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Interest Rate Risk Rewards in Stock Returns of Financial Corporations: Evidence from Germany

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Abstract

The interest rate sensitivity of stock returns of financial and non-financial corporations is a well-known phenomenon. However, only little is known about the part of total stock returns that is attributable to the compensation an investor receives for being exposed to interest rate risk when investing in equity securities. We pursue here a benchmark portfolio approach, constructing benchmark portfolios having the same interest rate risk exposure as a particular stock. By studying the time series of returns of these asset-specific benchmarks, we find: i) Regardless of the industry considered, the interest rate risk benchmarks of German corporations have mostly earned a significantly positive reward. ii) Returns of interest rate risk benchmarks of financial institutions exceeded significantly those of non-financial corporations. iii) An investor willing to bear nothing but the average interest rate risk of German financial institutions would have earned a mean return of about or even exceeding 70% of the corresponding total stock returns. iv) Returns of the interest rate risk benchmarks of the German insurance sector

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were significantly higher than those of German banks, which seems to contradict conventional market wisdom that insurances hedge interest rate risks.

Keywords: *interest rate risk*, *risk rewards*, *Nelson-Siegel approach*, *German financial corporations*, *benchmark portfolio approach*

JEL classification: *G*12, *G*21, *G*22

1. Introduction

Financial institutions perform the economic role of being intermediaries in the allocation of capital between lenders and borrowers. For this reason, they hold predominantly nominal and often fixed-rate assets and liabilities, i.e. financial claims whose present value is directly determined by discount rates and thus by the term structure of interest rates. Based on this fact, the influence of changing interest rates on the market value of equity (i.e. the interest rate sensitivity) of financial institutions, and banks in particular, typically results from unmatched maturities of assets and liabilities, since borrowers tend to borrow longer-term while lenders often prefer being able to withdraw their deposits at short notice. As a consequence of this gap, market values of the asset side and of the liability side of a balance sheet may change differently following movements in the term structure leading to an influence on equity values (Hirtle, 1997, Staikouras, 2003).

However, the phenomenon of interest rate sensitivity is not limited to financial institutions. Insofar as non-financial corporations do hold financial (i.e. nominal) assets and liabilities such as accounts payable and accounts receivable, bank loans, and pension reserves, changes in the term structure potentially affect their equity values as well. Additionally, by influencing the cost of capital, movements in the term structure may influence investment decisions and thus future cash flows.[1]

There is a vast literature investigating the interest rate sensitivity of (mainly but not exclusively financial) corporations, the majority of which employs variants of the two-factor model proposed by Stone (1974).[2] Although some authors find no or at the most weak evidence of this interest rate sensitivity and assume this finding to result in part from a prevalent use of interest rate risk management tools (see, e.g., Allen and Jagtiani, 1997, and Maher, 1997), a significant interest rate sensitivity has been mostly confirmed in other recent empirical studies. These include Madura and Zarruk (1995), Oertmann *et al.* (2000), and Bessler and Murtagh (2004), who compare the interest rate sensitivity of financial institutions in an international context; Faff and Howard (1999) for Australia; Dinenis and Staikouras (1998, 2000) for the UK; Elyasiani and Mansur (1998, 2004), Tai (2000), Fraser *et al.* (2002), and Brewer *et al.* (2007) for the USA, and, for the German stock market also investigated in this paper, Bartram (2002), Bessler and Opfer (2003, 2005), Behr and Sebastian (2006), and Scholz *et al.* (2008).

Due to the plentitude of fixed-income products available, in principle, even private investors are able to create an interest rate risk exposure that suits their personal risk preferences. Now, since there is empirical evidence that both financial and non-financial corporations apparently do not entirely hedge their interest rate risks, we take here an investor's perspective and assume that, much in the spirit of Modigliani and Miller

[1] Bartram (2002) discusses the relevance of interest rate risks for non-financial corporations.

[2] Staikouras (2003, 2006) provides an extensive review of theoretical and empirical evidence on this subject.

(1958), our investor is about to create his own homemade interest rate risk exposure. Let's assume that, when investing in the stocks of (financial) corporations, the shareholder is not willing to bear any associated interest rate risk at all. The question we ask is, what return does an investor sacrifice by hedging the interest rate risk exposure of a particular corporation? Or, laterally reversed but maybe more straightforward, what is the compensation a shareholder should expect to receive for being exposed to the risk of a changing term structure (we call this the 'interest rate risk reward') when investing in equity securities?

Our research is related to the question of whether interest rate risk is priced in the stock market. This issue has been extensively investigated and mostly confirmed in the context of APT models both for stock markets in general (see, e.g., Chen *et al.*, 1986, for the USA and Bessler and Opfer, 2003, for Germany) as well as for samples consisting of financial institutions only (see, e.g., Tai, 2000, for US banks and Staikouras, 2005, for UK financial intermediaries). Based on estimated interest rate risk sensitivities and factor risk premia, an asset-specific reward for being exposed to a particular risk factor could be easily calculated in an APT context (see, e.g., Chan *et al.*, 1985, and Chang and Pinegar, 1990). Still, little is known about what the reward for their interest rate risk exposure actually contributes to the total stock returns of financial corporations, a notable exception being Dinenis and Staikouras (2000), who document that interest rate risk rewards contribute up to 40% of average expected returns of UK insurance companies.

However, we do not apply a standard APT model which – in its unbiased one-step estimation approach[3] – would have an *ex post* perspective by construction. Instead, we contribute to the extant literature by proposing an *ex ante* benchmark portfolio approach to estimate the interest rate risk rewards in stock returns. This approach relates to the literature on mutual fund performance measurement (see, e.g., Sharpe, 1992). In this respect, we construct a pure fixed-income portfolio having the same interest rate risk exposure as a particular corporation. The fundamental assumption underlying this approach is that the same systematic risk should have the same price in different segments of the capital market. Thus, if this assumption holds true, by studying the time series of returns of such an interest rate risk benchmark of a firm, we are able to obtain an estimate of the reward shareholders should expect to receive to compensate them for the interest rate risk exposure of this firm. Consistent with our investor's perspective, this benchmark portfolio approach allows us to adopt a more realistic *ex ante* approach to estimate interest rate risk rewards which accounts for possibly changing exposures of firms to term structure movements.

In contrast to the literature on mutual fund performance measurement, we do not attempt to measure whether a particular corporation generates a positive 'alpha', i.e. a risk-adjusted excess return or, simply, shareholder value. Our goal is to quantify i) the reward an investor should receive for being exposed to interest rate risk when investing in equity securities and ii) the contribution of this interest rate risk reward to total shareholder return in order to assess the relevance of interest rate risks for stock returns.

Thus, by studying a broad sample of German financial and non-financial corporations, our paper bridges a gap left open by studies investigating either the influence of interest

[3] Classical two-step estimation of APT models may suffer from the well-known 'errors-in-variables' problem, see, e.g., Staikouras (2005). Since with a one-step estimation procedure, factor sensitivities and risk premia are jointly estimated, this approach has by necessity an in-sample and thus *ex post* perspective.

rate risk on stock return variability or the pricing of interest rate risks in the stock market. The main contribution of our empirical analysis is that, particularly in the case of financial institutions, a large part of total shareholder returns might have been earned directly in the bond market, leading to the question of whether investors should buy equities if they actually receive a bond market exposure.

This paper proceeds as follows. Our research hypotheses are formulated in the following Section 2. In Section 3, we discuss methodological aspects of this study. The data set employed in the empirical analysis will be described in Section 4. Our empirical findings are discussed in Section 5. Section 6 offers concluding remarks.

