# Which interest rate scenario is the worst one for a bank? Evidence from a tracking bank approach for German savings and cooperative banks

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**Abstract:** Interest income is the most important source of revenue for most banks. The aim of this paper is to assess the impact of different interest rate scenarios on the banks' interest income. As we do not know the interest rate sensitivity of real banks, we construct for each bank a portfolio with a similar composition of its assets and liabilities, called 'tracking bank'. We evaluate the effect of 260 historical interest rate shocks on the tracking banks of German savings and cooperative banks. It turns out that a sharp decrease in the steepness of the yield curve has the most negative impact on the banks' interest income.

**Keywords:** interest rate risk; stress testing.

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## 1 Introduction

For most banks, interest income is by far the most important source of revenue. Stress testing concerning the banks' interest income is therefore an important issue.[1] The aim of this paper is twofold: first, to present a method that allows estimation and forecasting of a bank's interest income, using accounting information, and second, to apply this method to find out which interest rate scenario is most harmful for a bank.

Banks earn their (net) interest income primarily from three sources:

1 risk premia for taking on credit risk

2 interest margins in return for providing customers access to financial markets

3 returns from term transformation.

The most important risk for (commercial) banks stems from the credit risk; therefore, most banking regulations are about this sort of risk. The second source of interest income, *i.e.*, interest margins, is not subject to direct risk. However, increasing competition among banks and a downturn in economic activities may put pressure on the margins, so that income from this source is indirectly, and from a long-term perspective, at risk. The third source of interest income, *i.e.*, returns form term transformation, relies on maturity mismatches between the banks' assets and liabilities. Normally, a bank hands out loans of long maturity and finances itself by short-term deposits. Given a normal term structure of interest rates, the bank can earn a positive return from these maturity mismatches. However, changes in the term structure of interest rates directly affect the banks' interest income. This paper is about the income risk arising from these changes.

The main idea of the paper is as follows: We do not know the consequences of an interest rate shock for a real bank, because we lack information about its future cash flows. Therefore, for each real bank, we construct a bank with a similar maturity composition, called 'tracking bank', and we presume that the real bank and its tracking bank are hit by an interest shock in the same way. Analysing the effects of an interest rate shock on the tracking banks, we transfer the results to the real banks.

The method of determining the interest rate sensitivity is comparable to performance measurement in portfolio theory: to measure the performance of a fund, one composes a portfolio with the same systematic risk (see, for example, Jensen, 1968) as the fund under consideration. The loadings of the systematic risk factor(s)[2] allow us to judge the extent to which the fund's return is determined by certain risk factors. The systematic risk factors in our case are the yields of investment strategies that consist in investing in default-free bonds of different maturities.

The tracking banks are assumed to behave completely passively, *i.e.*, their interest rate exposure is constant through time. Real banks, in contrast, are believed to change their interest rate exposure according to the shape of the term structure and the expectations about interest rate changes. Therefore, the tracking banks' interest rate exposure rather corresponds to the *average* interest rate exposure of the real bank, which will not be identical to the real bank's current exposure. Again, there is an analogy to performance measurement: When one estimates the market exposure of a mutual fund, one gets an estimate for the fund's average market exposure. The fund's current exposure, in contrast, may vary depending on the fund managers' market expectation.

Having established a tracking bank for each German savings and cooperative bank, we calculate the change in the interest income for each tracking bank for 260 historical interest rate scenarios in Germany.

It turns out that our tracking bank approach is able to explain a substantial part of the cross-sectional and time series variation of a bank's (net) interest income. Concerning the worst interest rate scenario, we find that a scenario with a sharp decrease in the steepness of the yield curve, *i.e.*, the short-term rates go up sharply and the long-term rates barely move, has the most negative impact on the bank's net interest income in the year after the shock and in the second year after the shock.

The paper is structured as follows: Section 2 gives a short overview of the literature in this field. In Section 3, we describe the model, and Section 4 gives a description of the data. Section 5 states the estimation results, and Section 6 is about finding the interest rate scenario with the worst impact on the banks. Section 7 concludes.

## 2 Literature

This paper contributes to two strands of the literature on the banks' interest income. First, we present a new method to estimate a bank's interest rate risk exposure that arises from term transformation. Our innovation is that we model the banks' interest income with tracking banks instead of interest rates.[3] Second, we contribute to the literature on stress testing of the banks' interest income.

Provided the banks' future cash flows and the maturity composition of their assets and liabilities are known, the income from term transformation is relatively easy to determine. However, outsiders (like investors or supervisory authorities) lack this information. Therefore, many studies rely on stock returns or on accounting-based data to assess a bank's exposure to interest rate risk arising from term transformation. Staikouras (2003) and Staikouras (2006) give an overview of these studies. Flannery and James (1984b), Saunders and Yourougou (1990), and Yourougou (1990) use stock returns of US banks to analyse the interest rate sensitivity of banks. Dinenis and Staikouras (1998) and Czaja *et al.* (2006) apply this analysis to UK and German banks, respectively. A general result of these studies is a significantly negative relation between the banks' stock returns and interest rate changes. Many studies find stronger effects during periods of high interest rate volatility. Accounting-based approaches have the advantage that they can be applied to the vast majority of banks that are not listed. Houpt and Embersit (1991) and Sierra and Yeager (2004) can derive a meaningful measure of interest rate sensitivity from the banks' balance sheet data. When applying these approaches, one has to keep in mind the implicit assumption that the maturity composition of the bank is (relatively) constant. This assumption is not trivial, because bonds, the entities that constitute the bank's assets and liabilities, change their maturity from day to day.

