and that banks do not appear to fully mitigate this additional exposure –

[16] The variable μ_t is closely connected to the steepness st_t of term structure. Concerning the first differences, the correlation between these two variables is 0.3695.

Table 4: Stationarity test

Variable	Level	First difference
fip_t	-1.387	-3.537***
st_t	-2.594*	-3.056**
$r_{10y,t}$	-0.107	-4.037***

This table shows the test statistics of the augmented Dickey-Fuller test for the variables fip_t, st_t and $r_{10y.t}$(4 lags, constant, but no trend). 2003Q1 - 2017Q2; quarterly data; 58 (57) observations in the level (first difference). ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

without delay – by using appropriate off-balance sheet positions or interbank loans.

Appendices

Appendix 1: Dickey-Fuller-Test

In Table 4, the results of the augmented Dickey-Fuller are reported. For the three variables fip_t, st_t and $r_{10y,t}$, the null hypotheses of a unit root process can only be rejected for their first differences, not for the levels, except for the variable st_t, where the null hypothesis of a unit root process can be rejected at the 10% level.

Appendix 2: Duration and Fixed-Interest Period

In this appendix, we derive the relationship between a loan's duration D and its fixed-interest period fip. In this setting, PV denotes the present value of a loan with fixed-interest period fip, r is the yield of the loan, a the time-constant rate of installments and d the share of the repayment of the principal (normalized to 1) at the end of the fixed-interest period. For ease of exposition, we remove the indexes t and i. The present value PV of such a loan (in continuous time) is

$$\begin{aligned} PV &= \int_0^{fip} a \cdot exp\left(-r \cdot t\right) dt + d \cdot exp\left(-r \cdot fip\right) \\ &= \frac{a}{r}\left(1 - exp\left(-r \cdot fip\right)\right) + d \cdot exp\left(-r \cdot fip\right). \end{aligned}$$

$$\frac{\partial PV}{\partial r} = -\frac{a}{r^2}\left(1 - exp\left(-r \cdot fip\right)\right) + \left(\frac{a}{r} - d\right) \cdot fip \cdot exp\left(-r \cdot M\right) \tag{12}$$

In the case $PV = 1$ (which we assume in the following), i.e. the loan is at par when granted, there are two implications: i) The derivative in Equation (12) equals the negative modified duration D of the loan and ii) the share d of the repayment of the principal is

$$d = exp\left(r \cdot fip\right) - \frac{a}{r}\left(exp\left(r \cdot fip\right) - 1\right). \tag{13}$$

Combining Equations (12) and (13) and setting $D = -\frac{\partial PV}{\partial r}$, we obtain

$$D = \frac{a}{r^2}\left(1 - exp\left(-r \cdot fip\right)\right) - \left(\frac{a}{r} - 1\right) \cdot fip. \tag{14}$$

For $a = r$, we obtain $d = 100\%$ (see Equation (13)) and $D = 1/r \cdot (1 - exp(-r \cdot fip))$, i.e. the modified duration of a par yield bond (see Memmel (2011)); and for $a = 0$, the modified duration D equals the fixed-interest period fip, i.e. the loan becomes to a zero-coupon bond and the share d of the repayment of the principal is greater than 100%. For small values of r Equation (14), becomes

$$\lim_{r \to 0} D = fip - \frac{a}{2} \cdot fip^2,$$

which can be seen when the rule of L'Hôpital is twice applied to Equation (14). For the empirical implementation, we set

$$a_{t,i} = r^b_{t,i} + red_t \tag{15}$$

where the installment $a_{t,i}$ is the sum of the bank rate $r^b_{t,i}$ for housing loans of bank i (for the corresponding fixed-interest period) and of the nationwide average of the initial redemption rate red_t.

Appendix 3: Market Outcome of Fixed-Interest Periods

In this appendix, we derive the length of the fixed-interest period in the market equilibrium in Equation (7). Starting with Equation (6), we look at the different cases below.

Case I: $a = 1$ (which corresponds to $\beta_S = \beta_D$). In this case, Equation (6) reduces to

$$0 = 4 \cdot b \cdot st \cdot fip, \tag{16}$$

where the general solution is $fip = 0$.