2. Research Hypotheses

All else being equal, any upward shift in the term structure of interest rates leads to lower discount factors and falling present values of a time series of future cash flows. For this reason, equity values, being the present value of future free cash flows to shareholders, should generally be negatively affected by rising interest rates. Indeed, the vast majority of studies investigating the interest rate risk exposure of firms finds a significant influence of term structure movements on the market value of equity. If this effect is additionally not diversifiable due to its general and market-wide influence on equity values, shareholders must be offered a reward for being exposed to the risk of rising interest rates. Therefore, our first research hypothesis can be formulated as follows.

H1: The interest rate risk rewards investors should receive when investing in the equity securities of banks, insurances, and non-financial corporations are positive on average.

However, the management of financial risks is a key business of financial institutions where interest rate-related business (still) accounts for a major part of total income. While relevant, movements in the term structure of interest rates should be of a lesser importance to non-financial corporations. We thus hypothesise for non-financial corporations:

H2: The reward shareholders should receive to compensate them for the interest rate risk exposure of non-financial firms is lower than the respective reward for an investment in financial institutions.

Both banks and insurance companies can be understood as risk transformers. While insurance companies are mostly assumed to match assets and liabilities in an attempt to avoid an influence of term structure movements on equity values (Scott and Peterson, 1986, Briys and de Varenne, 1997) banks are commonly engaged in maturity transformation, i.e. the financing of long-term assets with short-term liabilities. As Bhattacharya and Thakor (1993, p. 29) state: ‘The bank’s gain from maturity transformation is twofold: i) a reward for bearing interest rate risk and ii) a reward for the creation of liquidity.’ In view of the on average positive slope of the term structure, banks should therefore be able to profit the most from interest rate risks. The last hypothesis investigated in this study is hence:

H3: The reward shareholders should receive to compensate them for the interest rate risk exposure of banks is larger than the respective reward for an investment in insurance companies.

3. Methodology

In order to consistently measure the interest rate risk associated with an equity investment, it is necessary to quantify an asset's exposure to changes in the entire term structure of interest rates. In the following sections, we discuss such an approach based on the Nelson and Siegel (1987) model to fit the term structure. This model is briefly discussed in Section 3.1. In order to quantify the interest rate risk of asset returns, we proceed by calculating the sensitivities of asset returns to changes in the factors of the Nelson-Siegel approach (Section 3.2), which can be shown to model the drivers of term structure changes. However, where future asset cash flows are not known with reasonable certainty, these sensitivities must be estimated from historical data (Section 3.3). In the last subsection, we present how benchmark portfolios having the same interest rate risks as a target asset are constructed.

3.1. *The Nelson and Siegel (1987) approach to model the term structure*

Nelson and Siegel (1987) proposed a parsimonious model to fit the term structure which describes the yield of a zero bond, $s_t(m)$, with time-to-maturity m at time t as a function of four parameters L_t, S_t, C_t and τ_t. This model is sufficiently rich to capture upward sloping and downward sloping term structures combined with either concave or convex patterns and fits a single 'hump' (i.e. a local maximum/minimum caused by an inflexion point) as well (see Diebold and Li, 2006).

$$s_t(m) = L_t + S_t \frac{1 - \exp(-m/\tau_t)}{m/\tau_t} + C_t \left(\frac{1 - \exp(-m/\tau_t)}{m/\tau_t} - \exp\left(-\frac{m}{\tau_t}\right)\right) \qquad (1)$$

Willner (1996) and Diebold and Li (2006) discuss the economic intuition of these four factors. As they show, L_t models the level of the term structure of interest rates since the (implicit) loading of the spot rates $s_t(m)$ on L_t is independent of the time-to-maturity m. Hence, any change in this factor affects all spot rates equally and thus causes a parallel or a level shift of the term structure. Taking limits of Eq. (1), we obtain the long rate, $\lim_{m\to\infty} s_t(m) = L_t$, and the short rate, $\lim_{m\to 0} s_t(m) = L_t + S_t$, of the term structure. Defining the difference between the long rate and the short rate as the slope of the term structure, we find $-S_t$ to model the slope. C_t applies particularly to medium-term rates since the loading of spot rates on this factor, $(1 - \exp(-m/\tau_t))/(m/\tau_t) - \exp(-m/\tau_t)$, decays to zero for both short-term and long-term values of m and obtains a maximum for medium-term rates. Thus any change in C_t alters the curvature of the term structure. Finally, τ_t governs the decay of the exponential functions in Eq. (1). Low (high) values of this factor lead to a faster (slower) decay of the exponential functions in Eq. (1) and a lower (higher) value of m for which the loading of spot rates on the curvature factor achieves a maximum. However, in contrast to the other three factors, τ_t lacks a direct economic interpretation.[4]

The interpretation of the factors L_t, S_t, and C_t of the Nelson and Siegel (1987) approach as level, slope, and curvature of the term structure corresponds to the findings

[4] For economic as well as econometric reasons that will become clear in Section 4, we follow standard practice and fix τ_t at a prespecified and time-constant value (see, e.g., Barrett *et al.*, 1995, Willner, 1996, Diebold *et al.*, 2006, and Diebold and Li, 2006). Hence, the subindex t of this parameter will be ignored.

of Litterman and Scheinkman (1991) and Bliss (1997) who, using a factor-analytical approach, also find changes in the term structure to be largely driven by just three factors which they interpret as a level, a slope, and a curvature factor. Thus the Nelson and Siegel (1987) approach is consistent with these findings and allows one to rely on the underlying factors driving term structure movements.[5]

3.2. *Measuring the interest rate risk exposure of bonds*

To overcome the restrictive assumptions of the classical duration framework, Willner (1996) and Diebold *et al.* (2006) proposed a model which integrates the Nelson and Siegel (1987) approach into the key rate duration framework suggested earlier by Ho (1992). Consider a series of (credit risk free) cash flows occurring in $m = 1, \ldots, T$ periods where the present value, P_t, of this series at time t follows by discounting the relevant payments at the respective corresponding spot rates, $s_t(m)$. Let $D(m)$ denote the sensitivity of P_t to changes in the m-period spot rate which follows by differentiating P_t with respect to $s_t(m)$ and dividing the result by P_t.

$$D(m) \equiv -\frac{\partial P_t/\partial s_t(m)}{P_t} \tag{2}$$

As shown by Willner (1996) and Diebold *et al.* (2006), the sensitivities of P_t to changes in level, slope, and curvature or — synonymously — the level, slope, and curvature durations D_L, D_S, and D_C follow from (1) and (2) as

$$\begin{aligned} D_L &\equiv \sum_{m=1}^{T} D(m), \\ D_S &\equiv \sum_{m=1}^{T} D(m)\left(\frac{1-\exp(-m/\tau)}{m/\tau}\right), \quad \text{and} \\ D_C &\equiv \sum_{m=1}^{T} D(m)\left(\frac{1-\exp(-m/\tau)}{m/\tau} - \exp\left(-\frac{m}{\tau}\right)\right). \end{aligned} \tag{3}$$

Based on (3), the relative change in the present value P_t of this time series of cash flows given a possibly non-parallel change of the term structure can be approximated by multiplying level, slope, and curvature durations by the changes in the corresponding factors and summing over the products. Willner (1996) shows that (4) becomes exact for independent and infinitesimal changes.

$$\frac{\Delta P_t}{P_t} \approx -(D_L \Delta L_t + D_S \Delta S_t + D_C \Delta C_t) \tag{4}$$

Willner (1996) and Diebold *et al.* (2006) employ level, slope, and curvature durations as measures of interest rate risk and compare this method to classical (modified) duration in the context of bond risk management. Both empirical studies find a superior performance of level, slope, and curvature-based hedging, which supports the notion that

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[5] Although the Nelson and Siegel (1987) specification corresponds to findings from factor-analytical approaches and is widely used in practice, Filipović (1999) shows that no stochastic term structure model is consistent with this specification.

this three-factor method is indeed better suited to capture the interest rate risk exposure of assets than classical (one-factor) durations when future cash flows are known.

