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Banks' Net Interest Margin and the Level of Interest Rates

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Abstract

The prevailing view in the literature is that, in the long run, an increase in the level of interest rates will impact positively on banks' net interest margins. Using a time series of more than 40 years for the German banking system, we confirm this effect (the net interest margin increases by 7 basis points for every 100 basis point increase in the interest rate level). What is more, we show that the opposite effect exists in the short run. In addition, we analyze the consequences of the low-interest-rate environment and find that banks' interest margins on retail deposits, especially term deposits, have declined by up to 97 basis points.

Die Zinsspanne der Banken und das Zinsniveau

Zusammenfassung

Die vorherrschende Ansicht in der Literatur ist, dass sich langfristig ein Anstieg des Zinsniveaus positiv auf die Zinsspanne der Banken auswirkt. In dem Papier nutzen wir Zeitreihen des deutschen Bankensystems für einen Zeitraum von mehr als 40 Jahren und bestätigen den Effekt (die Zinsspanne nimmt um 7 Basispunkte zu je Anstieg des Zinsniveaus um 100 Basispunkte). Unser Hauptbeitrag ist, zu zeigen, dass es in der kurzen Frist den gegenteiligen Effekt gibt. Außerdem untersuchen wir die Auswirkungen des Niedrigzinsumfelds und finden, dass sich die Zinsmarge der Banken auf Kundeneinlagen, besonders auf Termingeld, um bis zu 97 Basispunkte verringert hat.

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I. Introduction

Structural changes in a bank's net interest income – or, similarly, in its net interest margin – have a huge impact on its profitability and are likely to lead to changes in the bank's behavior, for instance in its risk taking. As a bank's net interest margin results from a mix of interest-bearing products and as the rates of these products are linked to market interest rates in a variety of ways, the structural impact of changes in the market interest rate level on this margin is not obvious. The aim of this paper is to empirically establish this important relationship. This issue is especially relevant in an environment of structurally falling or rising interest rates. In normal times, cyclical interest rate movements may lead as well to changes in bank's net interest margins. However, these changes are only transitory and vary with the phase of the interest cycle.

If all the interest-bearing assets and liabilities are directly linked to market rates and if there is no gap between the volumes of interest-bearing assets and liabilities, then, in the long run, a bank's net interest margin will not be affected by (parallel) shifts in the interest rate level. However, in the short run, the net interest margin may fluctuate as a consequence of shifts in the interest rate level, even if all assets and liabilities are completely linked to market rates. To illustrate this point, we take the example of a bank that recursively invests in long-term government bonds and that finances this investment by issuing short-term bonds. In the short run, its net interest income fluctuates whenever there is a parallel shift in the term structure of interest rates. This is because the assets have a longer maturity than the liabilities, which means that, in a given time span, a portion of the assets is adjusted to the new interest rates which is smaller than the portion of liabilities that is adjusted. In the long run, however, the net interest margin of this bank will be unaffected by parallel shifts in the term structure, because all the assets and all the liabilities will then be adjusted to the new interest rates. In this paper, we will use this as the definition of the net interest margin being independent of the level of interest rates.

In contrast to the example above, there are bank products that are linked only weakly, or not at all, to market rates, such as non-interest bearing checking accounts. These deposits cause no interest expenses for the bank (although they do lead to administrative costs, which are, however, not part of a bank's interest expenses) and it makes a great difference whether a bank invests these funds in loans at an annual interest rate of 3 or 10 percent. In cases where the deposits are mainly used as a substitute for money (i.e. payment purposes as the main usage), banks' interest income is comparable to the seigniorage income of central banks, which is proportional to the central bank's policy rate.

To sum up, there is the possibility that, in the long run, a bank's net interest margin is independent of the level of interest rates, for instance in those special cases in which all product rates are completely tied to market rates or where the incomplete linkages to market rates on the asset and liability sides merely cancel one another out. However, based on evidence in the literature, one can guess that the long-run relationship is positive, meaning that the net interest margin increases when the level of interest rates rises. In that case, falling interest rates would compress interest margins in the long run. In addition, this effect could be intensified in a low-interest-rate environment, where markups on the interest rates for liability-side products are squeezed due to the zero lower bound.

In this paper, we address the following two topics: (i) the general connection between interest rates and interest margins and (ii) the effects of the low-interest-rate environment on margins of liability-side products. First, using a time span of more than 40 years of data on the German banking system, we separate long-term effects from cyclical fluctuations in the term structure. Indeed, we find that, in the long run, there exists an economically relevant positive relationship between a bank's net interest margin and the level of interest rates. An increase of 100 basis points in the interest rate level causes the net interest margin to widen by around 7 basis points. However, in the short run, we document the opposite effect. We estimate the time span after which the effect turns from negative to positive to one-and-a-half years. Second, special attention is given to the low-interest-rate environment which we have observed especially in Germany in the recent years. We apply data from the monthly interest rate statistics, where German banks' rates for different products are collected, to the question of whether retail bank rates are set differently in a low-interest-rate environment. To do this, we forecast the retail bank rates, based on model parameters from the time before the low-interest-rate period, and compare them with the actual retail bank rates in the low-interest-rate environment. We find that the margins on retail deposits, especially term deposits, have declined by up to 97 basis points.

This paper is structured as follows. In Section II, we briefly review the literature in this field. In Section III, we discuss the empirical models and in Section IV the data. Section V gives the results, while Section VI concludes.

II. Literature

Memmel (2011) empirically analyzes the short-term effects of changes in the term structure on German banks' net interest margin. Constructing a passive trading strategy in risk-free government bonds and scaling its return with a bank's exposure to interest rate risk, he finds that this scaled return explains a significant part of the changes in banks' net interest margins. However, the long-term effects of parallel shifts in the term structure are zero by construction, because he implicitly assumes that all interest-bearing positions in bank balance sheets are completely linked to market interest rates.

Whereas *Memmel* (2011, 2014) finds that there is a close connection between a bank's present value of the banking book and its net interest margin, meaning that an increase in the interest rate level leads to a temporary decline in banks' net interest rate margins, the results of Banca d'Italia (2013) do not support this view. Instead, it is found that the present value effects of a parallel shift in the term structure are only loosely connected with the corresponding changes in banks' net interest income in the following year. What is more, for eight out of the 11 Italian banks in the sample, the effect of the upward shift in the interest rate level would be beneficial to their net interest income. *Bolt* et al. (2012) and *Albertazzi/Gambacorta* (2009) likewise find that the level of market interest rates has a positive impact on banks' net interest margin. However, they do not distinguish between short-term and long-term effects. *English* et al. (2014) distinguish between long-run and short-run effects of an increase in the short-term interest rates, but their model does not allow for different signs of the short-term and long-term effects. They find that the short-term effect is significantly positive, but far smaller than the long-run effect. To sum up, concerning the relationship between market interest rates and banks' net interest margins, there seems to be a tendency for the long-run effect to be positive. Concerning the short-run effect, the empirical results seem to be mixed even with respect to the direction of the effect.

Alessandri/Nelson (2015) provide a theoretical model (which they test with data from UK banks) that, in the long run, shows a positive relationship between the interest rate level and banks' net interest margin. In the short run, however, the increase in the interest rates compresses banks' net interest margin. This compression is also found in the theoretical model of *Dell'Ariccia* et al. (2014), where an increase in interest rates leads to a decline in the net interest margin, which then impacts on banks' risk taking.

Our contribution to the literature is to present an empirical model for banks' net interest margin that is, at the same time, parsimonious and makes it possible to distinguish between short-run and long-run effects of changes in the interest rate level. This means that our approach is flexible enough to allow for different signs of the short-run and long-run effect of a change in the interest rates. This model expands on the empirical model of *Busch* et al. (2015). In contrast to their study and most other empirical studies in this field, we do not carry out statistical inference by using a sample with a large number of banks and a short time period, but by investigating a long period of more than 40 years. This long period allows us to disentangle short-run and long-run effects.