Often, the economic value perspective is chosen, which estimates the loss in the bank's present value given a certain change in the yield curve. The earnings perspective is common as well (see, for example, Flannery, 1981; Flannery, 1983; van den End *et al.*, 2006), especially when analysing traditional commercial banking as the business model and when analysing the short-term effects on the profit and loss account.[4] In this paper, we choose the earnings perspective and not the economic value perspective for two reasons. First, we look at small- and medium-sized banks, which are primarily engaged in commercial banking. Second, we are interested in the effects of the interest rate changes on the banks' profit and loss accounts in the near future, *i.e.*, in a horizon of one or two years.

Mostly, the accounting information at one point in time is used to assess the banks' exposure to interest rate risk. A counterexample is the work by Entrop *et al.* (2008). They use time series of accounting information and they show that this additional information considerably improves the estimation of the bank's duration gap. Their calculation, however, is time-consuming, involves quadratic programming and works best when there are no structural breaks in the time series of the bank's balance sheet data. In this paper, we use the banks' accounting information at one point in time. The neglect of the time series information may reduce the precision of our estimates. However, the calculation is much less time-consuming and the question does not arise of how to deal with banks for which there are fewer observations than the length of the time series. This question is relevant because there was a merger wave among German savings and cooperative banks in the period under consideration (see Kötter, 2005).

As mentioned above, the second strand of literature we contribute to is about stress testing. To assess the stability of the financial system, many central banks in Europe carry out interest rate risk stress tests using information on the banks' balance sheets.[5] The methods described in this paper can help design scenarios for interest rate stress tests and interpret the results.

## 3 Modelling interest income and expenses

For each bank, we create a passively behaving bank with a similar maturity structure. This bank is called a 'tracking bank' and serves us as an approximation of the respective real bank.[6] The tracking bank is assumed to follow a passive, stationary business model, *i.e.*, it reinvests the funds that become due in investments of the same kind: when a five-year loan matures, the bank hands out a new loan with five years of maturity. The same applies to the bank's financing. In detail, we have these five assumptions:

1. The composition of the tracking bank's balance sheet remains unchanged in the course of time. Whenever a loan or a bond matures, the bank replaces it with a loan or a bond of the same initial time to maturity.
2. In theory, this replacement of maturing bonds and loans is continuous. However, we choose monthly discretion.
3. There exists only one sort of financial instrument: bonds (or loans) of different initial maturity that quote at par when issued and that redeem the whole principal at maturity.
4. Whereas the principal is reinvested at maturity, the interest paid contributes to the bank's interest income (in the case of an asset) or to the interest expenses (in the case of a liability).
5. All bonds and loans are default-free.

A tracking bank can be seen as a portfolio of investment strategies $S(T)$. These strategies $S(T)$ consist in investing each month the constant part $1/T$ in par-yield bonds with maturity $T$ (given in months, *i.e.*, $T = 48$ corresponds to a maturity of four years). As one can see, these strategies are in accordance with the assumptions of the stationary tracking bank: the money collected from redemption in a certain month corresponds to the amount invested. The interest income is withdrawn each month. This interest income yields in month $t$:

$$z_t = \frac{1}{12}\bar{r}_{t-1}(T) \tag{1}$$

with:

$$\bar{r}_t(T) = \frac{1}{T}\sum_{i=0}^{T-1} r_{t-i}(T) \tag{2}$$

where $r_t(T)$ is the yield of par bonds with maturity $T$ in time $t$.[7] In other words, the yield of the strategy $S(T)$ equals the moving average of the interest rate (divided by 12 to get the monthly yield).

As we only observe the interest income once a year, we sum up the last 12 monthly interest incomes to obtain the income for the whole year, *i.e.*:

$$\begin{aligned} Z_t(T) &= \sum_{i=0}^{11} z_{t-i}(T) \\ &= \frac{1}{12}\sum_{i=0}^{11} \overline{r}_{t-1-i}(T) \\ &= \frac{1}{12T}\sum_{i=0}^{11}\sum_{j=0}^{T-1} r_{t-1-i-j}(T) \end{aligned} \tag{3}$$

if $t$ is a multiple of 12. From Equation (3), we see that the current interest income of strategy $S(T)$ is the weighted sum of past par-bond yields with a maturity of $T$ months.

As mentioned above, the tracking bank's assets are a portfolio of investment strategies $S(T)$. Let $w_I(T_k)$ with $k = 1,\ldots,K_I$ be the share of the total assets that is invested in the strategy $S(T_k)$; then we can calculate the tracking bank's interest income ($Z_t^I$) (normalised to the bank's total assets) as:

$$Z_t^I = \sum_{k=1}^{K_I} w_I(T_k)\cdot Z_t(T_k). \tag{4}$$

Accordingly, we can interpret the bank's liabilities as a portfolio of investment strategies $S(T)$ with the corresponding weights $w_E(T_k)$ and we can calculate the interest expenses ($Z_t^E$).

For instance, assume the tracking bank revolvingly hands out loans of one-year, four-year and six-year maturity and the weights of one-year loans, four-year loans and six-year loans are 20%, 30% and 45%, respectively; then the normalised interest income is:

$$Z_t^I = 0.2\cdot Z_t(12) + 0.3\cdot Z_t(48) + 0.45\cdot Z_t(72).$$

Please note that the weights need not sum up to 100%: usually, banks hold non-interest-bearing assets such as real estate and shareholdings as well. In the case of liabilities, the difference to 100% is even greater, because the banks' capital does not count among the interest-bearing liabilities. Further note that the maturity is given in months (and not in years), *i.e.*, the share of loans with an initial maturity of four years is denoted as $w_I(48) = 0.3$.