3.3. *Measuring the interest rate risk exposure of stocks*

Since future cash flows of stocks are highly uncertain, we cannot calculate the level, slope, and curvature durations based on (3). Therefore, we estimate the sensitivities of stock returns (i.e. their empirical durations, see Reilly *et al.*, 2005) to changes in level, slope, and curvature of the term structure from historical data.[6] To this end, we specify the following regression model, which is the empirical counterpart to (4), except for an additional fourth factor which controls for general risk factors impacting the stock market which are not captured by term structure changes.

$$R_{i,t} = \alpha_i + \beta_{i,L}\,\Delta L_t + \beta_{i,S}\,\Delta S_t + \beta_{i,C}\,\Delta C_t + \beta_{i,M} R^{\perp}_{M,t} + \varepsilon_{i,t} \tag{5}$$

$R_{i,t}$ is the return of an asset i at time t. The error term $\varepsilon_{i,t}$ denotes the part of the stock return at time t not explained by the regressors where α_i is the sample mean of the errors. The estimated coefficients $\beta_{i,L}$, $\beta_{i,S}$, and $\beta_{i,C}$ represent the empirical level, slope, and curvature durations of the i-th asset. Necessarily, the empirically estimated durations relate to a certain time period and are therefore an average of the true but unknown sensitivities during that period.[7] In contrast, the analytically calculated or numerically determined durations are valid for a precise point in time. To be meaningful, we need to assume that the interest rate risk exposure of corporations does not change entirely over short periods of time. While multicollinearity of the regressors in Eq. (5) could be potentially harmful, we will show in Section 4 that their correlations are not so strong that problems caused by multicollinearity are likely to be present. The residual market factor, $R^{\perp}_{M,t}$, constitutes the residuals of an auxiliary regression of a broad stock market index on the three interest rate risk factors. The intention here is to control for market risk beyond interest rate risk (see, e.g., Akella and Greenbaum, 1992, and Fraser *et al.*, 2002). However, since the residual market factor is uncorrelated to the term structure factors by construction, the inclusion of this factor has no implications for the estimated sensitivities to changes in the term structure.

Eq. (5) builds on Stone (1974), who extended the basic market model by including an interest rate risk factor. However, there are two main differences compared to Stone's model. First, since we are solely interested in interest rate effects, we employ the residual market factor instead of a 'classical' market factor since the latter would already capture the general influence of term structure changes on the entire stock market. Second, we

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[6] Since we estimate interest rate sensitivities based on historical stock returns, we measure the net effect of interest rate changes comprising all interest rate-sensitive positions of a company. For financial institutions, the maturity gap precipitated by their role as maturity intermediary (which borrows short and lends long) may have a strong impact on the overall net position. However, the resulting negative interest rate sensitivity will be more or less heightened or countervailed by other positions. For example, assuming that the spread between interest rates for loans and deposits is positive, Hasan and Sarkar (2002) show that interest rate changes will have an opposite effect on the value of *loans in place* and on *potential loans*. Therefore, a banks' option to lend might at least partly countervail the interest rate sensitivity resulting from their nominal asset-liability maturity mismatch.

[7] See Sharpe (1992) for a similar argument in the context of mutual fund performance measurement.

specify three interest rate factors where Stone's model incorporates only one. When this interest rate factor constitutes changes in a single interest rate,[8] the similarity to classical duration analysis of this one-(interest rate) factor approach becomes evident.

3.4. *Construction of benchmark portfolios*

Based on the methodology presented in the last two subsections, the basic idea pursued in this section is to construct a benchmark portfolio having the same interest rate risk exposure as a particular firm. Our approach implies the assumption that two portfolios having an identical systematic risk exposure will earn the same return.

Since we take here the point of view of an investor, who typically has limited access to the internal data of a firm, we estimate the interest rate risk exposure of a company using the regression model presented in Eq. (5). One could run a single regression over the total sample period in order to determine the average interest rate risk exposure a company had during this period. Based on this estimate, one would observe the benchmark return in-sample, i.e. for the same period where the interest rate risk exposure had been estimated. We believe this *ex post* view to be unrealistic. Instead, consistent with the external perspective of this study, we choose a more realistic *ex ante* approach where the interest rate risk exposure of a company is estimated over a relatively short window and the return of the benchmark will be observed for a subsequent period, i.e. out-of-sample. The time-series of benchmark returns follows by sequentially rolling the estimation window over the total sample period. This procedure offers the additional advantage that we better account for the possibly non-constant interest rate risk exposures which have been documented by, e.g., Kane and Unal (1988), Kwan (1991), and Maher (1997).

In order to obtain a realistic picture of the reward an investor should expect to earn because of the interest rate risk associated with a particular investment, we must exclude the possibility that benchmark returns are influenced by risks other than movements in the term structure. The problem associated with using, e.g., government bond indices as base assets from which to construct the benchmark portfolios is that factors such as options included in bond prices, non-constant durations of the indices, or simply (although admittedly marginal) credit or liquidity spreads influence the returns. Therefore, following Ehrhardt (1991), we choose fictitious zero bonds as base assets whose (one-period) holding period returns, $R_t(m)$, for an assumed revolving investment in a bond of a time-to-maturity of m periods, follow directly from the term structure as estimated in Eq. (1) (see Campbell *et al.*, 1997). This allows us to reduce idiosyncratic or non-interest rate risk influences to a minimum.

$$R_t(m) = \frac{(1 + s_t(m-1))^{-(m-1)}}{(1 + s_{t-1}(m))^{-m}} - 1 \tag{6}$$

In the subsequent empirical analysis, holding period returns of zero bonds with fixed maturities of one, five, and ten years will be employed. Having three zero bonds as base

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[8] For a similar specification of the interest rate factor see, e.g., Madura and Zarruk (1995), Dinenis and Staikouras (1998), Oertmann *et al.* (2000), and Fraser *et al.* (2002). Other studies including, e.g., Bessler and Murtagh (2004) employ bond returns as the interest rate factor. While this approach to specify the interest rate factor does not allow one to interpret the regression coefficient in terms of duration, Scholz *et al.* (2008) demonstrate that it leads to a similar – though differently defined – assessment of the interest rate risk of the investigated stock.

assets and three conditions to match (i.e. the sensitivities of a particular asset to changes in level, slope, and curvature), the weights of the benchmark portfolio can easily be determined analytically.[9, 10] To sum up, for each stock i at time t in our sample, we conduct the following four-step procedure.