As mentioned above, the second part of our paper deals with the additional complications due to the low-interest-rate environment. In this context, it is necessary to decompose the bank rates for the different retail products into the appropriate risk-free interest rate and the remaining margin. The literature provides us with different methods of performing this decomposition. One consists in subtracting the market interest rates from the bank rate (see, for instance, HSBC Global Research 2006). The market interest rate is chosen according to the legal maturity of the retail product. For daily callable accounts, for instance, the overnight market interest rate is used. This method is quite robust and no estimation needs to be carried out. However, this method neglects the fact that the actual duration of retail products largely tends to differ from the legal duration. In the example above, the actual empirical duration of daily callable accounts tends to be several years, although the customers have the right to withdraw their money without prior notice. Another approach in the literature (see European Central Bank 2006) takes into account the fact that the actual and the legal durations of retail products may differ. In this approach, the correlation between the product interest rate and the market interest rates of various maturities is calculated and the maturity for which the correlation is maximal is chosen. Our contribution is to suggest an alternative approach. This consists in determining a portfolio of risk-free bonds of different maturities. It can be shown that our approach is equivalent to that of the European Central Bank (2006) insofar as ours is restricted to exactly one maturity of bonds (See Appendix 3). Moreover, our approach has two advantages over that of the European Central Bank (2006). First, it also gives the weights of the reference portfolio, while the ECB approach only states which maturity to choose. Second, it is applicable to two or more interest rates of different maturities. In this sense, our approach is a generalization of the ECB approach, because we choose the portfolio of bonds of different maturities, and not only the maturity of a single interest rate, whose correlation to the bank rate is maximal (See Appendix 4).

In the academic literature, the pass-through from market rates to bank rates is often modelled by explaining the bank rate as a linear combination of own lagged values and past and present interest rates (see *Kleimeier/Sander* (2006) for an overview). For our purposes, the approach in this paper has several advantages over the approach used in this strand of literature. First, the approach in this paper yields the composition of an actual tracking portfolio, so that it can be implemented by banks, whereas there is no feasible strategy behind the coefficients estimated by the approach from the literature. Second, the proposed approach makes use of interest rates of very many – in principle infinite – different maturities, while, in the approach from the literature, one or at most two different maturities are used.

III. Empirical Models

1. Normal Times

In the setting from which we derive our empirical model, we analyze a bank that is engaged in traditional commercial banking: on the asset side, there are customer loans C and cash L, where – without loss of generality – the balance sheet is normalized to 1 and the respective portions are ϕ_L and ϕ_C. The bank extends revolving risk-free loans with maturity M_L and coupons c corresponding to the risk-free interest rate , i.e. maturing loans are replaced by new loans with an identical maturity M_L and with coupon c_t, equaling the then current interest rate r_t. This strategy is quite comparable to a strategy of revolving investment in risk-free par yield bonds of a constant initial maturity M_L. *Memmel* (2014) investigates the impact of changes in the interest rate level on these strategies' present value (PV) and interest income margin (IIM_{sh}) in the first year after a change in interest rate r (subscript: *sh*). He shows that the present value change is approximately

$$\frac{\partial PV(M_L)}{\partial r} = -\phi_L \cdot \frac{M_L}{2} \tag{1}$$

Note that this relationship only exactly holds for $r = 0\%$, where the exact expression is $\partial PV(M_L) / \partial r = \phi_L \cdot \left(1 - \exp(r \cdot M_L) - r \cdot M_L\right) / \left(r^2 \cdot M_L\right)$ (see *Memmel* 2014). For $M_L = 10$ and $\phi_L = 1$, the exact value of the derivative would be −4.84 for $r = 1\%$ and −4.26 for $r = 5\%$ (instead of −5.00 for $r = 0\%$). The equation above may be illustrated with a comparison to a bullet bond. The modified duration of such a bond (which corresponds to the negative derivative of its present value with respect to the interest rate for a par-yield bond) is approximately its residual maturity; this approximation is especially good when the interest rate level is low. The residual maturity of the strategy described above is about half the original maturity M_L (which is stated in Equation (1) apart from the factor ϕ_L).

The interest income margin (IIM) change of the above strategy in the first year after the change in the interest rate amounts to

$$\frac{\partial IIM_{sh}(M_L)}{\partial r} = \phi_L \cdot \frac{1}{2M_L} \tag{2}$$

This relationship only exactly holds if compound interest, i.e. interest on interest within the first year, is neglected (see *Memmel* (2014) for the expression where the compound interest is accounted for). The rationale behind this equation is as follows: Suppose a bank grants revolving loans with an initial maturity of $M_L = 10$ years. If an interest rate shift occurs at the beginning of the accounting year, then $10\% = 1/M_L$ of the loans in the bank's portfolio are renewed in the current accounting year, where the new loans contribute on average half a year to the interest income (which explains the factor $\frac{1}{2}$). The long-term (subscript: *lg*) impact can be expressed as

$$\frac{\partial IIM_{\mathrm{lg}}(M_L)}{\partial r} = \phi_L, \tag{3}$$

which means that in the long run the pass-through is complete for the loans and zero for the cash holdings. The present value of cash C is unaffected by interest rate shocks and always equals the nominal amount. Also, the interest income of cash C is always zero. Therefore, the derivatives (1) to (3) for the cash holdings are zero and the derivatives for the loans L_M equal the derivatives for the whole assets A. An implicit assumption in this setting is that banks' markups (on the asset side) and markdowns (on the liability side) are not affected by changes in the interest rate level (because they are implicitly assumed to be zero). By contrast, in the approach in Subsection 3.2, we analyze how the low-interest-rate environment impacts the mark-downs of retail products on the liability side.

Note that a different interpretation of the approach is possible. Instead of assuming that, say, $\phi_L = 0.7$ means that 70 % of bank assets are loans and 30 % cash, one can think of bank assets of which 100 % are loans with a long-run interest rate pass-through of 0.7, which is more in line with the empirical literature.[1]

On the liability side, there are customer deposits D (portion ϕ_D, maturity M_D), which can as well be suitably described by issuing revolving risk-free par yield bonds (see Subsection 3.2), and other liabilities R (share ϕ_R), which do not cause interest expenses (equity, allowances, …). This yields terms similar to those of Equations (1) to (3). Combining Equations (1) to (3) and the corresponding equations for the liability side as well as the definition of the net interest margin $NIM = IIM - IEM$ gives us

$$\frac{\partial PV(E)}{\partial r} = -\frac{\phi_L \cdot M_L}{2} + \frac{\phi_D \cdot M_D}{2}, \tag{4}$$

$$\frac{\partial NIM_{sh}}{\partial r} = \frac{\phi_L}{2 \cdot M_L} - \frac{\phi_D}{2 \cdot M_D} \tag{5}$$

and

$$\frac{\partial NIM_{\mathrm{lg}}}{\partial r} = \phi_L - \phi_D, \tag{6}$$

[1] See, for example, European Central Bank (2009).

where E denotes the bank's equity, i.e. the residual between its assets (A) and liabilities (L) except for equity $E := A - L$.

It is well known that German banks suffer present value losses in the event of a rise in interest rates (see, for instance, Deutsche Bundesbank 2011). And yet, even with this additional information, one cannot theoretically determine the signs of the changes in the net interest margins (NIM) in Equations (5) and (6). Therefore, we choose an empirical specification that is flexible enough to take into account all possible signs of the relationships. In accordance with *Busch* et al. (2015), we assume that banks' interest income margin IIM and interest expense margin IEM are a function of the level of interest rates and of their own lagged values:

$$IIM_t = \alpha_{IIM} + \beta_{IIM,1} \cdot IIM_{t-1} + \beta_{IIM,2} \cdot r_t + \varepsilon_{IIM,t} \tag{7}$$

and

$$IEM_t = \alpha_{IEM} + \beta_{IEM,1} \cdot IEM_{t-1} + \beta_{IEM,2} \cdot r_t + \varepsilon_{IEM,t} \tag{8}$$

We model the interest margins in Equations (7) and (8) as autoregressive processes of order 1. Recursively applying Equation (7), one can express the interest income margin as

$$IIM_t = \beta_{IIM,2} \cdot \frac{1-\beta^k_{IIM,1}}{1-\beta_{IIM,1}} \cdot r + \beta^k_{IIM,1} \cdot IIM_{t-k} + \sum_{i=0}^{k-1} \beta^i_{IIM,1} \cdot \varepsilon_{IIM,t-i}\,, \tag{9}$$

where k denotes the years that one goes back in the past. The short-run effect (subscript: *sh*) of an interest rate shock equals the derivative with respect to r at $k = 1$

$$\frac{\partial IIM_{sh}}{\partial r} = \beta_{IIM,2} \tag{10}$$

and the long-run effect (subscript: *lg*) is the mentioned derivative at $k \to \infty$

$$\frac{\partial IIM_{\mathrm{lg}}}{\partial r} = \frac{\beta_{IIM,2}}{1-\beta_{IIM,1}}. \tag{11}$$