Even if we knew the real bank's maturity composition, the interest income and the interest expenses of the real bank and the tracking bank would differ considerably. Nevertheless, given the available information, the tracking bank approach seems to be superior to other approaches (see Section 5).

The differences may be due to the following reasons:

- The real bank does not need to behave as passively as the tracking bank. It is likely that the bank increases the term transformation in times of a steep yield curve. Moreover, in times of an economic boom the bank will hand out more loans than during recessions or financial crises.

- The real bank does not charge and pay the interest rate of default-free government bonds. In fact, one major function of a bank is to give customers access to the capital market and to take on credit risk. Therefore, banks tend to charge more for the loans and pay less for the deposits than the interest rate of the corresponding government bond. By contrast, the tracking bank charges and receives the interest rate of default-free government bonds.
- Real banks deal as well in much more complicated financial instruments than straight, default-free bonds (See Assumptions 3 and 5). For instance, they are engaged in off-balance-sheet activities, such as interest rate swaps and options.

Besides the differences mentioned above, there is the problem that the maturity composition of a bank's assets and liabilities is not known exactly, at least to outsiders and to the supervisory authorities. At best, the assets and liabilities are broken down into different maturity brackets and into different lender and borrower groups. The assumption is that the bank spreads its money equally over all the different initial maturities (we assume initial maturities in six-month steps). For instance, assume that a bracket covers all the loans to banks from more than one to up to three years of initial maturity. This assumption of spreading the loans equally makes the bank in our example invest one-quarter into bank loans with 18-month, 24-month, 30-month and 36-month initial maturities, respectively.

Let $x_{t,i,j}$ be the normalised interest income contribution of the maturity bracket $j$ of asset class $i$ to the normalised interest income $Z_t^I$ of the tracking bank; then the following relationship holds, given the assumption of equally spread maturities within a bracket:

$$Z_t^I = x_{t,1,1} + x_{t,1,2} + \ldots + x_{t,i,j} + \ldots + x_{t,N,M_N} \tag{5}$$

where $N$ defines the number of asset classes and $M_i$ is the number of brackets into which the asset class is broken down. Let us return to the example above, *i.e.*, the bracket for loans with more than one year and up to three years of initial maturity. Denote this bracket with $i = 1$ and $j = 3$. Assume that the assets in this bracket account for 15% of the bank's total assets. In this case, we obtain:

$$x_{t,1,3} = 0.15 \cdot (0.25 \cdot Z_t(18) + 0.25 \cdot Z_t(24) + 0.25 \cdot Z_t(30) + 0.25 \cdot Z_t(36)).$$

However, Equation (5) holds only for the tracking bank; in reality, we only observe the interest income of the real bank, denoted by $R_t^I$. As the tracking bank and the real bank do not act identically, the contributions $x_{t,i,j}$ do not enter with the weight of one into the equation and there remains a residual. We therefore estimate the following regression:

$$R_t^I = \alpha + \beta_{1,1} \cdot x_{t,1,1} + \beta_{1,2} \cdot x_{t,1,2} + \ldots + \beta_{N,M_N} \cdot x_{t,N,M_N} + \varepsilon_t, \tag{6}$$

where $R_t^I$ is the normalised interest income of the real bank. Please note that we estimate regression (6) as a panel regression, *i.e.*, for reasons of simplicity, the indexes or the banks are left out. Note as well that a similar equation is estimated for the bank's liabilities.

The better that the assumptions made for the tracking bank fit the real bank, the closer the coefficients $\beta_{i,j}$ will be to 1. The constant $\alpha$ will be estimated separately for each bank. The higher this constant, the more the bank is able to charge margins above the risk free interest rate.

## 4 Data

The Deutsche Bundesbank estimates the yield curve for government bonds using the method of Svensson (1994).[8] This method is a further development of the Nelson and Siegel (1987) method and approximates the real yield curve by a function depending on six parameters. We use monthly data of these parameter estimates from January 1980 to August 2007. Having established an entire yield curve for each month, we calculate the implicit yield of bonds quoted at par and the year-end interest income of the various investment strategies $S(T)$.

In Table 1, the summary statistics of the interest income for the strategies $S(T)$ with different initial maturity $T$ is given. The period is from 1990 to 2006, *i.e.*, 17 observations. The mean return of the different strategies increases with the initial maturity. In the period under consideration, term transformation has been a lucrative source of revenue. The revolving investment in papers of six-month maturity yields on average an interest income of 4.62%, whereas the revolving investment in ten-year (=120-month) bonds yields an interest income of 6.56%. The relationship between mean return and initial maturity is monotone and slightly concave, *i.e.*, the increases in mean return become smaller the longer the initial maturity. By increasing the initial maturity by one year, one augments the mean interest income by approximately 20 basis points. At the same time, the income volatility decreases as the initial maturity increases. However, this result may be misleading: not only the earning volatility counts but the volatility of the economic value as well, and, from an economic value standpoint, strategies based on bonds with long maturities are quite risky.