1. Eq. (5) is estimated for a window ranging from $t-60$ to $t-1$ in order to obtain proxies of the i-th stock's empirical level, slope, and curvature duration at time $t-1$, yielding a three-dimensional column vector $\hat{\boldsymbol{D}}_{i,t-1}$.
2. Using Eq. (3), level, slope, and curvature durations for the base assets are calculated for time $t-1$, yielding a (3×3) matrix $\boldsymbol{D}_{ZB,t-1}$ where the base assets are listed in the columns and the respective durations in the rows.
3. The system of equations $\boldsymbol{D}_{ZB,t-1}\boldsymbol{w}_{i,t-1} = \hat{\boldsymbol{D}}_{i,t-1}$ is solved for the three-dimensional column vector $\boldsymbol{w}_{i,t-1}$ which contains the interest rate risk benchmark portfolio weights of asset i at time $t-1$.
4. The out-of-sample return of the ith asset's interest rate risk benchmark portfolio, $BP_{i,t} = \boldsymbol{w}'_{i,t-1}\boldsymbol{R}_{ZB,t}$, over the period from $t-1$ to t is recorded where $\boldsymbol{R}_{ZB,t}$ contains the holding period returns of the base assets over this period.[11]

4. Data

We examine here a sample of German financial and non-financial corporations ranging from January 1978 to December 2002. Throughout this paper, we use monthly discrete returns in excess of the one-month German interbank rate.[12] This implies that return sensitivities are adjusted for the sensitivity of the one-month rate to term structure changes. Given an initial period of 60 months to construct the first benchmark portfolio, we observe a 20-year period of interest rate risk benchmark returns starting in January 1983.

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[9] Willner (1996) uses a similar approach to construct what he calls duration-replicating portfolios.

[10] Alternatively, we could have used more than just three base assets, in which case an infinite number of solutions would exist that match the condition of having the same level, slope, and curvature duration. Hence, one would have to proceed by choosing the solution that optimises a target function such as minimal portfolio weights (i.e. maximal diversification) or minimal unexplained portfolio variance (see, e.g., Diebold *et al*., 2006). As a robustness check, we employed such an approach using seven zero bonds. However, this did not improve our results significantly, which is explained by the fact that the base assets employed in this study are – by construction – (almost) free of idiosyncratic or non-interest rate risk influences.

[11] This procedure is somewhat similar to Sharpe (1992) who uses a related approach in order to analyse the performance of mutual funds from an investor's point of view as well. However, while it is Sharpe's intention to evaluate a fund's style, i.e. its performance related to investing in several broad indices, we only aim at quantifying the return that should be associated with the estimated interest rate risk exposure of a firm. Additionally, Sharpe excludes negative weights in his portfolio construction process since mutual funds are usually prohibited from levering. This implies that he has to rely on a quadratic programming approach to calculate his portfolio weights. In contrast, since the liability side of a corporation normally consists to a notable extent of debt, we do not have to exclude negative weights.

[12] We use one-month FIBOR and one-month EURIBOR before and after the introduction of the Euro, respectively. Both time series are available from the time series database of the Deutsche Bundesbank.

4.1. *Fixed-income*

We use end-of-month bond price quotes provided by the German capital market database of the University of Mannheim to estimate the German term structure of interest rates. For consistency reasons with benchmark data provided by the Deutsche Bundesbank, we only include bills, notes, and bonds issued by the Federal Republic of Germany. For the same reason, we exclude any securities with a time-to-maturity of less than three months (see Deutsche Bundesbank, 1997).

Studies by, e.g., Nelson and Siegel (1987), Barrett *et al.* (1995), and Willner (1996) as well as our own calculations have shown that the fit of Eq. (1) is relatively insensitive to the value of τ_t. Therefore, following standard practice, we fix the value of the decay parameter to a time-constant value of 1.5627.[13] Fixing τ offers two advantages: i) Eq. (1) can be solved using standard OLS instead of a non-linear optimisation approach and ii) an intertemporal comparison of the slope and the curvature factor is facilitated since loadings on these factors are independent of time t.

Eq. (1) has been estimated as suggested by Diebold and Li (2006). First of all, in order to obtain initial estimates of the left-hand side of Eq. (1), we apply the well-known iterative procedure of Fama and Bliss (1987) to extract zero bond yields directly from the prices of the coupon bonds selected according to the criteria described for a given point in time t. Then, for all time-to-maturities m corresponding to the bonds available in t and using the value of 1.5627 for τ, the values of the regressors (i.e. the loadings of spot rates on the factors of Eq. (1)) are calculated. Finally, the previously calculated 'Fama-Bliss zero yields' are regressed on the loadings from Eq. (1) and a constant to obtain estimates of the parameters L_t, S_t, and C_t. This procedure is applied for every month t in our sample period.

In Table 1 we present descriptive statistics for the estimated Nelson-Siegel factors. We find the average spot rate curve to have a positive slope of approximately 170 basis points. The negative curvature parameter has two effects. First of all, the concave shape of the term structure determined solely by the slope factor is reduced and, second, an inflexion point is induced for a time-to-maturity of about 2.25 years. Thus, for maturities shorter than this, the average term structure is (slightly) convex, whereas for longer maturities it is concave.

Table 2 contains descriptive statistics of 60-month rolling correlations between changes in the factors of the Nelson and Siegel (1987) model where the windows

[13] The value of 1.5627 for τ_t is the mean value of the time series of optimised τ-values resulting from a tentatively investigated non-linear optimisation of Eq. (1) over the sample period. This value is reasonably close to the value of 1.3683 used by Diebold and Li (2006) (note that the authors use a reciprocal definition of the decay parameter and a time-to-maturity measured in months) and the value of 3 suggested by, e.g., Barrett *et al.* (1995) and Willner (1996) but leads to a slightly better fit for our data set. In order to give a rough indication of the magnitude of the error caused by constraining the value of τ, we compared goodness-of-fit measures for both the constrained and of the fully optimised model. On average, the Mean Absolute Error (between, on the one hand, the extracted 'Fama-Bliss zero yields' and, on the other hand, the estimated term structure for a given point in time) of the constrained model is only 2.2 basis points higher than the MAE of the fully optimised model over the entire sample period – which seems negligible compared to, e.g., an average long-term yield of about 7.5%.

Table 1

Descriptive statistics, Nelson-Siegel factors

We use the Nelson and Siegel (1987) approach to estimate the term structure of interest rates using end-of-month 'Fama-Bliss zero yields' as input data which are calculated from securities issued by the German government. The model is based on equation (1), $s_t(m) = L_t + S_t(1 - \exp(-m/\tau))/(m/\tau) + C_t\,((1 - \exp(-m/\tau))/(m/\tau) - \exp(-m/\tau))$, with τ_t fixed at 1.5627. L_t denotes the level of the term structure of interest rates, S_t is its slope, C_t its curvature, and τ_t is an decay factor for the period t where $s_t(m)$ is the previously determined 'Fama-Bliss zero yield' of a time-to-maturity of m periods measured in years. For each estimated factor, the table contains descriptive statistics (mean, standard deviation, minimum, and maximum) of the respective time series of estimates. All values are stated in %, thus 1 denotes 1%. The sample period is 1978:01 to 2002:12.