Equation (10) corresponds directly to the model results in Equation (2):

$$\beta_{IIM,2} = \phi_L \cdot \frac{1}{2M_L} \tag{12}$$

and Equation (11) corresponds directly to the model results in Equation (3):

$$\frac{\beta_{IIM,2}}{1-\beta_{IIM,1}} = \phi_L. \tag{13}$$

The same applies equivalently to the interest expense margin (IEM). By combining Equations (12) and (13), the equivalent expressions for the interest expense margin (IEM) and the definition $NIM = IIM - IEM$, we obtain expressions for the effect of a change in the interest rate on the net interest margin (NIM) in the short run and the long run. In the short run, the effect will be

$$\frac{\partial NIM_{sh}}{\partial r} = \beta_{IIM,2} - \beta_{IEM,2} \tag{14}$$

and, in the long run, i.e. for the infinite future, the expression is

$$\frac{\partial NIM_{\text{lg}}}{\partial r} = \frac{\beta_{IIM,2}}{1-\beta_{IIM,1}} - \frac{\beta_{IEM,2}}{1-\beta_{IEM,1}} \tag{15}$$

The expression in Equation (15) is closely linked to the above definition of the net interest margin being independent of the level of interest rates. In this case, this expression would equal zero. By contrast, if $\partial NIM_{\text{lg}} / \partial r$ is positive, then there is a positive relationship between the net interest margin and the level of interest rates. In Appendix 1, we give the closed form of the asymptotic standard deviation of the expression (15). Note that those time series models of interest margins are only a rough description of the real world over a period spanning decades. In all likelihood, there have been structural breaks and shifts in the composition of bank balance sheets. In Subsection 5.2, some of these issues are addressed as robustness checks.

As stated above, there may even be qualitative differences in the impact on a bank's net interest margin in the short run (see Equation (14)) and in the long run (see Equation (15)). For instance, the short-run impact of a parallel upward shift in interest rates on the net interest margin may be negative, whereas the long-run effect may be positive. The intuition behind this is that, in the short run, due to the usually shorter maturities of the liabilities, a larger portion of the liabilities is adjusted to the interest rate level in a given time. In the long run, this effect vanishes because even the products with the longest maturities will be adjusted to the new interest rate level and the effect of the higher pass-through on the asset side prevails.[2] In technical terms, the above-mentioned effect would be relevant if the degree of persistence for the assets side $\beta_{IIM,1}$ were sufficiently

[2] See, for example, European Central Bank (2009).

larger than the one for the liability side $\beta_{IEM,1}$ so as to offset the stronger short-run effect $\beta_{IEM,2}$ on liabilities than on assets ($\beta_{IIM,2}$). The appropriate test statistics to be analyzed would be

$$LvsS = \left(\beta_{IIM,2} - \beta_{IEM,2}\right) \cdot \left(\frac{\beta_{IIM,2}}{1-\beta_{IIM,1}} - \frac{\beta_{IEM,2}}{1-\beta_{IEM,1}}\right), \tag{16}$$

where *LvsS* stands for "Long-run versus short-run effect" (see Appendix 1 for the closed form of the asymptotic distribution of this test statistics). This test statistics can be seen as the product of the short-run effect and the long-run effect. If *LvsS* is negative, then one of the two effects is negative and the other one is positive, i.e. there is a qualitative difference concerning the short-run and long-run effects of a change in the interest rate level.

Equations (14) and (15) are the expressions for the change in the net interest margin in the limiting cases, i.e. for a horizon of one year ($k=1$) and for an infinite horizon ($k \to \infty$). In the case of an arbitrary horizon k [in years], the expression is (see Equation (9)):

$$\frac{\partial NIM(k)}{\partial r} = \beta_{IIM,2} \cdot \frac{1-\beta_{IIM,1}^{k}}{1-\beta_{IIM,1}} - \beta_{IEM,2} \cdot \frac{1-\beta_{IEM,1}^{k}}{1-\beta_{IEM,1}} \tag{17}$$

In the event that a change in the interest rate level impacts on the net interest margin differently in the long and short run, there exists a horizon k^{*} for which the impact due to a change in the interest rate level is zero. Unfortunately, there does not exist a closed-form expression for this horizon, but k^{*} can be easily determined using numerical methods, and the asymptotic standard errors of the estimated k^{*} can even be calculated analytically (see Appendix 2).

The change in the equity's present value (Equation (4)) can be expressed in terms of the beta coefficients. By combining Equations (1), (12) and (13), we obtain:

$$\frac{\partial PV(A)}{\partial r} = -\frac{1}{4} \cdot \frac{\beta_{IIM,2}}{(1-\beta_{IIM,1})^{2}}, \tag{18}$$

yielding the equivalent to Equation (4):

$$\frac{\partial PV(E)}{\partial r} = -\frac{1}{4} \cdot \left(\frac{\beta_{IIM,2}}{(1-\beta_{IIM,1})^{2}} - \frac{\beta_{IEM,2}}{(1-\beta_{IEM,1})^{2}}\right) \tag{19}$$

In Appendix 1, we give the closed form of the asymptotic standard deviation of this expression.

2. Low Interest Rate Environment

The empirical model in the previous subsection is about a bank's interest income and interest expenses as a whole, not broken down into different bank products. To derive meaningful results from this model concerning the impact of interest rate shocks, certain assumptions have to be met; in particular, the margins on the different bank products have to be stable. In normal times, i.e. when interest rates fluctuate in an interval of, say, 3 % to 6 % p.a., this assumption is likely to hold. By contrast, in a low-interest-rate environment, this assumption may be violated, especially concerning retail products on banks' liability side. This may be because retail products on banks' liability side, such as current accounts, are usually remunerated below market rates where the margin is often used to cross-subsidize bank services relating to payment or liquidity management. Therefore, we can guess that the bank rates for retail products on the liability side are the first to be affected by the zero lower bound if the interest rate level falls. For this reason, we go more into detail in this subsection and analyze the response of liability-side markups to interest rate changes in the low-interest-rate environment.

The interest rate on retail products can be decomposed into two parts: (i) the interest rate on an alternative investment at the capital market, and (ii) the interest margin that banks charge their customers where, for liability-side product, the interest margin reduces the remuneration received by customers. This margin is determined by the competition the bank faces and by the costs associated with the retail product. Current accounts, for instance, are relatively costly, because banks have to carry out the payment and liquidity management for the current account holders (see *Busch/Memmel* 2016). In addition, this margin contains a liquidity premium arising from the fact that – at least for daily callable accounts – the customers always have the funds at their disposal. For loan products, banks additionally have to charge a premium for credit risk.

We assume that the margin is constant through time and that changes in the bank rates are driven only by changes in the market rates, but abstain from the assumption that changes in the market rates are completely passed through to the bank rates. In detail, we look at the following interest rates and yields (t is the time index [in months]):

- Bank rate: $R_{j,t}$ is the rate with which banks remunerate holdings of the product j.
- Government bonds: $r_t(M)$ is the return of par yield government bonds with maturity M [in months] at time t.

- Strategy $S(M)$: $z_t(M)$ is the return of an investment strategy that consists of investing each month $1/M$ in par yield government bonds with maturity M [in months].[3]

$$z_t(M) = \frac{1}{M} \sum_{i=1}^{M} r_{t-i+1}(M) \tag{20}$$

- Investment opportunity P: r_P is the return of an investment opportunity with a rate that does not change over time. For our study, it is set equal to $r_P = 4\%$ p. a. Note that the level of this rate does not impact on the composition of the reference portfolio.

Note that, in Subsection 3.1, the whole term structure is described by one interest rate, whereas in this subsection, the term structure is described – in each time period – by different interest rates $r_t(M)$, depending on the maturity M.

As stated above, the interest rate of the retail product is compared with an alternative capital market investment. In this paper, the alternative investment is a passive strategy, i.e. there exists a mechanical rule for buying and selling government bonds. For instance, such a passive strategy may consist of investing 30 % of the funds in strategy $S(36)$ and 70 % in investment opportunity . The assumption of a constant margin is translated into the objective to minimize the timely variation of the margin, i.e. the difference between the product interest rate and the alternative investment at the capital market. In Appendix 4, we show that this is equivalent to maximizing the correlation to a portfolio of government bonds, where the maturity of the bonds and their weights are the parameters for the optimization. We assume that assets can be allocated to investment opportunity P and to two different investment strategies $S(M_1)$ and $S(M_2)$.