**Table 1** Interest income

| *Maturity* | *No. of obs.* | *Mean* | *Standard dev.* | *Minimum* | *Maximum* |
|---|---|---|---|---|---|
| 6 | 17 | 4.62 | 2.37 | 2.06 | 9.16 |
| 12 | 17 | 4.72 | 2.27 | 2.21 | 8.92 |
| 24 | 17 | 4.99 | 2.06 | 2.50 | 8.83 |
| 48 | 17 | 5.49 | 1.62 | 3.17 | 8.15 |
| 72 | 17 | 5.90 | 1.30 | 3.92 | 7.54 |
| 120 | 17 | 6.56 | 0.96 | 4.68 | 7.66 |

Notes: Summary statistics for the yearly interest income (in percentage) for the investment strategy $S(T)$. $S(T)$ is an investment strategy that consists in investing revolvingly in par-yield bonds of maturity $T$ (in months). Yearly data from 1990 to 2006. Only selected maturities are reported in this table.

To construct the different interest scenarios, we make use of the same data set from above. Starting in 1986, we calculate for each month and each maturity the year-to-year change in the interest rate. This procedure yields 260 overlapping scenarios for interest rate changes.[9]

In Table 2, the summary statistics are given concerning these interest changes. The volatility of the interest rate changes is about 1%. As expected, the smaller the volatility, the longer the maturity. For the six-month interest rate, the volatility is 1.22%, and it gradually goes down to 0.85% for the volatility of the ten-year interest rate. The regulatory framework of Basel II stipulates an interest rate stress test for the banks' banking book. This stress test consists of an upward and downward 200 bp parallel shift of the yield curve or, equivalently, a parallel shift of the first and 99th percentile of the yearly interest rate changes (see Basel Committee on Banking Supervision, 2004). Looking at the corresponding percentiles in Table 2, we see that the two alternatives lead to shocks of approximately the same severity, especially when looking at the longer maturities. For short-term interest rates, however, the year-to-year change may be up to 300 bp.

**Table 2** Changes in interest rates

| *Maturity* | *No. of obs.* | *Mean* | *Standard deviation* | *Percentile* | | | |
|---|---|---|---|---|---|---|---|
| | | | | *1st* | *10th* | *90th* | *99th* |
| 6 | 260 | –0.07 | 1.22 | –2.54 | –1.65 | 1.49 | 2.99 |
| 12 | 260 | –0.07 | 1.21 | –2.49 | –1.64 | 1.44 | 3.11 |
| 24 | 260 | –0.09 | 1.20 | –2.79 | –1.73 | 1.58 | 2.58 |
| 48 | 260 | –0.12 | 1.08 | –2.54 | –1.56 | 1.50 | 2.08 |
| 72 | 260 | –0.13 | 0.97 | –2.03 | –1.38 | 1.28 | 2.15 |
| 120 | 260 | –0.14 | 0.85 | –1.58 | –1.11 | 1.04 | 2.07 |

Notes: Year-to-year changes in the interest rates (zero-bond yields, in percentage points), derived from German government bonds for selected maturities (in months). Monthly data for the period from January 1986 to August 2007.

We restrict our analysis to the savings and to the cooperative banks in Germany. The banks of these two sectors are relatively homogeneous; they account for more than 80% of all German institutions and they generate the vast majority of their business with the classical banking activities, *i.e.*, by handing out loans and by receiving deposits.

In Table 3, we give summary statistics on the variable of interest, *i.e.*, the banks' net interest income normalised to the banks' total assets.[10] In 1998, there was a major break in the time series. Therefore, we use the period from 1999 to 2006. During this period, the interest margin was 2.47% for the median bank. However, from 2003 onwards, we see a decline in this margin. The number of banks in the sample continuously fell from more than 2500 banks in 1999 to about 1600 banks in 2006. This decrease in number was due to a merger wave in the German savings bank and cooperative bank sector (see Kötter, 2005).

The maturity composition of the banks' assets and liabilities can only be approximately inferred from the data available to us. We make use of the information from the Deutsche Bundesbank's monthly balance sheet statistics. The monthly balance sheet statistics are broken down into different assets and liabilities and into different initial maturity brackets. Table 4 gives this breakdown of the initial maturities for different assets and liabilities.

**Table 3** Net interest income

| *Year(s)* | *No. of. obs.* | *25th percentile* | *Median (%)* | *75th percentile* |
|---|---|---|---|---|
| 1999 | 2563 | 2.30 | 2.55 | 2.81 |
| 2000 | 2314 | 2.20 | 2.51 | 2.80 |
| 2001 | 2118 | 2.09 | 2.37 | 2.64 |
| 2002 | 1967 | 2.21 | 2.50 | 2.77 |
| 2003 | 1838 | 2.27 | 2.56 | 2.83 |
| 2004 | 1769 | 2.22 | 2.52 | 2.79 |
| 2005 | 1690 | 2.14 | 2.43 | 2.68 |
| 2006 | 1636 | 2.01 | 2.29 | 2.52 |
| 1999–2006 | 15 895 | 2.18 | 2.47 | 2.74 |

Note: Net interest income over total assets (= standardised interest income) of German savings and cooperative banks.