Factor	Mean	Std. Dev.	Minimum	Maximum
L_t (Level)	7.486	1.156	4.987	10.352
S_t (Slope × (−1))	−1.682	2.055	−5.278	4.207
C_t (Curvature)	−1.552	2.394	−6.348	3.367

Table 2

Rolling 60-month correlations of changes in Nelson-Siegel factors

Rolling 60-month correlations and Variance Inflation Factors of monthly changes in the factors of the Nelson and Siegel (1987) approach in Eq. (1) are calculated. L_t denotes the level of the term structure of interest rates, S_t is its slope, and C_t its curvature. The first window ranges from 1978:01 to 1982:12, the last one from 1997:12 to 2002:11, and windows are sequentially advanced by one month (a total of 240 observations). The Variance Inflation Factor (VIF) for a given factor is calculated as $1/(1 - R^2)$ where the R^2 results from a regression of this factor on the other two respective factors. A VIF of 1 signals linear independency. The table reports descriptive statistics (mean, standard deviation, minimum, and maximum) for each time series of pairwise calculated rolling correlations of changes in the factors of the Nelson and Siegel (1987) approach (columns 2–4). Likewise, the same descriptive statistics are given for the Variance Inflation Factors of these factors in columns 5–7.

	Correlations			Variance Inflation Factors		
	$\rho(\Delta L_t;\Delta S_t)$	$\rho(\Delta L_t;\Delta C_t)$	$\rho(\Delta S_t;\Delta C_t)$	VIF(ΔL_t)	VIF(ΔS_t)	VIF(ΔC_t)
Mean	−0.505	−0.351	0.036	1.947	1.727	1.231
Std. Dev.	0.213	0.127	0.159	0.765	0.757	0.131
Max.	−0.082	−0.141	0.254	3.857	3.661	1.567
Min.	−0.850	−0.570	−0.306	1.079	1.017	1.030

correspond to the time periods for which Eq. (5) will be estimated.[14] On average, we find an increase in the level of the term structure of interest rates to be accompanied by a steeper term structure and a reduction in concavity, all else being equal. The maximum variance inflation factors are always well below the critical value of ten, indicating that problems caused by multicollinearity are unlikely.[15]

[14] Of course, since the residual market factor in Eq. (5) is constructed to be uncorrelated with the interest rate risk factors, we refrain from including this factor in Table 2.

[15] See, e.g., Kennedy (2003, p. 213). Additionally, since multicollinearity affects mainly the standard errors of estimated coefficients, whereas we do not evaluate the significance of the sensitivities in Eq. (5), even the partly observed, relatively high (absolute) correlation coefficients do not pose a problem for our results.

For expository purposes, we further use the monthly total return time series of German government bond indices (GBI) calculated by J.P. Morgan. These indices are subdivided into the maturity classes 1–3, 3–5, 5–7, and 7–10 years and are available from January 1987 to December 2002.

4.2. *Equities*

The data set investigated here consists of a sample of 48 German financial institutions with data available from Datastream. The respective company names are listed in the appendix. In addition, to form a control group, we select 145 non-financial companies that, at any point in time prior to the end of our sample period in 2002, were included in either the German large or mid-cap index, DAX or MDAX.[16] Total returns are used, i.e. stock prices are adjusted for dividends and stock splits.[17] Finally, we employ the comprehensive German DAFOX index as the market factor which is calculated by the University of Karlsruhe for academic purposes.

Along the lines suggested in, e.g., Dinenis and Staikouras (1998), Elyasiani and Mansur (1998), Fraser *et al.* (2002), Behr and Sebastian (2006), and Brewer *et al.* (2007), we start by analysing individual company data grouped according to industry affiliation, i.e. into a bank, insurance, or non-financial portfolio, which are all equally weighted. Since German banks are quite heterogeneous, both with respect to business activities and scope, we additionally construct an international, a regional, and a mortgage bank portfolio. The international bank portfolio consists of the largest banks in our sample that conduct both commercial and investment banking and have an international dimension to their business activities. The regional bank portfolio often contains much smaller banks that are mostly more focused both with respect to the geographical extension of their business and the array of banking services offered. Mortgage banks have the most narrow focus regarding the banking services performed since, until recently, they have been limited by law to real estate and public financing and to the issuance of '*Pfandbriefe*', i.e. a sort of mortgage-backed security as a means of refinancing. Because of this narrow focus on traditional (interest rate-related) banking business consisting of lending and borrowing, we might expect interest rate risk rewards to dominate total stock returns of mortgage banks while for international banks, due to the variety of services performed besides classical banking business, interest rate risk rewards might be much less prominent. Regional banks could be expected to be somewhere in between the other two groups. However, we need to take account of a possibly offsetting effect. Exactly because of the narrow focus on lending and borrowing with few opportunities to diversify, mortgage banks are possibly forced to limit their interest rate risk exposure rather strictly. Much in contrast, international banks may have better access to global capital markets and especially to the derivatives market because of their size and

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[16] See the list of companies provided in Deutsche Börse Group (2005, pp. 3–4 and 6–8) for details.

[17] Until recently, a squeeze-out of remaining shareholders was not possible following an acquisition or a merger of a company in Germany. Occasionally, firms remained listed after such a transaction for this reason but the very low free float did not allow for liquid trading of the respective stock. For this reason, if we observed signs of illiquidity in the time series of stock returns (such as, e.g., extended periods without price changes) following an acquisition, we excluded the stock for the proceeding periods. Additionally, in cases where data was missing for a company, the respective stock was also excluded for these periods.

reputation. While, in principle, derivatives might be used to control the interest rate risk stemming from the banking book, Hirtle (1997) finds evidence that increases in the use of derivatives correspond to the more pronounced interest rate sensitivity of US banks. Thus it might be possible that large banks use their better access to the derivatives market to effectively increase their interest rate risk exposure.

As Bartram (2002) points out, studying only those firms which have complete data over the total sample period might cause a survivorship bias. This effect might be induced by firms that had a particularly high interest rate risk exposure (i.e. whose shareholders should have been rewarded with particularly high interest rate risk rewards, all else remaining equal) and which might not have existed for the entire sample period because of these high risk exposures.[18] If stock portfolios are examined, this bias can be avoided if, for any period of time, all companies having data for the respective period are included in the portfolio as suggested in, e.g., Elyasiani and Mansur (2004) and Brewer *et al.* (2007). This means that the number of companies included in a portfolio changes over time if firms are acquired, merge, fail, or are newly listed.

As noted by, e.g., Elyasiani and Mansur (1998) and Brewer *et al.* (2007), a further advantage of studying portfolios instead of individual stock data is that idiosyncratic noise affecting stock returns is averaged out and thus produces more reliable results. However, one faces the trade-off that possible differences within an industry are masked. For this reason, as suggested in Bartram (2002), we additionally analyse individual company data and compare the results to those obtained from studying portfolios.

We choose two different subsamples from all companies selected for this study. The first sample consists of all companies having complete data over the total sample period. Hence this sample is consistent over time but is subject to survivorship bias. Additionally, we select all those companies to form a second subsample that, in an attempt to guard against outliers, fulfill a minimum data-length requirement of at least 120 periods of data resulting in at least 60 months of observable benchmark returns given an initial period of 60 months to set up the first benchmark portfolio. Obviously, this second sample is subject to influences of market climates but reduces a possible survivorship bias. In order to check the robustness of our results, we run the relevant analyses for each sample separately.

5. Empirical Results

5.1. *Bond indices*

If a benchmark portfolio reliably mimics the characteristics of a particular asset with respect to its exposure to systematic risk sources, it is expected to earn the same return as the investigated asset. In order to evaluate the robustness of our methodology, we start by investigating the returns of German government bond indices. Since returns of these

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[18] The way to deal with a possible survivorship bias in the selection of sample companies is a highly debated topic in the relevant literature. Elyasiani and Mansur (1998), Bartram (2002), and Brewer *et al*. (2007), among others, provide discussions of the subject. However, each of these studies chooses a different approach to this problem. While Elyasiani and Mansur (1998) consider only those companies that have been listed over the total sample period, Bartram (2002) studies several short subperiods of his total sample period and chooses only those firms that had complete data for a respective subperiod. Finally, Brewer *et al*. (2007) construct portfolios of all firms with available data for a specific point in time.

assets are expected to be almost exclusively driven by movements in the term structure and by coupon payments, benchmark returns and bond index returns should be largely identical if this approach performs well.