The optimization problem has two layers. The outer one is to determine the appropriate maturities M_1 and M_2, while the inner one is to obtain the optimal weights (w_1, w_2 and w_P) for the three investments, given the maturities M_1 and M_2. Formally, we can state the optimization problem as

$$\min_{M_1, M_2} \left(\min_{m, w_1, w_2, w_P} \frac{1}{T} \sum_{t=1}^{T} \varepsilon_t^2 \right) \tag{21}$$

subject to

$$\varepsilon_t = R_t - \left(m + w_1 \cdot z_t(M_1) + w_2 \cdot z_t(M_2) + w_P \cdot r_P\right) \tag{22}$$

[3] See *Memmel* (2008) for further information on this investment strategy.

and

$$w_1 + w_2 + w_P = 1 \tag{23}$$

where is the time-constant margin that the bank earns above its funding costs. Using an approach set forth in *Kempf/Memmel* (2006), we can rewrite the inner minimization problem, i.e. the one between the brackets, as a linear regression and solve it using the ordinary least squares (OLS) technique:

$$R_t - r_P = \alpha + \beta_1 \left(z_t\left(M_1\right) - r_P\right) + \beta_2 \left(z_t\left(M_2\right) - r_P\right) + \varepsilon_t \tag{24}$$

where $m = \alpha$, $w_1 = \beta_1$, $w_2 = \beta_2$ and $w_P = 1 - \beta_1 - \beta_2$. In addition, we impose non-negative constraints for the weights w_1, w_2 and w_P. The non-negative constraints on the weights make the optimization more robust. In particular, we can ease the problem of near-multicollinearity that arises if the regressors are highly correlated (which is the case for returns of investment strategies with similar maturity). The outer minimization problem can be solved by trying out all possible discrete pairs of maturity combinations $\left(M_1, M_2\right)$ and then checking which pair yields the lowest sum of squared residuals.

We fit the parameters for the period from January 2003 to September 2008, the month of the Lehman failure. For the determination of the reference portfolio, we neglect the subsequent low-interest-rate period. Instead, we try to answer the following question: If the composition of the reference portfolio had been unchanged in the low-interest-rate environment, what would the margins have been in this environment? Using the composition of the reference portfolios, we can calculate hypothetical bank rates and compare them to the actual bank rates. Note that structural breaks like the Lehman failure may have changed the model parameters, too. Therefore, the estimated change in the margins may be – at least in part – also attributed to changes in model parameters, not only to a change in actual margins.

IV. Data

For our analysis, we use publicly available data provided by the Deutsche Bundesbank. Our first data source is aggregated profit and loss data of German universal banks broken down into banking groups.[4] We look at two subsamples: the small banks, which consist of the savings and cooperative banks, the smaller

[4] Universal banks are broken down into commercial banks, which can be further divided into big banks, smaller private commercial banks and subsidiaries of foreign banks, savings banks, "Landesbanken", credit cooperatives and central institutions of credit cooperatives.

private commercial banks and the subsidiaries of foreign banks; and the large banks, which consist of the large commercial banks and the central institutions of the savings and cooperative banks. Here, we obtain information on interest income, interest expenses, net interest income and total assets for the period 1968–2013 at yearly frequency. Second, we use information on German government bond yields. To be more precise, we use the yield on the outstanding government bonds ("Umlaufrendite"). As the interest rates for different maturities and their yearly changes are highly correlated, we abstain from applying two or more interest rates of different maturities and we interpret the yield on the government bonds outstanding as the interest rate level.[5] We test for unit roots in our time series (interest income to total assets, interest expenses to total assets, and bond yields) using the Augmented Dickey-Fuller (ADF) unit root test. Under the null hypothesis, time series contain a unit root, where under the alternative the time series are stationary. Our test statistics show that, for the relevant time series in levels, the null hypothesis cannot be rejected (see Table 1). This is in line with the findings of *Diebold/Li* (2006). Furthermore, the tests show that the first differences of the variables can be assumed to be stationary.

Table 1

Dickey-Fuller-Test

Variable		All banks	Small banks	Large banks
Interest income margin	Level	−0.129	−0.477	0.046
	First difference	−3.178**	−3.189**	−3.203**
Interest expense margin	Level	−0.607	−0.831	−0.312
	First difference	−3.372**	−3.404**	−3.317**
Net interest margin	Level	−0.475	−0.994	−0.745
	First difference	−3.399**	−3.853***	−3.696***
Interest rate	Level	−0.917	−0.917	−0.917
	First difference	−4.651***	−4.651***	−4.651***

Test statistics of the Augmented Dickey-Fuller Test, period 1968–2013, two lags are included in all time series, 43 observations in the level specification, 42 observations in the first difference specification. ** and *** denote the 5% and 1% p-value for the null hypothesis "Time series contains a unit root".

[5] *Litterman/Scheinkman* (1991) and *Bliss* et al. (1997) find that the first component of principal component analyses of the US yield curve for different periods usually accounts for more than 80% of the variation and *Memmel* (2014) finds for Germany a share of even more than 90% of the variation.

For the retail deposit rates, we use data from the German part of the MFI interest rate statistics. Since January 2003, all member states of the European Monetary Union have been carrying out a monthly survey among the banks in their countries, surveying the interest rates for various retail products (for the German data of the MFI interest rate statistics, see Deutsche Bundesbank 2004). The retail deposits are broken down into six different categories: daily callable accounts (sight deposits), three types of term deposits (up to one year, more than one year to two years, more than two years), and two types of savings accounts (period of notice of up to three months, periods of notice of more than three months). For the purpose of presentation, daily callable accounts and the savings accounts are subsumed under the term "non-maturing accounts". We confine ourselves to retail deposits and ignore retail loans for two reasons. First, the rates for loan products also contain a mark-up for credit risk, which cannot be easily assumed to be constant over time as we assume with the remaining margin. Second, the rates for deposit products are usually lower than those for loan products and the market interest rates. Therefore, the zero lower bound in a low-interest-rate environment tends to be more quickly binding for these products, so that a noticeable effect can be expected to be seen especially here.

The returns on German government bonds are taken from Deutsche Bundesbank. The Bundesbank estimates for each trading day the term structure of listed German government bonds using the *Svensson* (1994) approach, which is an extension to the Nelson/Siegel method (see *Schich* 1997). Table 2 shows summary statistics of the return for the investment strategy $S(M)$ and of the return of government bonds $r(M)$ for different maturities M.

Table 2

Summary Statistics

Maturity M [in months]	Strategy S(M)		Government bonds r(M)	
	mean (p. a.)	stand. dev. (p. a.)	mean (p. a.)	stand. dev. (p. a.)
6	1.73 %	1.40 %	1.68 %	1.43 %
12	1.89 %	1.36 %	1.77 %	1.43 %
18	2.06 %	1.29 %	1.85 %	1.42 %
24	2.24 %	1.21 %	1.95 %	1.40 %
30	2.44 %	1.13 %	2.04 %	1.37 %
36	2.63 %	1.06 %	2.14 %	1.35 %

(Continue next page)

(Table 2: Continued)

Maturity M [in months]	Strategy S(M)		Government bonds r(M)	
	mean (p.a.)	stand. dev. (p.a.)	mean (p.a.)	stand. dev. (p.a.)
42	2.81 %	1.00 %	2.24 %	1.32 %
48	2.98 %	0.93 %	2.34 %	1.29 %
54	3.14 %	0.86 %	2.43 %	1.27 %
60	3.29 %	0.79 %	2.53 %	1.24 %
66	3.42 %	0.72 %	2.62 %	1.21 %
72	3.55 %	0.67 %	2.70 %	1.19 %
78	3.66 %	0.64 %	2.78 %	1.16 %
84	3.77 %	0.63 %	2.86 %	1.14 %
90	3.87 %	0.63 %	2.93 %	1.11 %
96	3.97 %	0.63 %	3.00 %	1.09 %
102	4.08 %	0.65 %	3.07 %	1.06 %
108	4.18 %	0.67 %	3.13 %	1.04 %
114	4.28 %	0.68 %	3.19 %	1.02 %
120	4.37 %	0.68 %	3.24 %	1.00 %

Summary statistics for the returns on the strategies S(M) and of the returns on German government bonds, issued at par, for different maturities M. Period: January 2003 to April 2014, 136 monthly observations.