**Table 4** Breakdown into the reporting forms

| *Position* | *1st bracket* | *2nd bracket* | *3rd bracket* | *4th bracket* |
|---|---|---|---|---|
| *Assets* | | | | |
| Loans to banks | Daily | up to 1 y | 1 y to 5 y | more than 5 y |
| Loans to nonbanks | up to 1 y | 1 y to 5 y | more than 5 y | |
| Bonds | up to 1 y | 1 y to 5 y | more than 5 y | |
| *Liabilities* | | | | |
| Loans from banks | Daily | up to 1 y | 1 y to 2 y | more than 2 y |
| Loans from nonbanks | daily | up to 1 y | 1 y to 2 y | more than 2 y |
| Subordinated debt | | no breakdown | | |
| Savings accounts | up to 3 mo. | more than 3 mo. | | |

Note: Breakdown of the initial maturities of the banks' assets and liabilities according to the reporting forms of the Deutsche Bundesbank's monthly balance sheet statistics.

Additionally, we make assumptions concerning the distribution of the initial maturities in the brackets (see Section 3): The maturities are assumed to be equally distributed in brackets in which the discretion is six months. However, there are three exceptions:

1 For the brackets with daily maturity, we apply the strategy $S(3)$ based on the three-month interest rate to avoid the high volatility of the overnight money interest rate.

2 The longest maturity for the brackets *more than two years* and *more than five years* is 96 months.

3 For the savings accounts, we assume a tracking portfolio that is composed of equal shares of the six-month and the 114-month strategy (for the *up to three month* bracket) and of equal shares of the 12-month and the 120-month strategy (for the *more than three month* bracket).[11]

In Table 5, we report the composition of the banks' assets and liabilities. On average, the positions included in our analysis account for 91.4% of a bank's assets and for 88.7% of the liabilities. By far the largest asset position is 'loans to non-banks' (on average 62.2% of total assets). Savings accounts, on average, account for one-third of the banks' funding, at least for the relatively small banks in our sample. As the composition of the assets and liabilities in Table 5 does not vary much, we have further evidence that the group of banks under consideration is relatively homogeneous.

**Table 5** Composition of assets and liabilities

| *Position* | *No. of obs.* | *25th percentile* | *Median (%)* | *75th percentile* |
|---|---|---|---|---|
| Assets included to total assets | 15 895 | 87.4 | 91.4 | 93.6 |
| Loans to banks | 15 895 | 5.9 | 9.7 | 14.8 |
| Loans to nonbanks | 15 895 | 54.4 | 62.2 | 68.6 |
| Bonds | 15 895 | 11.5 | 16.6 | 23.1 |
| Liabilities included to total liabilities | 15 895 | 85.4 | 88.7 | 90.9 |
| Loans from banks | 15 895 | 10.0 | 14.4 | 19.6 |
| Loans from nonbanks | 15 895 | 30.1 | 35.6 | 41.7 |
| Subordinated debt | 15 895 | 0.0 | 0.0 | 0.8 |
| Savings accounts | 15 895 | 29.4 | 34.9 | 40.7 |

Notes: Summary statistics of the composition of the German savings and cooperative banks' assets and liabilities normalised to the banks' total assets. Time period: from 1999 to 2006.

## 5 Estimation results

We report the regression results for Equation (6). This equation was separately estimated for the assets with the normalised interest income, *i.e.*, interest income to total assets, as the dependent variable, and for the liabilities with the normalised interest expenses, *i.e.*, interest expenses to total liabilities, as the dependent variable. Please note that we additionally include as explanatory variables the coverage ratio of assets (*variable: assets included to total assets*) and the coverage ratio of liabilities (*variable: liabilities included to total liabilities*), respectively. The Hausman (1978) test clearly rejects the hypothesis of a random-effects model. We therefore estimate a fixed-effects regression with a heteroscedasticity robust covariance matrix.

Table 6 gives the estimation results for the interest income. In accordance with expectations, the estimated coefficients are all positive, but some of them differ considerably from 1. The estimated coefficients fit especially well for the positions 'Loan to nonbanks'; here the coefficients are close to 1. The explanatory power is satisfactorily high, as can be seen from the different coefficients of determination (R-squared); the overall R-squared is 73%.

The corresponding estimation results for the liabilities are shown in Table 7. As with the regression for the interest income, the coefficients are all positive, but differ from 1. The cross-sectional explanatory power (R-squared between) is a bit lower than in the case of the interest income (42.9% versus 62.9%).

**Table 6** Regression (assets)

| *Variable* | *Bracket* | *Coefficient* | *Stand. dev.* | *t-statistics* |
|---|---|---|---|---|
| Assets incl. to total assets | | –0.006 | 0.001 | –4.22 |
| Loans to banks | 1st | 0.573 | 0.024 | 24.16 |
| | 2nd | 0.438 | 0.024 | 18.52 |
| | 3rd | 0.609 | 0.027 | 22.54 |
| | 4th | 0.516 | 0.030 | 17.22 |
| Loans to nonbanks | 1st | 0.991 | 0.035 | 28.59 |
| | 2nd | 1.190 | 0.023 | 52.45 |
| | 3rd | 0.903 | 0.010 | 94.51 |
| Bonds | 1st | 0.555 | 0.173 | 3.21 |
| | 2nd | 0.761 | 0.105 | 7.25 |
| | 3rd | 0.587 | 0.012 | 49.74 |
| Constant | | 0.018 | 0.000 | 56.69 |
| R-sq: | Within | 0.824 | | |
| | Between | 0.629 | | |
| | Overall | 0.730 | | |
| Number of | Observations | 15 895 | | |
| | Groups | 2579 | | |
| Estimation | Fixed effects | | | |

Notes: Panel regression with fixed effects; dependent variable: interest income over total assets of German savings and cooperative banks; regressors: the bank's hypothetical interest incomes (normalised to the bank's total assets) from the different assets and maturity brackets. White's (1980) correction for the standard errors.