The first 60-month period to estimate the interest rate risk exposure of the bond indices investigated starts in 1987, which means that the first (out-of-sample) benchmark return is observed in January 1992. Altogether, we observe 132 benchmark returns between 1992 and 2002 for each of the four bond indices investigated. The results are evaluated according to two criteria. First of all, the mean difference between the returns of the benchmark and the returns of the bonds investigated should be zero to avoid a systematic bias. Second, benchmark returns should not only be 'right' on average but should also match the entire time series of returns, i.e. the variance of the differences between benchmark returns and bond returns should be small (if not zero). If both criterion 1 and 2 are fulfilled; this implies that the time series of returns of a bond index and its benchmark will be highly correlated. Table 3 contains the results of this exercise.

We find clear evidence that our benchmark portfolio approach on average matches the returns of all indices investigated since mean differences are very close to zero. Moreover, we observe the standard deviations of the time series of differences (i.e. the hedging error – if we consider this to be a risk management application) to be significantly reduced compared to those of the returns of the original return series. In fact, the standard deviation of the differences for the relevant maturity class of 3–5 years is comparable with the one reported by Diebold *et al.* (2006), who analyse the hedging performance of a similar approach for US bonds with time-to-maturities of about five years.[19] Consequently, our benchmark portfolio approach generates time series of returns whose correlations with the original returns are close to one.[20]

5.2. *Industry portfolios*

Having demonstrated the application of the benchmark portfolio approach to bond returns, we will focus here on the returns of interest rate risk benchmarks that mimic the interest rate risk exposure of industry-specific stock market portfolios. We calculate the returns of interest rate risk benchmarks for stock portfolios covering the German banking, insurance, and non-financial sector using the methodology described in Section 3.4. In order to examine the first research hypothesis, we then test whether mean returns are significantly larger than zero by applying a one-sided t-test. However, it is a well-known phenomenon to find time series of returns to be non-normally distributed, which might bias the statistical significance. Therefore, following standard practice (see, e.g., Chang and Pinegar, 1988), we additionally calculated the non-parametric Wilcoxon signed-ranks test to determine whether median returns of an interest rate risk benchmark are larger than zero.

[19] See Diebold *et al*. (2006, p. 269, panel A) where a standard deviation of 12 basis points is reported for the slightly shorter period 1993:07 to 2001:12.

[20] One particular reason why the correlation is not equal to one is that all indices had a non-constant average maturity and, thus, a non-constant exposure to interest rate risks. While the moving-window regression underlying our methodology to construct interest rate risk benchmark portfolios accounts in principle for changing interest rate risk exposures, it does so with a time lag since an exposure is estimated over a period of time.

Table 3

Returns of JPM German government bond indices and their respective interest rate risk benchmarks

For each JP Morgan German government bond index of a given maturity class listed in the table, the time series of interest rate risk benchmark returns is estimated, i.e. returns of a portfolio that is constructed to match the level, slope, and curvature exposure of the respective index. The columns labelled 'Index' contain the mean and the standard deviation of the time series of monthly returns of the indices themselves. The columns labelled 'Interest rate risk benchmark' contain the mean and the standard deviation of the time series of monthly returns of the index-specific interest rate risk benchmark portfolio. The columns headed 'Difference' contain mean and standard deviation of the time series of return differences between an index and its benchmark. The column labelled 'Index/Benchmark' reports the correlation coefficient between the returns of an index and its corresponding benchmark portfolio. Means and standard deviations of (differences of) returns are in %/month. 0.1 denotes a tenth of a percent. Returns are in excess of the 1-month interbank rate. The time period is 1992:01 to 2002:12.

	Index		Interest rate risk benchmark		Difference		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std.-Dev.	Index/Benchmark Correlation
JPM GBI (1–3Y)	0.118	0.452	0.119	0.444	−0.001	0.119	0.965
JPM GBI (3–5Y)	0.200	0.774	0.207	0.735	−0.006	0.165	0.978
JPM GBI (5–7Y)	0.278	1.064	0.277	1.011	0.000	0.230	0.977
JPM GBI (7–10Y)	0.292	1.302	0.314	1.224	−0.022	0.325	0.969

Table 4

Returns of industry portfolios and their respective interest rate risk benchmarks

For each industry, the time series of interest rate risk benchmark returns is estimated, i.e. of a portfolio that is constructed to match the level, slope, and curvature exposure of the respective industry index. The columns labelled ‘Index’ contain the mean and the standard deviation of the time series of monthly returns of the industry indices themselves. The first two columns labelled ‘Interest rate risk benchmark’ contain the mean and the standard deviation of the time series of monthly returns of the corresponding interest rate risk benchmarks. The Jarque-Bera (JB) statistic tests the null hypothesis of a normal distribution of a benchmark portfolio return series. The t-test (Wilcoxon signed-ranks (WSR) test) investigates the null hypothesis of whether the mean (the median) of a benchmark portfolio return series is smaller than or equal to zero. The contribution ratio (given in %) is defined as mean benchmark return divided by mean index return. Mean returns and standard deviations are in %/month. 0.1 denotes a tenth of a percent. Returns are in excess of the 1-month interbank rate. The time period is 1983:01–2002:12.

	Index		Interest rate risk benchmark					
	Mean	Std.-Dev.	Mean	Std.-Dev.	JB-Stat.	t-Stat.	WSR-Stat.	Contrib. Ratio
Banks (composite)	0.338	4.782	0.266	1.991	22.219***	2.066**	2.845***	78.7
International banks	0.559	8.131	0.344	3.164	17.481***	1.685**	2.591***	61.6
Regional banks	0.240	5.006	0.227	1.774	15.917***	1.979**	2.831***	94.3
Mortgage banks	0.311	4.358	0.245	1.743	139.378***	2.177**	3.363***	78.7
Insurances	0.769	6.771	0.535	2.541	134.227***	3.259***	2.976***	69.5
Non-Financials	0.552	5.251	0.148	1.620	13.505***	1.417*	1.865**	26.9

Notes: */**/*** denotes statistical significance at the 10%/5%/1% level.

From the t-test and Wilcoxon signed-ranks test statistics reported in Table 4 we see that mean and median returns of interest rate risk benchmarks of all industry portfolios investigated are significantly larger than zero. Thus we find clear evidence to support hypothesis H1. This finding has two meanings. First of all, banks, insurance companies, and non-financial corporations are (on an aggregated industry level) exposed to changes in interest rates. Second, this finding is in line with the conjecture that interest rate risks are of a systematic nature. Consequently, if corporations are exposed to the risk of changing term structures, investors must be compensated for these risks.

It is well known that interest rate-related business (still) accounts for a significant part of the income of financial institutions (see, e.g., Hirtle, 1997). Therefore, one might have expected this business to have a decisive impact on expected stock returns of financial institutions. However, the magnitude of interest rate risk benchmark returns relative to total stock returns is striking. We define the 'contribution ratio' for a given stock (portfolio) as the ratio of the mean return of its interest rate risk benchmark to its mean total stock return to assess the relative importance of interest rate risk rewards.