We see that the mean returns of the strategies $S(M)$ and the mean return of the government bonds $r(M)$ increase monotonically with the maturity of the underlying government bonds. During our observation period from January 2003 to April 2014, the mean return for the strategy of investing in revolving bonds with a maturity of six months is 1.73 % compared to the mean return of 4.37 % for strategy $S(120)$. The respective figures for the return on government bonds are 1.68 % and 3.24 %.

V. Empirical Results

1. Normal Times

The Breusch-Pagan test shows that the errors in the two Equations (7) and (8) are not independent. As we need the joint distribution of the estimated coefficients of the interest income and interest expenses (Equations (7) and (8)), we estimate Equation (25) as a panel specification, which incorporates the correlated error structure. Here, the cross-sectional dimension consists of two units: the interest income margin (IIM) and interest expense margin (IEM) ($N = 2; T = 44$). In addition, there is autocorrelation in the two error terms. We opt for the following panel specification:

$$\begin{aligned} \Delta i_t = {} & \alpha_{IIM} \cdot D_{IIM} + \beta_{IIM,1} \cdot D_{IIM} \cdot \Delta IIM_{t-1} + \beta_{IIM,2} \cdot D_{IIM} \cdot \Delta r_t + \\ & \alpha_{IEM} \cdot D_{IEM} + \beta_{IEM,1} \cdot D_{IEM} \cdot \Delta IEM_{t-1} + \beta_{IEM,2} \cdot D_{IEM} \cdot \Delta r_t + \nu_{i,t} \end{aligned} \tag{25}$$

with $i = IIM, IEM$ and, D_{IIM} and D_{IEM} are dummy variables that take on the value one in the event that $i = IIM$ and $i = IEM$, respectively.[6] We estimate in first differences, because the interest margins do not seem to be stationary (See Table 1). Endogeneity may be an issue in the equation above because (the change in) the market interest rate is contemporaneously included. However, we do not claim that we measure a causal relationship from the market rates to the bank rates. Our main goal is to identify comovement between market and bank rates; this may include indirect linkages (for instance, the impact on the borrowers' riskiness due to changes in the market rates) and reverse effects (for instance, if the central bank takes into account the earning situation of banks when setting the policy rate).

Our estimator accounts for autocorrelation of order 1 in the error terms. For reasons of clarity, the results in Table 3 are displayed as if they were derived from univariate regressions, although they are estimated from the panel specification (25). The results are given for the sample of all universal banks and broken down into small and large banks.

[6] The STATA command *xtgls*, which we use in our study, allows for heteroskedastic and autocorrelated error structures. Furthermore, we allow panels to be correlated and choose the option "panels(correlated)". *Philipps/Sul* (2007) show that the bias in the autoregressive coefficient can be neglected if the number of time series observations is relatively large.

Table 3

Interest Income and Expenses

Variable	All banks		Small banks		Large Banks	
	Int. income	Int. exp.	Int. income	Int. exp.	Int. income	Int. exp.
Lagged dep. variable	0.3162*** (0.0650)	0.2081*** (0.0682)	0.3122*** (0.0671)	0.1981*** (0.0694)	0.2293*** (0.0710)	0.1361* (0.0730)
Interest rate level	0.5355*** (0.0582)	0.5617*** (0.0612)	0.5262*** (0.0361)	0.5462*** (0.0599)	0.5477*** (0.0613)	0.5872*** (0.0647)
Constant	0.0001 (0.0005)	0.0002 (0.0005)	0.0001 (0.0005)	0.0002 (0.0005)	0.0000 (0.0005)	0.0002 (0.0005)
Number of years	44	44	44	44	44	44

The relationship between interest rate level and interest income/interest expenses. The dependent variables are "Int. income" (interest income over total assets = Interest income margin) and "Int. exp." (interest expenses over total assets = Interest expense margin). Yearly data, 1968–2013. See Equations (7) and (8), and for the actual estimation Equation (25). Robust standard errors in brackets. * and *** denote significance at the 10 % and 1 % level, respectively.

The interest income and expenses are significantly positively related to changes in the level of interest rates. The same is true of the impact of the lagged dependent variable. The impact of the lagged dependent variable is larger for small banks than for large banks. This can be interpreted to mean that the maturities on the balance sheet of small banks are greater than those of the large banks.

For all samples, we see in Table 4 that the short-run impact of an increase in the interest rate level is highly positive for interest income and interest expenses, ranging between 0.53 and 0.59. The short-run impact on interest expenses is larger than on interest income, leading to a negative net effect (as can be seen in the column "NIM"), which is statistically significant for the samples of all banks and of large banks (see Appendix 1 for the derivation of the test statistics). By contrast, in the long run, the net effect of an increase in the interest rate level is positive, which is significant for the samples of all banks and of small banks. For the sample of all banks, we see that, in the short run, banks' net interest margin goes down by 2.6 bps after a 1-percentage-point increase in the interest rate level and, in the long run, it will go up by 7.4 bps. This qualitative difference, as laid down in Equation (16), is significant for the sample of all banks at the 5 % level (see Table 5 and Appendix 1). This means that the theoretical predictions of *Dell'Ariccia* et al. (2014) hold for the short-term horizon, but not for the long run.

Table 4

Impact of a Shift in the Yield Curve

Sample	Impact of a 1-percentage-point increase in the interest rate level			
	Horizon	Int. income	Int. expenses	NIM
All banks	short-run	0.5355*** (0.0650)	0.5617*** (0.0682)	–0.0261** (0.0133)
	long-run	0.7832*** (0.0985)	0.7093*** (0.0831)	0.0738*** (0.0265)
Small banks	short-run	0.5261*** (0.0671)	0.5462*** (0.0694)	–0.0200 (0.0149)
	long-run	0.7651*** (0.1006)	0.6811*** (0.0820)	0.0840*** (0.0309)
Large banks	short-run	0.5477*** (0.0710)	0.5872*** (0.0730)	–0.0396*** (0.0136)
	long-run	0.7106*** (0.0891)	0.6797*** (0.0779)	0.0309 (0.0213)

Pass-through (in percentage points) of a 1-percentage-point increase in the interest rate level. Robust standard errors in brackets (See Appendix 1). ** and *** denote significance at the 5 % and 1 % level, respectively. "Int. income" is the interest income over total assets. The same standardization applies for "Int. expenses" (= interest expenses). "NIM" is the net interest margin, i.e. net interest income over total assets. Yearly data 1968–2013.

Table 5

Further Test Statistics

Test statistics	All banks	Small Banks	Large Banks
LvsS x1000	–1.930** (0.895)	–1.682 (1.081)	–1.221* (0.727)
Horizon k* [in years]	1.464*** (0.256)	1.325*** (0.259)	1.814*** (0.427)
Present value change	–0.0624*** (0.0204)	–0.0658*** (0.0228)	–0.0338*** (0.0136)

Long-run versus short-run effects *LvsS*, time horizon k^* and change in present value. "*LvsS*" is the test statistic defined in Equation (16), "k^*" is the horizon where the change in the level of interest rates has no effect on banks' net interest margin (See Equation (27)) and the "Present value change" is the change (measured relative to total assets) in the bank equity's present value due to a 100 bp upward shift of the term structure (See Equation (19)). Robust standard errors in brackets (See the Appendices 1 and 2). *, ** and *** denote significance at the 10 %, 5 % and 1 % level, respectively.

Table 5 also shows the horizon where the different effects of an increase in the interest rate level exactly offset each other, i.e. before this critical horizon k^* the net effect is negative and, after this point in time, it is positive. It turns out that this critical horizon k^* is less than two years; for the sample of small banks, the estimate is 1.3 years, for the large banks 1.8 years, and for the whole sample, 1.5 years. The standard errors (see Table 5 and the Appendix 2) range between a quarter of a year and half a year, meaning that the estimates of this horizon are relatively precise.

Finally, in the last row of Table 5, the impact of a rise in the interest level on the present value of the bank equity is given. For all samples, this impact is negative and significant at the 1 % level. This result shows that the empirical model is able to replicate an important empirical feature of the German banking sector, namely the term transformation carried out by the banks (see Deutsche Bundesbank 2011). The coefficient for the small banks (–0.0658) is about twice as large as the one for the large banks (–0.0338), hinting at the feature that small banks are more engaged in term transformation than the large banks.