As mentioned above, real banks (from which we take the dependent variable of the regression) do not behave as passively as the tracking banks (from which we take the regressors). This deviation from the assumptions may result in misspecifications, for instance, in autocorrelated disturbances. Using a likelihood-ratio-test for first-order autocorrelation, we can clearly reject the hypothesis of serially uncorrelated disturbances. However, we decided to keep the model above for two reasons:

1 Estimating the model with first-order autocorrelation leads to the loss of one out of only eight years of observations.

2 Autocorrelated disturbances do not cause biases in the estimation of coefficients, but biases in the estimated covariance matrix.

As we are much interested in the coefficients and not so much in the standard deviations, the harm due to this misspecification is of minor importance.

**Table 7** Regression (liabilities)

| *Variable* | *Bracket* | *Coefficient* | *Stand. dev.* | *t-statistics* |
|---|---|---|---|---|
| Liabilities incl. to total liabilities | | 0.020 | 0.001 | 15.08 |
| Loans from banks | 1st | 0.604 | 0.068 | 8.94 |
| | 2nd | 0.480 | 0.033 | 14.48 |
| | 3rd | 1.177 | 0.111 | 10.60 |
| | 4th | 0.831 | 0.015 | 57.00 |
| Loans from nonbanks | 1st | 0.173 | 0.013 | 13.60 |
| | 2nd | 0.718 | 0.014 | 50.46 |
| | 3rd | 0.882 | 0.043 | 20.69 |
| | 4th | 0.839 | 0.021 | 39.91 |
| Subordinate debt | | 1.406 | 0.115 | 12.28 |
| Savings accounts | 1st | 0.696 | 0.008 | 88.91 |
| | 2nd | 0.531 | 0.013 | 40.58 |
| Constant | | 0.002 | 0.000 | 6.92 |
| R-sq: | Within | 0.864 | | |
| | Between | 0.429 | | |
| | Overall | 0.637 | | |
| Number of | Observations | 15 895 | | |
| | Groups | 2579 | | |
| Estimation | Fixed effects | | | |

Notes: Panel regression with fixed effects; dependent variable: interest expense over total assets of German savings and cooperative banks; regressors: the bank's hypothetical interest expenses (normalised to the bank's total assets) from the different liability and maturity brackets. White's (1980) correction for the standard errors.

We are primarily interested in the banks' net interest income. To see whether our method is a real improvement, we compare its in-sample explanatory power with two alternative models. The first alternative model consists in using the interest income of the strategies $S(12)$ and $S(60)$ as explanatory variables. This model is similar to the approach by van den End *et al.* (2006), who use a short-term and a long-term interest rate to explain the variation of large Dutch banks' interest income. Approaches like this are often used by supervisory agencies to determine the sensitivity of the banks' interest income to changes in short- and long-term interest rates. In our study, we do not use interest rates, but moving averages of interest rates. We do this because changes in interest rates not only affect the current interest income, but the future interest income as well, and we believe that moving averages capture this phenomenon better than interest rates alone,[12] especially when the bank follows a stationary business model. The second alternative model uses dummies for each year to capture the interest rate dynamics. This model is a generalisation of the two-investment-strategy model from above.

Let $R$ be the normalised net interest income of the real bank and let $\hat{R}$ be its in-sample estimate; we estimate the following fixed-effects panel regression:

$$R_{t,i} = \alpha + \beta \hat{R}_{t,i} + \varepsilon_{t,i} \tag{7}$$

where $j$ denotes the three different methods to be compared, *i.e.*, the method of using a tracking bank, of using the interest income of the two strategies $S(12)$ and $S(60)$, and of using year dummies.

Table 8 shows that the proposed method of using tracking banks leads to the best results. As we estimate Equation (7) to be a fixed-effects regression, there are three different coefficients of determination (in the following R-squared, R-sq). The within R-squared states how well the model can explain *changes* in the net interest income of a bank. The within R-squared for the tracking bank model is 28.4% and is much higher than the R-squared of the other two models (13.8% for the interest income and 19.1% for the year dummies). The between R-squared tells by how far the *cross-sectional variation* in the explanatory variables can explain the cross-section of the banks' net interest income. The tracking bank model is able to explain roughly one-fifth of the cross-sectional variation in the net interest income; the corresponding measures for the other two strategies are close to zero.[13] The overall R-squared is the squared correlation between the net interest income of the real bank and the fitted net interest income. This measure combines the *time series* and *cross-sectional* goodness of fit. The tracking bank model yields a goodness of fit measure of 22.3%, which is far above the fit for the other two models.

**Table 8** Goodness of fit

| *Method* | *R-sq within* | *R-sq between* | *R-sq overall* |
|---|---|---|---|
| Tracking bank | 0.284 | 0.195 | 0.223 |
| Interest income of the 2 strat. $S(12)$ and $S(60)$ | 0.138 | 0.019 | 0.028 |
| Year dummies | 0.191 | 0.022 | 0.036 |

Notes: Goodness of fit for three different methods of forecasting (in-sample) the banks' net interest income. R-sq (R-squared): Coefficient of determination of a panel regression of the actual net interest income on the predicted net interest income (see Equation (7)). Net interest income in this context is the bank's net interest income normalised to the bank's total assets.