The contribution ratio for the composite bank portfolio as well as for insurances and non-financials can be simply calculated from Table 4 as 78.7%, 69.5%, and 26.9%, respectively. Put differently, if an investor had decided to bear nothing but the estimated interest rate risk exposure of either the German banking or insurance industry over the sample period, his return would amount to about or even exceed 70% of the total return from investing in either stock portfolio. At the same time, his investment risk (as measured by the standard deviations of benchmark returns) would be significantly lower. As stated before, this observation does not imply an assessment of whether companies have created shareholder value since the only systematic risk we focus on is interest rate risk.

If one compares the contribution ratios of the three disaggregated banking portfolios one finds further differences. Despite the fact that the interest rate risk benchmark of international banks earns the highest mean return of the three banking portfolios, the contribution ratio of this portfolio is the smallest: By accepting solely the respective estimated interest rate risk exposure, one would have earned about 61.6% of the mean total stock return in the case of international banks but 78.7% and even 94.3% in the case of mortgage and regional banks. This observation is consistent with the previously stated assumption that international banks engage in a variety of non-interest rate-related banking services and therefore generate a higher part of their total returns from non-interest rate-related income.

It becomes evident from Table 4 that possibly industry-related differences in returns of interest rate risk benchmarks exist. In order to investigate the matter more rigorously, we apply a paired-comparison t-test and its non-parametric alternative, the Wilcoxon matched-pairs signed-ranks test, to the time series of return differences of all possible pairs of portfolios and test whether mean and median differences are significantly larger or smaller than zero, respectively.

The results presented in the last row of Table 5 support our research hypothesis H2, since the mean (median) differences between the returns of the interest rate risk benchmark portfolio of non-financial corporations compared to any other portfolio are found to be significantly smaller than zero. Aside from one exception, this observation is independent of the test statistic employed. Combined with the results presented in Table 4, this shows that non-financial corporations do have an interest rate risk exposure but this exposure is less relevant and therefore warrants a smaller compensation

Table 5

Differences between the returns of industry-specific interest rate risk benchmarks

For each industry, the time series of interest rate risk benchmark returns is estimated, i.e. of a portfolio that is constructed to match the level, slope, and curvature exposure of the respective industry index. This table reports descriptive statistics of the time series of differences between the returns of the respective interest rate risk benchmark of an industry listed in a row (as the minuend) and an industry listed in a column (as the subtrahend). For ease of reading, values related to testing the aggregated portfolios are given in bold. The Jarque-Bera (JB) statistic tests the null hypothesis of a normal distribution of the time series of return differences. The matched-pairs t-test and the Wilcoxon matched-pairs signed-ranks test (WMPSR) investigate the null hypothesis that the mean/the median of a time series of differences is smaller (larger) than or equal to zero if the mean/the median is larger (smaller) than zero. Since the WMPSR test uses the absolute values of the differences, the test statistic is always larger than zero by construction. Means and standard deviations of return differences are given in %/month. 0.1 denotes a tenth of a percent. The time period is 1983:01–2002:12.

		Banks (composite)	International Banks	Regional Banks	Mortgage Banks	Insurances
Intern. Banks	Mean	0.079				
	Std.-Dev.	1.347				
	JB-Stat.	180.824***				
	t-Stat.	0.903				
	WMPSR-Stat.	2.305**				
Regional Banks	Mean	−0.039	−0.118			
	Std.-Dev.	0.572	1.616			
	JB-Stat.	74.724***	191.593***			
	t-Stat.	−1.057	−1.127			
	WMPSR-Stat.	1.377*	2.138**			

Mortgage Banks	Mean	−0.021	−0.099	0.018		
	Std.-Dev.	0.774	2.004	1.113		
	JB-Stat.	143.431***	107.668***	135.012***		
	t-Stat.	−0.412	−0.766	0.257		
	WMPSR-Stat.	1.943**	2.165**	0.698		
Insurances	Mean	**0.269**	0.190	0.308	0.290	
	Std.-Dev.	**1.342**	1.822	1.410	1.640	
	JB-Stat.	**116.390*****	49.430***	177.464***	66.455***	
	t-Stat.	**3.104*****	1.619*	3.384***	2.735***	
	WMPSR-Stat.	**2.986*****	1.005	3.375***	2.715***	
Non-Financials	Mean	**−0.117**	−0.196	−0.078	−0.097	**−0.386**
	Std.-Dev.	**1.016**	1.854	0.857	1.316	**1.621**
	JB-Stat.	**349.060*****	26.045***	163.610***	74.441***	**133.016*****
	t-Stat.	**−1.791****	−1.637*	−1.417*	−1.139	**−3.693*****
	WMPSR-Stat.	**2.675*****	2.252**	2.120**	1.476*	**3.682*****

Notes:
*/**/*** denotes statistical significance at the 10%/5%/1% level.

compared to financial institutions. This finding is consistent with the notion of non-financial corporations having a higher percentage of their total market value being related to real assets which are not as interest rate sensitive as nominal or financial assets (Bartram, 2002).

In addition, we test the mean (median) differences between the returns of the interest rate risk benchmarks of insurance companies and of banks. The test statistics are reported in the penultimate row of Table 5. Astonishingly, we find mean and median returns to be significantly higher for insurance companies than for banks, which is exactly the opposite of our assumption underlying hypothesis H3, where we expected returns of the interest rate risk benchmark of banks to be the highest since they perform maturity transformation. This finding applies to regional and mortgage banks without qualification. However, when the international bank portfolio is compared to the insurance portfolio, this finding is somewhat weaker since only the parametric test decides statistical significance.

In line with our findings, Scott and Peterson (1986), Bae (1990), and Allen and Jagtiani (1997) document a somewhat higher interest rate risk exposure for US insurance companies compared with commercial banks which, given the systematic nature of interest rate risk, would help explain the higher rewards observed here for interest rate risk in the case of insurances.[21] Evidence for the German market is rather scarce. While Oertmann *et al.* (2000) do not confirm the results presented for the US market, Scholz *et al.* (2008), investigating a much longer sample, also find evidence of German insurances being more sensitive to changes in the term structure than banks.

Possible explanations for the observed high importance of interest rate risk rewards to investors of insurance companies centre around three aspects. First, insurance companies hold investment portfolios consisting to a large extent of long-term bonds (see, e.g., Staking and Babbel, 1995, and Santomero and Babbel, 1997). Second, while insurers usually attempt to match assets and liabilities, this is complicated by the plenitude of options included in (particularly life) insurance contracts (see, e.g., Smith, 1982). In fact, Briys and de Varenne (1997) show that an option-adjusted duration (i.e. a duration accounting for the interest rate contingency of cash flows) of a life insurance contract with an allegedly long-term maturity is often notably shorter than a classical duration measure where cash flows are assumed to be fixed. This leads the authors to conclude that '(m)any insurance companies still manage their liabilities using a long-term horizon while they should be aiming for a much shorter time frame. The outcome of such practices is clear: an outsized mismatch between the durations of assets and liabilities jeopardises the value of equity when interest rates increase' (Briys and de Varenne, 1997, p. 676). This claim is supported by other authors, including Santomero and Babbel (1997) and Babbel and Merrill (2005), who also document that, at least up to the middle of the 1990s, many insurers faced problems in actually quantifying the interest rate sensitivity of their liability side. Thus it is possible that the observed large return of the interest rate risk benchmark of the German insurance sector stems from an unintended maturity mismatch. In this context, it is important to

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[21] Allen and Jagtiani (1997) investigate whether a market segmentation exists in both (interest rate) risk taking and the pricing of these risks for different types of US financial intermediaries. They also document that (the absolute value of) interest rate risk premia are significantly higher in stock returns of insurances compared to banks, an observation which lends even more support to our findings.

remember that relatively small deviations in the maturity structure can be exacerbated by i) the above-mentioned long-term nature of the asset side of an insurer's balance sheet and ii) the high leverage on the liability side (see Babbel and Merrill, 2005). Third, in an ever more competitive market, insurances are forced to pay attractive returns on their policies, possibly leading to more aggressive investment policies (Deutsche Bundesbank, 2004). However, since investments in equity securities are limited by German insurance laws, insurances may have invested in higher-risk fixed-income securities.