2. *Robustness Checks*

Several robustness checks are carried out. First, in 2010, there was a major structural break in the accounting rules where banks' total assets, especially those of the large banks, increased by roughly 10 % (the "Act to Modernize Accounting Law" ["Bilanzmodernisierungsgesetz"]). This increase in total assets, which was driven purely by changes in accounting rules, led to a corresponding decline in the interest margins. Leaving aside the years from 2010 on does not change the results qualitatively, but increases the statistical significance of the results. Second, an autoregressive process of order 1 may not be sufficient to adequately describe the time series properties of the interest margins. In order not to lose too many of the yearly observations, we confine ourselves to including one additional lag. The coefficient of this additional lag turns out to be statistically significant for all samples and margins, but negative, meaning that the pass-through share even becomes smaller (given that the direct effect of the change in the market interest rates mainly remains the same). The qualitative effect on the net interest margin, i.e. negative in the short run and positive in the long run, remains intact (results are available upon request).[7] Third, the estimations are carried out using OLS and applying the standard errors proposed by *Driscoll/Kraay* (1998) to better account for correlation across panels and to al-

[7] We prefer the model with only one lagged endogenous variable, as the Akaike information criterion (AIC) for small samples indicates a better trade-off between goodness of fit and simplicity for this specification.

low for a higher order of autocorrelation in the error terms. The results remain qualitatively unchanged, although there is a tendency toward weaker significance (results are available on request). Fourth, interest margins may be influenced by banks' credit risk. We consider the fraction of firms going into bankruptcy in Germany. On the one hand, corporate insolvency and the corresponding credit defaults should directly lower interest income. On the other, assuming rational expectations, banks should demand a higher credit risk premium whenever credit risk is on the rise. In order to check if the consideration of credit risk does change our results, we introduced the fraction of firms going into bankruptcy (in first differences), and as a second specification, we introduced the five-year moving average of that fraction. In both cases the results do not change and the bankruptcy variables do not provide a significant explanation. Fifth, the relationship between the interest margin and interest rate level could be driven by third factors. Introducing contemporaneous GDP growth (first differences) does not provide additional significant explanation and results remain stable. The lagged GDP growth shows statistical significance, but the economic relevance seems to be rather negligible, as coefficients are very small.[8] In this specification qualitative effects remain stable, but with weaker significance. Sixth, part of the total assets are not interest-bearing. Regression results may be influenced if the volume of interest-bearing liabilities does not correspond to the volume of interest-bearing assets. In order to address this aspect, we calculate the ratios of interest-bearing assets to total assets and interest-bearing liabilities to total assets and interact these ratios with the interest rate level. Neither the interaction terms nor the ratios shows a statistically significant impact on the interest margins.

3. Low Interest Rate Environment

In Table 6, the results of the optimization (21) concerning the replication strategies are displayed for the six different retail products: daily callable accounts, short-term and long-term savings accounts and term deposits (short-term, medium-term, and long-term).

The table gives the weights in the two passive trading strategies (w1, w2) and states the maturities of these two trading strategies (M1, M2). In addition, the weight of the passive investment strategy (wP) is given. There are three main results. First, the pass-through of changes in the market interest rates is incomplete for these retail bank deposits, even in the long run. This holds especially true for sight deposits (long-term pass-through of 35.9 %) and for short-term

[8] A one-percentage-point increase in GDP growth is associated with a roughly 0.002-percentage-point increase in interest expenses and interest income.

Table 6

Tracking Portfolio

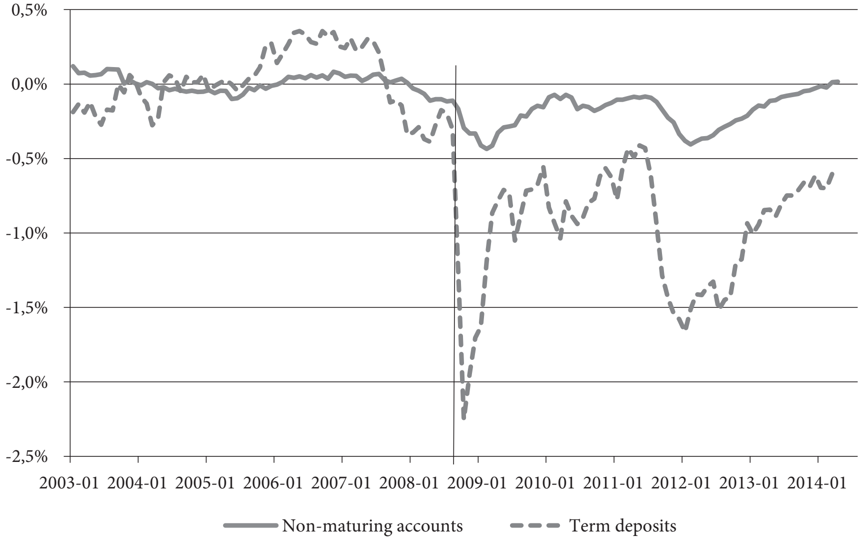
Number	Product	M1	w1	M2	w2	wP	Explanation
1	Daily callable accounts	6	35.9 %			64.1 %	94 %
2	Savings account (short-term)	6	25.5 %	54	27.9 %	46.6 %	89 %
3	Savings account (long-term)	18	72.4 %	30	18.0 %	9.6 %	98 %
4	Term deposits (short-term)	6	98.8 %			1.2 %	91 %
5	Term deposits (medium-term)	6	83.2 %	66	15.2 %	1.6 %	91 %
6	Term deposits (long-term)	6	7.2 %	120	57.2 %	35.7 %	60 %

Solution to the optimization (21). M1 and M2 are maturities (in months) of the replication strategies; w1 and w2 are the respective weights; wP is the weight of the time-invariant investment strategy. Non-negative constraints on the weights w1, w2 and wP. The column "Explanation" gives the coefficient of determination of the regression in Equation (24) and can be interpreted as the share of the serial variation explained by the passive portfolio strategies. Optimization period: January 2003 to September 2008.

savings accounts (53.4 %). By contrast, for term deposits the pass-through is more than 98 %, at least for short- and medium-term deposits. This compares with the estimate of the long-run pass-through to the interest expenses of 70.9 % (see Table 4), which can be seen as a weighted average of these figures. Second, trading strategies based on short-term interest rates, mostly 6-month rates, are always included in the replicating portfolio. This holds especially true for short-term term deposits, where the share of the trading strategy in 6-month bonds is 98.8 %.[9] Third, the replicating portfolios are able to explain around 90 % of the serial variation in the product rates (with the exception of long-term deposits, where the share of explanation is only 60 % of the serial variation).

In Figure 1, the change in the margin that the banks earn on the deposit products is displayed. As defined in Subsection 3.2, the margin is the difference between the product interest rate and the return on a portfolio of passive invest-

[9] Deposits like this, i.e. deposits with a very close link to market interest rates, best correspond to those in the model of *Dell'Ariccia* et al. (2014). However, in October 2014, the volume of these short-term deposits in Germany was less than one-tenth of that of sight deposits (see Deutsche Bundesbank 2014).



Difference in margins on bank products, relative to the average margin, from January 2003 to September 2008. Margins are derived as the difference relative to a portfolio of investment strategies whose composition is determined in the Jan. 2003 to Sep. 2008 period. "Non-maturing accounts" comprise "daily callable accounts" and two kinds of savings accounts. "Term deposits" comprise three retail kinds of retail deposits (up to 1 year, 1 up to 2 years, more than 2 years of maturity). The differences in margins are weighted with the volume of the amounts (daily callable and savings accounts) and with the volume of new business (term deposits).

Figure 1: Differences in Margins

ment strategies in government bonds. We see that, after the cut-off date of September 2008, the margin has become dramatically smaller. This holds true especially for the term deposits, where the average change in the margin is –0.97 % p. a., and not so much for the non-maturing accounts (daily callable accounts and savings accounts), where the average change in the margin is only –0.19 % p. a. However, if we assume that the low-interest-rate environment did not start until August 2012, then the changes in the margins are smaller, namely –0.87 % p. a. and –0.11 % p. a., respectively. Note that the decrease in the retail margins on the liability side need not have the same quantitative impact on banks' income and the degree of impact is likely to vary in the cross section of banks. First, banks' may try to mitigate the margin declines by, for instance, increasing fee and commission income. Second, the composition of the liabilities greatly varies in the cross section and banks with much wholesale liabilities are less impacted.