We carried out the same analysis using interest rates instead of the corresponding moving averages, *i.e.*, the interest incomes of the strategies $S(T)$. The results were significantly in favour of the interest incomes of the strategies $S(T)$. In addition, we checked the out-of-sample forecasting ability of our model by using it to predict the banks' net interest income in year 2007. (These data were not available when we estimated the model as described in Equation (6)). We ran a regression of the banks' actual net interest income (in year 2007) on the predicted net interest income (comparable to Equation (7)); the R-squared was 0.241. For comparison, we made a new parameter estimation according to Equation (6), adding the 2007 data to the sample, and predicted (in-sample) the banks' net interest income for year 2007. The corresponding in-sample R-squared was 0.248. From this robustness check we conclude that the in-sample and the out-of-sample R-squared are comparable.

To sum up, to explain a banks' net interest income, it is recommendable to include the information contained in the monthly balance sheet statistics and to use moving averages of interest rates instead of the interest rates themselves.

## 6 Looking for the worst interest rate scenario

The common guess is that commercial banks 'borrow short and lend long'. Therefore, we expect that the banks' net interest income goes down if the interest rates increase. This guess need not be true, especially for relatively large banks. Flannery (1981), for instance, does not find any hint for term transformation in a sample of relatively large US banks.

We apply the tracking bank method to find out which interest rate scenario is most harmful to the banks. The measure of harm is the change in the standardised net interest income one year and two years after the interest rate shock.

The procedure is as follows: We assume that the yield curve is unchanged from August 2007 to December 2007. In January 2008, there will be a shock according to one of the 260 historical scenarios. After the shock, the yield curve is assumed to remain unchanged at the new level. For each of the 1636 tracking banks and each of the 260 interest rate scenarios, we calculate the net interest income for the year 2008 and the year 2009. These interest incomes are compared with the interest income in the case of no interest shock, the basis scenario, *i.e.*, we calculate the difference between the income in one of the shock scenarios and the one in the basis scenario. This procedure yields $1636 \times 260 = 425{,}360$ differences in net interest income. To condense the information, we apply two different criteria to find the worst scenario:

1. For each of the 260 scenarios, we calculate the median of the cross-sectional change in the net interest income that is caused by a scenario. The lower the median change in the net interest income, the worse the scenario is.
2. For each of the 1636 banks, we determine which of the 260 scenarios is the worst one in 2008 and in 2009. The more often a scenario is named as the worst one, the worse the scenario is.

Table 9 gives the median change in the net interest income for the five worst scenarios according to criterion 1. The scenarios are labelled according to the month in which the 12-month-period for the year-to-year-change ends. For instance, the scenario called *1989–05* consists of the changes in the interest rates that occurred from May 1988 to May 1989. The number –0.276, for example, in the third column of Table 9 states that the median standardised net interest income (= net interest income over total assets) goes down by 0.276 percentage points. From Table 3 we see that the median standardised net interest income is about 2.5%, *i.e.*, the median change due to the worst scenario causes a reduction of the net interest income by some 11%. Please note that the 260 shocks are overlapping and therefore not independent. This is why the five worst scenarios according to criterion 1 are clustered around spring 1989.

Whereas Table 9 makes a statement for the average (= median) tracking bank, it is important to know if a scenario that is identified as severe for the average tracking bank is severe for a large part of the banks as well. To answer this question, we identified the worst scenario for each bank, and we counted how often each scenario was identified as the worst one (criterion (2)). Table 10 shows the five scenarios that were most often found to be the worst ones.

**Table 9** Five worst scenarios, criterion 1

| Rank | *Net interest income 2008* | | *Net interest income 2009* | |
|---|---|---|---|---|
| | *Scenario* | *Change (median)* | *Scenario* | *Change (median)* |
| 1 | 1989–05 | –0.276 | 1989–05 | –0.338 |
| 2 | 1989–02 | –0.252 | 1989–02 | –0.285 |
| 3 | 1989–04 | –0.232 | 1989–04 | –0.280 |
| 4 | 1989–03 | –0.224 | 1989–03 | –0.253 |
| 5 | 1989–01 | –0.209 | 1989–01 | –0.252 |

Notes: Median change in the banks' standardised net interest income in percentage points for the five worst scenarios (out of 260 historical scenarios). The scenarios consist of historical year-to-year changes in the term structure of the interest rates; the scenarios are named according to the month of the year-to-year period's end. For instance, *1989–05* describes the year-to-year period from May 1988 to May 1989.

**Table 10** Five worst scenarios, criterion 2

| Rank | *Net interest income 2008* | | *Net interest income 2009* | |
|---|---|---|---|---|
| | *Scenario* | *No. of banks* | *Scenario* | *No. of banks* |
| 1 | 1989–05 | 1610 | 1989–05 | 1489 |
| 2 | 1992–11 | 7 | 2001–01 | 72 |
| 3 | 1989–02 | 6 | 1995–12 | 34 |
| 4 | 1989–03 | 4 | 1989–09 | 14 |
| 5 | 1993–03 | 4 | 1993–03 | 8 |

Notes: Number of banks for which the scenario named in the second column (year 2008) and in the fourth column (year 2009) leads to the worst change in the net interest income (out of 260 historical scenarios). The scenarios consist of historical year-to-year changes in the term structure of the interest rates; the scenarios are named according to the month of the year-to-year period's end. For instance, *1989–05* describes the year-to-year period from May 1988 to May 1989. There are 1636 German savings and cooperative banks in total.

According to both criteria, scenario *1989–05* is by far the worst. The year-to-year change in the interest rates for this scenario *1989–05* are shown in Figure 1.