Case II: $a \neq 1$ (which corresponds to $\beta_S > \beta_D$ or $\beta_S < \beta_D$). In this case, Equation (6) becomes

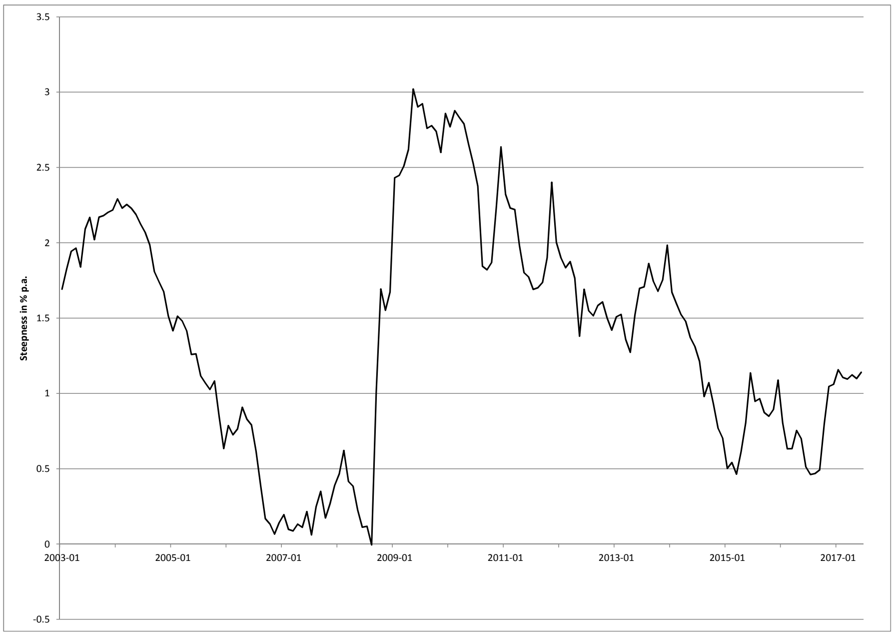
$$0 = fip^2 + 2 \cdot \frac{a+1}{a-1} \cdot b \cdot st \cdot fip + b^2 \cdot st^2. \tag{17}$$

According to the formula to solve quadratic equations, the two roots are

$$\begin{aligned} fip_{1/2} &= -\frac{a+1}{a-1} \cdot b \cdot st \pm \sqrt{\frac{(a+1)^2}{(a-1)^2} \cdot b^2 \cdot st^2 - b^2 \cdot st^2} \\ &= -\frac{\left(\sqrt{a} \pm 1\right)^2}{a-1} \cdot b \cdot st. \end{aligned} \tag{18}$$

We discard the root $fip_1 = -\frac{\left(\sqrt{a}+1\right)^2}{a-1} \cdot b \cdot st$ for the economic reason that this root lies outside the interval with the endpoints fip_S and fip_D.

Figure 2: Steepness of the Term Structure



In this figure, the steepness (in per cent) of the German term structure (German government zero-coupon bonds, 10 years vs. 1 year) is shown; monthly data; period January 2003 - June 2017.

Appendix 4: Steepness of the Term Structure and the Fixed-interest Period of Housing loans

In this appendix, the steepness of the term structure and the fixed-interest period of housing loans are plotted in the course of time.

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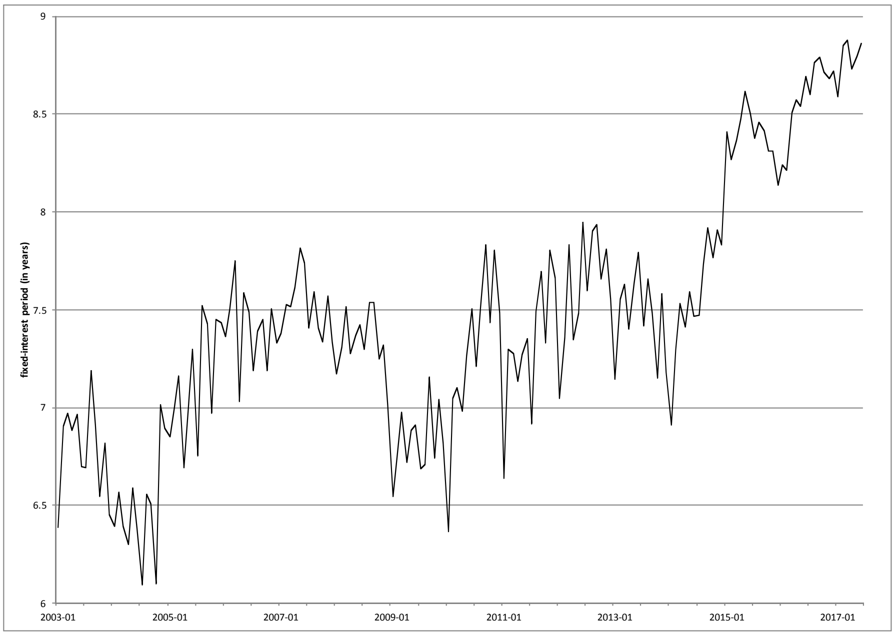
Figure 3: Fixed-interest Period of Housing Loans



In this figure, the fixed-interest period of newly granted housing loans in Germany is shown; monthly data; period January 2003 - June 2017.

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