For the non-maturing accounts (daily callable accounts and savings accounts), the change in margin vanishes in fact at the latest available date. The relatively large reduction in the margin of the term deposits is due to the high weights of the market rates in the replicating portfolio: When the market rates reached zero or even negative values, the replicating portfolio followed suit, but the bank rates stayed significantly positive, which compressed the margins.

All in all, our empirical results suggest that there is a structural break in the margins for retail products on the liability side, especially for term deposits. This shows that it is sensible to make a distinction between "normal" periods and periods with very low interest rate levels.

VI. Conclusion

Our analysis suggests that, in the long run, an increase in the level of interest rates leads to an increase in banks' net interest margin. This finding adds a further perspective to the conventional wisdom that banks lose as interest rates rise. The story seems somehow more complicated: While it seems that banks lose in the short run in an environment of rising interest rates, they benefit in the long run from higher interest rates. This empirical finding seems to be relevant for the question of how banks respond to structurally changing interest rate levels, because a bank's net interest margin has a huge impact on its behavior. Our empirical results further show that the turning point, i.e. the horizon where the positive and the negative effects offset each other, is at about one-and-a-half years. This finding concerns, for instance, the design of stress test scenarios, because the stress scenarios are often embedded in an environment of rising interest rates, where the stress test horizon is up to three years, so that scenarios like this are not adverse for the banks.

We distinguish between periods with a "normal" interest rate level and periods with a very low interest rate level. Our analysis in the second part shows that the bank margins for retail product on the liability side are negatively affected by a low-interest-rate environment. We conclude that in the long run interest margins shrink in response to falling interest rates, because long-term pass-through is higher for asset-side products than for liability-side products. This effect is more pronounced in a low-interest-rate environment, because the zero lower bound of deposit products puts some additional stress on banks, especially concerning the margin of term deposits.

References

Albertazzi, U./*Gambacorta*, L. (2009): Bank Profitability and the Business Cycle, Journal of Financial Stability, Vol. 5(4), pp. 393–409.

Alessandri, P./*Nelson*, B. (2015): Simple Banking: Profitability and the Yield Curve, Journal of Money, Credit and Banking, Vol. 47 (1), 143–175.

Banca d'Italia (2013): Financial Stability Report, Number 6, November 2013.

Bliss, R. R. (1997): Movements in the Term Structure of Interest Rates, Economic Review, Federal Reserve Bank of Atlanta, Fourth Quarter, 1997.

Bolt, W./*de Haan*, L./*Hoeberichts*, M./*van Oordt*, R. C./*Swank*, J. (2012): Bank Profitability During Recessions, Journal of Banking and Finance, Vol. 36, 2552–2564.

Busch, R./*Koziol*, P./*Mitrovic*, M. (2015): Many a Little Makes a Mickle: Macro Portfolio Stress Test for Small and Medium-Sized German Banks, Deutsche Bundesbank Discussion Paper 23/2015.

Busch, R./*Memmel*, C. (2016): Quantifying the Components of the Banks' Net Interest Margin, Financial Markets and Portfolio Management, Vol. 30(4), pp. 371–396.

Dell'Ariccia, G./*Laeven*, L./*Marquez*, R. (2014): Monetary Policy, Leverage, and Bank Risk Taking, Journal of Economic Theory, Vol. 149, 65–99.

Deutsche Bundesbank (2004): Monthly Report 01/2004.

– (2011): Financial Stability Review 2011.

– (2014): Monthly Report 12/2014.

Diebold, F./*Li*, C. (2006): Forecasting the Term Structure of Government Bond Yields, Journal of Econometrics, Vol. 130, 337–364.

Drechsler, I./*Savov*, A./*Schnabl*, P. (2014): The Deposit Channel of Monetary Policy. Working Paper NYU.

Driscoll, J./*Kraay*, A. (1998): Consistent Covariance Matrix Estimation with Spatially Dependent Data, Review of Economics and Statistics, Vol. 80, 549–560.

English, W./*van den Heuvel*, S./*Zakrajsek*, E. (2014): Interest Rate Risk and Bank Equity Valuation, Federal Reserve Board Working Paper.

European Central Bank (2006): Differences in MFI Interest Rates Across Euro Area Countries, September 2006.

– (2009): Recent Developments in the Retail Bank Interest Pass-Through in the Euro Area, ECB Monthly Bulletin, August, 93–105.

Greene, W. H. (2003): Econometric Analysis, 5th ed., Pearson Education.

HSBC Global Research (2006): German Margin Call, Report of HSBC Trinkaus & Burkhardt AG.

Judge, G. G./*Bock*, M. E. (1978): The Statistical Implications of Pre-Test and Stein-Rule Estimators in Econometrics, New York, North-Holland.

Kempf, A./*Memmel*, C. (2006): Estimating the Global Minimum Variance Portfolio, Schmalenbach Business Review, Vol. 58, 332–348.

Kleimeier, S./*Sander*, H. (2006): Expected Versus Unexpected Monetary Policy Impulses and Interest Rate Pass-Through in Euro-Zone Retail Banking Markets, Journal of Banking and Finance, Vol. 30, 1839–1870.

Litterman, R./*Scheinkman*, R. (1991): Common Factors Affecting Bond Returns. Journal of Fixed Income, Vol. 1, 51–61.

Memmel, C. (2008): Which Interest Rate Scenario is the Worst One for a Bank? Evidence from a Tracking Bank Approach for German Savings and Cooperative Banks, International Journal of Banking, Accounting and Finance, Vol. 1(1), 85–104.

– (2011): Banks' Exposure to Interest Rate Risk, Their Earnings From Term Transformation, and the Dynamics of the Term Structure, Journal of Banking and Finance, Vol. 35, 282–289.

– (2014): Banks' Interest Rate Risk: the Net Interest Income Perspective Versus the Market Value Perspective, Quantitative Finance, Vol. 14(6), 1059–1068.

Nelson, C. R./*Siegel*, A. (1987): Parsimonious Modeling of Yield Curves, Journal of Business, Vol. 60, 473–489.

Phillips, P./*Sul*, D. (2007): Bias in Dynamic Panel Estimation with Fixed Effects. Incidental Trends and Cross Section Dependence, Journal of Econometrics, Vol. 137, 162–188.

Schich, S. T. (1997): Estimating the German Term Structure, Deutsche Bundesbank Discussion Paper, Series 1, 04/1997.

Svensson, L. E. O. (1994): Estimating and Interpreting Forward Interest Rates: Sweden 1992–94. IMF Working Paper 114, 1994.

Appendix 1

The delta method states that, if the standardized vector x is asymptotically normally distributed, i.e. $\sqrt{T}\cdot(x-\mu)\longrightarrow N(0;\Sigma)$, and $f(\cdot)$ is a differentiable function, the expression $\sqrt{T}\cdot(f(x)-f(\mu))$ is asymptotically normally distributed with expectation zero and variance $\left(\frac{\partial f}{\partial x}\right)'\Sigma\left(\frac{\partial f}{\partial x}\right)$(see Greene, 2003, pp. 913f). In our paper, $x=\left(\hat{\beta}_{IIM,1},\hat{\beta}_{IIM,2},\hat{\beta}_{IEM,1},\hat{\beta}_{IEM,2}\right)'$. Table A1 gives $f(\cdot)$ and $\partial f/\partial x$ for the different cases.