The curve for the interest rate changes is relatively smooth. This smoothness is due to the fact that the Svensson method uses a function to approximate the actual yield curve.

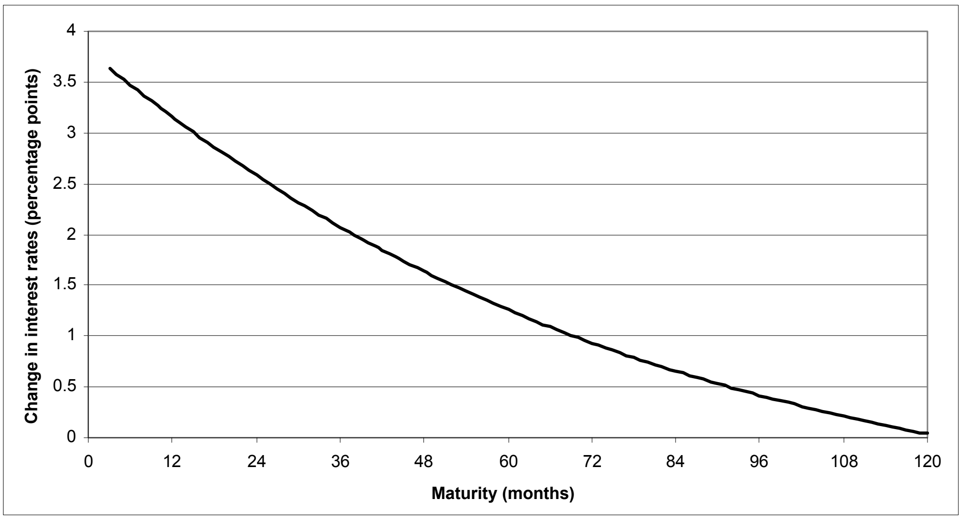
From Tables 9 and 10 as well as from Figure 1, we obtain the following statements concerning the severity of interest rate shocks:

- From an earnings perspective, the short term interest rates are crucial for the severity of interest rate shocks. The worst of the 260 scenarios is a sharp decrease in the steepness of the yield curve: whereas the three-month-rate goes up by more than three percentage points, the ten-year rate remains almost the same (see Figure 1).

- For nearly all of the tracking banks, and therefore presumably for nearly all of the real banks, the worst scenario is the same: a sharp decrease in the steepness of the term structure. For 1610 out of the 1636 tracking banks, the scenario *1989–05* has the most negative impact on the net interest income after one year.
- The effect of an interest rate shock is not restricted to the first year. It turns out that the effects become worse in the second year, as can be seen from Table 9. In addition, the effects become more dispersed and less uniform, as can be seen from Table 10.

Result 1 is not fully in line with the results of interest rate stress tests that apply the economic value perspective, as reported, for instance, in Deutsche Bundesbank (2006). When looking at the economic value, the changes in the interest rates of longer maturities are crucial, and the changes in the short-term rates are of secondary importance. It seems as though the earnings perspective and the economic perspective look at the interest rate risk from different angles: whereas the economic value perspective stresses the present value of the current holdings, the earnings perspective includes parts of the future business as well.[14] However, the earnings perspective puts the emphasis only on the near future, whereas the economic value perspective may give a more comprehensive picture of the bank's situation.

**Figure 1** Scenario 1989–05




Notes: Scenario *1989–05*, year-to-year interest rate changes (from May 1988 to May 1989) for different maturities. Underlying interest rates (zero-bond yields) derived from German government bonds.

## 7 Conclusion

The tracking bank approach of finding the worst interest rate scenario relies on several strong assumptions: for instance, that the tracking bank and the corresponding real bank are hit by an interest rate shock in the same way, and that the composition of the assets and liabilities of a bank remains constant throughout the interest rate shock. The concept of tracking banks is a purely hypothetical construct and one has to keep in mind that banks continuously rebalance their assets and liabilities depending on their market expectations and the competitive pressure around them. Moreover, we look only at the risk due to maturity mismatches, but we neglect the indirect effects of an interest rate change, such as increasing margins in times of a boom. Nevertheless, the tracking bank approach seems to give valuable insights into the sensitivity of the banks' interest income to different interest rate shocks. This approach, which only takes interest income from term transformation into account, is able to explain roughly 22% of the variation in the banks' net interest income. Surprisingly, practitioners estimate that term transformation is responsible for about 20% of the banks' net interest income. Future research can be directed at the question of whether these two figures coincide by chance, and the tracking bank approach can be used to estimate the portion of the interest income that is due to term transformation.

It seems that, for a large part of the German savings and cooperative banks, the same interest rate scenario has the worst impact on their interest income: a sharp decrease in the steepness of the yield curve, *i.e.*, the interest rates of longer maturities are of secondary importance, when looking at the next two years' net interest income. By contrast, when looking at the economic value of a bank, the interest rate changes in the longer maturities seem to be more important. Further work has to deal with the question of how to reconcile the economic value and the earnings perspective.

The results of this paper are especially relevant for supervisory authorities, because they are in a middle position concerning data availability: they do not have the exact data the banks have, but they have better data than are usually available to the public. With the help of the tracking bank approach and the data that are available to them, they can carry out (top-down) interest rate stress tests for each bank and the banking sector as a whole. Moreover, when the supervisory authorities design stress test scenarios, which are to be calculated by the banks (bottom-up stress tests), they can better calibrate the scenarios.

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