Appendix 2

The change in the net interest margin can be written as

$$\Delta NIM(k)=\beta_{IIM,2}\cdot\frac{1-\beta_{IIM,1}^{k}}{1-\beta_{IIM,1}}-\beta_{IEM,2}\cdot\frac{1-\beta_{IEM,1}^{k}}{1-\beta_{IEM,1}}. \tag{26}$$

The variable denotes the horizon for which this change equals zero, i.e.

$$\Delta NIM(k^*)=0. \tag{27}$$

Using the theorem about implicit functions gives us

$$\frac{\partial k^*}{\partial\beta_{i,j}}=-\frac{\dfrac{\partial\Delta NIM}{\partial\beta_{i,j}}}{\dfrac{\partial\Delta NIM}{\partial k^*}} \tag{28}$$

Table A1

Components of the Delta Method

Case i	Elasticity/ test statistics	$f_i(x)\big\|_{x=\mu}$	$\left(\partial f_i / \partial x\right)'\big\|_{x=\mu}$
1	Short-term interest income	$\beta_{IIM,2}$	$(0,1,0,0)$
2	Long-term interest income	$\frac{\beta_{IIM,2}}{1-\beta_{IIM,1}}$	$\left(\frac{\beta_{IIM,2}}{(1-\beta_{IIM,1})^2},\frac{1}{1-\beta_{IIM,1}},0,0\right)$
3	Short-term interest expenses	$\beta_{IEM,2}$	$(0,0,0,1)$
4	Long-term interest expenses	$\frac{\beta_{IEM,2}}{1-\beta_{IEM,1}}$	$\left(0,0,\frac{\beta_{IEM,2}}{(1-\beta_{IEM,1})^2},\frac{1}{1-\beta_{IEM,1}}\right)$
5	Short-term NIM	$\beta_{IIM,2}-\beta_{IEM,2}$	$(0,1,0,-1)$
6	Long-term NIM	$\frac{\beta_{IIM,2}}{1-\beta_{IIM,1}}-\frac{\beta_{IEM,2}}{1-\beta_{IEM,1}}$	$\left(\frac{\beta_{IIM,2}}{(1-\beta_{IIM,1})^2},\frac{1}{1-\beta_{IIM,1}},-\frac{\beta_{IEM,2}}{(1-\beta_{IEM,1})^2},-\frac{1}{1-\beta_{IEM,1}}\right)$

(Continue next page)

(Table A1: Continued)

Case	Elasticity/ test statistics	$f_i(x)\vert_{x=\mu}$	$\left(\partial f_i / \partial x\right)' \vert_{x=\mu}$
7	LvsS	$f_5(\mu)\cdot f_6(\mu)$	$\left(f_5(\mu)\cdot\frac{\beta_{IIM,2}}{(1-\beta_{IIM,1})^2}, f_6(\mu)+\frac{f_5(\mu)}{1-\beta_{IIM,1}}, -f_5(\mu)\cdot\frac{\beta_{IEM,2}}{(1-\beta_{IEM,1})^2}, -f_6(\mu)-\frac{f_5(\mu)}{1-\beta_{IEM,1}}\right)$
8	Present value of the bank's equity	$\frac{-\frac{1}{4}\beta_{IIM,2}}{(1-\beta_{IIM,1})^2}-\frac{-\frac{1}{4}\beta_{IEM,2}}{(1-\beta_{IEM,1})^2}$	$\left(-\frac{\beta_{IIM,2}}{2\cdot(1-\beta_{IIM,1})^3}, -\frac{1}{4\cdot(1-\beta_{IIM,1})^2}, \frac{\beta_{IEM,2}}{2\cdot(1-\beta_{IEM,1})^3}, \frac{1}{4\cdot(1-\beta_{IEM,1})^2}\right)$

Parameters for the calculation of tests statistics using the delta method. "NIM" denotes net interest margin; "LvsS" is defined in Equation (16) as the test statistic to check whether there is a change in the sign of the relationship between interest rates and a bank's net interest margin. Interest income and interest expenses relative to total assets.

where the numerator and the denominators of Equation (28) for the four different cases $i = IIM, IEM$; $j = 1, 2$ can be obtained as follows:

$$(29) \qquad \frac{\partial \Delta NIM}{\partial \beta_{IIM,1}} = \beta_{IIM,2} \cdot \frac{-k^* \cdot \beta_{IIM,1}^{k^*-1} \cdot (1-\beta_{IIM,1}) + \left(1-\beta_{IIM,1}^{k^*}\right)}{(1-\beta_{IIM,1})^2}$$

$$(30) \qquad \frac{\partial \Delta NIM}{\partial \beta_{IIM,2}} = \frac{1-\beta_{IIM,1}^{k^*}}{1-\beta_{IIM,1}}$$

$$(31) \qquad \frac{\partial \Delta NIM}{\partial \beta_{IEM,1}} = -\beta_{IEM,2} \cdot \frac{-k^* \cdot \beta_{IEM,1}^{k^*-1} \cdot (1-\beta_{IEM,1}) + \left(1-\beta_{IEM,1}^{k^*}\right)}{(1-\beta_{IEM,1})^2}$$

$$(32) \qquad \frac{\partial \Delta NIM}{\partial \beta_{IEM,2}} = -\frac{1-\beta_{IEM,1}^{k^*}}{1-\beta_{IEM,1}}$$

$$(33) \qquad \frac{\partial \Delta NIM}{\partial k^*} = -\beta_{IIM,2} \cdot \frac{\ln \beta_{IIM,1} \cdot \beta_{IIM,1}^{k^*}}{1-\beta_{IIM,1}} + \beta_{IEM,2} \cdot \frac{\ln \beta_{IEM,1} \cdot \beta_{IEM,1}^{k^*}}{1-\beta_{IEM,1}}$$

Using the delta method (as outlined in Appendix 1) enables us to calculate the asymptotic standard deviation of k^* in a closed-form expression.

Appendix 3

In the event that one has to choose exactly one possible passive investment strategy, the minimization (21) reduces to

$$(34) \qquad \min_{M_1} \left(\min_{m, w_1, w_P} \frac{1}{T} \sum_{t=1}^{T} \varepsilon_t^2 \right)$$

subject to

$$(35) \qquad {}_t = R_t - \left(m + w_1 \cdot z_t(M_1) + w_P \cdot r_P\right)$$

and

$$(36) \qquad w_1 + w_P = 1$$

Again, this minimization problem can be seen as a linear regression:

$$(37) \qquad R_t - r_P = \alpha + \beta_1 \left(z_t(M_1) - r_P\right) + \varepsilon_t$$

where $m = \alpha$, $w_1 = \beta_1$ and $w_P = 1 - \beta_1$. For a linear regression with only one regressor, we get $R^2 = \hat{\rho}^2_{M_1}$, where R^2 is the coefficient of determination and $\hat{\rho}_{M_1}$ is the empirical correlation coefficient between R_t and $z_t(M_1)$. Using $\min_{m,w_1,w_P} \frac{1}{T}\sum_{t=1}^{T} \varepsilon_t^2 =: \hat{\sigma}^2_\varepsilon = \left(1 - \hat{\rho}^2_{M_1}\right)\hat{\sigma}^2_R$, we can rewrite the minimization in (34) as

$$\min_{M_1} \hat{\sigma}^2_R \left(1 - \hat{\rho}^2_{M_1}\right), \tag{38}$$

where $\hat{\sigma}^2_R$ is the empirical variance of R_t. For positive correlations, the approach (38) is equivalent to the approach by the European Central Bank (2006), which is

$$\max_{M_1} \hat{\rho}_{M_1} \tag{39}$$

Appendix 4

Let $Z_t = \left(z_t(M_1),\ldots,z_t(M_n)\right)'$ be a vector of returns from passive investment strategies; let R_t be the interest rate of the retail product. The vector c includes all the covariances, i.e. $c = \left(\mathrm{cov}(z_t(M_1),R_t),\ldots.,\mathrm{cov}(z_t(M_n),R_t)\right)'$, the matrix $\Omega = \mathrm{var}(Z_t)$ is the covariance matrix of the vector Z_t. As the inner optimization of (21) is equivalent to linear regression, the solution for the vector of coefficients w is (see Kempf and Memmel, 2006)

$$w^* = \Omega^{-1} c. \tag{40}$$

Next, we consider the correlation between the return of an arbitrary portfolio $w'Z_t$ of passive investment strategies and the return R_t of the retail product. The squared correlation coefficient for arbitrary portfolio weights$w$is given by

$$\rho^2 = \frac{\mathrm{cov}\left(w'Z_t, R_t\right)^2}{\mathrm{var}\left(w'Z_t\right)\cdot \sigma^2_R} = \frac{\left(w'c\right)^2}{w'\Omega w \cdot \sigma^2_R} \tag{41}$$

where   is the variance of the product interest rate R_t.

From matrix theory, we know that the maximal squared correlation is (See Judge and Bock, 1978, p. 317, Theorem A.3.14.)

$$\rho^2_{\max} = \frac{c'\Omega^{-1}c}{\sigma^2_R} \tag{42}$$

When using the solution (40) as the weights in Equation (41), we get – after some algebraic conversions – the maximum value as given in (42).