Finally, the time series of differences in interest rate risk benchmark returns between the three disaggregated banking portfolios are examined in the second and the third row of Table 5. While there is no evidence of significant differences between regional and mortgage banks, the non-parametric test determines a statistical significance in the return differences between the interest rate risk benchmark of international banks and both the regional and the mortgage bank portfolios.

5.3. *Individual companies*

In this section, we investigate the relevance of interest rate risk rewards for the stock returns of individual firms in order to check whether the previous analysis of aggregated portfolios masked some of the properties of individual companies. Because of a possible survivorship bias, two samples are investigated. The first comprises the subset of all companies with at least ten years of consecutive data and the second one contains all companies with complete data over the sample period. Analogous to the last section, the time series of returns of interest rate risk benchmarks are calculated for each firm based on the methodology presented in Section 3.4. From these time series, mean interest rate risk benchmark returns and contribution ratios are calculated for all companies individually. In Table 6 we present descriptive statistics of the cross-sectional distributions of mean firm-specific interest rate risk benchmark returns within each of the industries investigated.

The rank ordering of all industries considered is quite robust to either of the two sample selection criteria if one compares the cross-sectional distributions of mean firm-specific interest rate risk benchmark returns for all of the industries investigated: Insurances are consistently ranked first and non-financials last, while banks are placed in between — which corroborates our earlier results based on industry portfolios. The only exception applies to regional banks, which are ranked fourth of the six industries investigated when companies with at least ten years of data are considered (Panel A) — but sixth in the case of the smaller sample comprising firms with complete data (Panel B). Besides the close correspondence of rankings, the mean values of the cross-sectional distributions for a particular industry across the two samples are also numerically similar while differences are both positive and negative. In general, these findings apply to the median values of the cross-sectional distributions of mean firm-specific interest rate risk benchmark returns as well. Thus there is no (obvious) evidence of a possible survivorship bias. Not surprisingly, the much larger number of firms investigated in Panel A results in an extended range between minimum and maximum values and consequently of the standard deviations of the cross-sectional distributions of mean firm-specific interest rate risk benchmark returns.

Moreover, the last two columns of Table 6 report the percentage shares of firms per industry where the mean and median return of the corresponding interest rate

Table 6
Descriptive statistics of the cross-sectional distributions of mean firm-specific interest rate risk benchmark returns

For each individual company in the sample, the time series of returns of its interest rate risk benchmark is estimated, i.e. of a portfolio that is constructed to match the level, slope, and curvature exposure of the respective company, and the mean of this time series is calculated. The table reports descriptive statistics (mean, median, standard deviation, minimum, and maximum) of the cross-sectional distribution of these firm-specific mean returns within an industry. Panel A reports results based on a sample of German firms that have at least 10 years of consecutive data. Panel B reports results based on a subsample of those companies examined in Panel A that have complete data over the entire sample period. The column labelled 'Number' reports the number of individual companies contained in the respective industry. The last two columns report the number of firms (in percent of all firms of an industry) where the corresponding interest rate risk benchmark earned a mean (median) return that is significantly larger than zero at the 10% level according to the t-test (the Wilcoxon signed-ranks (WSR) test). The t-test (WSR test) investigates the null hypothesis of whether the mean (the median) of the time series of returns of the interest rate risk benchmark returns of a specific company is smaller than or equal to zero. Returns are in %/month and are in excess of the 1-month interbank rate. 0.1 denotes a tenth of a percent. The time period is 1983:01–2002:12.

							% of firms with signif. interest rate risk reward	
	Number	Mean	Median	Std.-Dev.	Min.	Max.	t-test	WSR-test
Panel A: Companies with at least ten years of consecutive data								
Banks (composite)	23	0.300	0.306	0.189	0.051	0.718	65.2	82.6
International banks	5	0.424	0.343	0.189	0.251	0.718	80.0	100.0
Regional banks	9	0.284	0.307	0.177	0.051	0.514	77.8	77.8
Mortgage banks	9	0.246	0.139	0.189	0.069	0.576	44.4	77.8
Insurances	15	0.443	0.401	0.253	−0.123	0.747	80.0	80.0
Non-Financials	87	0.119	0.161	0.352	−1.032	1.200	40.2	57.5
Panel B: Companies with complete data								
Banks (composite)	7	0.260	0.251	0.170	0.086	0.576	42.9	85.7
International banks	3	0.300	0.306	0.046	0.251	0.343	66. 7	100.0
Regional banks	1	0.086	0.086	N/A	0.086	0.086	0.0	0.0
Mortgage banks	3	0.278	0.133	0.259	0.125	0.576	33.3	100.0
Insurances	8	0.535	0.576	0.165	0.279	0.747	100.0	100.0
Non-Financials	42	0.179	0.194	0.126	−0.081	0.548	47.6	57.1

risk benchmark is significantly larger than zero at the 10% level. Again, for almost all industries, the percentage shares of firms with significant interest rate risk benchmark returns are quite robust to the sample selection. Differences exist rather within the same sample between the two test statistics which results in part from the mostly leptokurtic distribution of interest rate risk benchmark returns over time.

We observe that, for both samples, a large majority of the interest rate risk benchmarks of financial institutions earns a mean (median) return significantly larger than zero. Generally, this finding applies to a still large although comparatively smaller share of non-financial firms as well. Therefore, the analysis of individual company data lends additional support for hypothesis 1.

While investigating stock portfolios, we found clear evidence of differences between interest rate risk benchmark returns depending on the respective industry affiliation. In order to evaluate the subject matter in the context of the individual firm data investigated here, we test whether the median values of the cross-sectional distributions of mean firm-specific interest rate risk benchmark returns are equal across the industries investigated. In view of the non-normality of the time series of returns of interest rate risk benchmarks, we apply here a variant of the non-parametric median test, which is based upon Pearson's χ^2 test of independence (see Daniel, 1990), to evaluate the statistical significance of these results. Note that we do not have to rely on assumptions regarding the cross-sectional distribution of mean returns of interest rate risk benchmarks if we use the median value of this distribution to partition our results.[22] The median of the cross-sectional distribution of all (i.e. regardless of the respective industry affiliation) firm-specific mean interest rate risk benchmark returns over the sample period amounts to 0.206% (0.210%) per month, when all companies having at least ten years of consecutive data (only companies with complete data) are considered. Table 7 lists the number of companies whose interest rate risk benchmarks earn a mean return which is larger (smaller) compared to the median value of the cross-sectional distribution of the respective values of all firms. By comparing observed and expected frequencies in Table 7, we can calculate the χ^2 test statistic which is 12.468 (10.510) with two degrees of freedom and a corresponding p-value of 0.196% (0.522%).[23] Thus the hypothesis of equal median values of the cross-sectional distributions of mean firm-specific interest rate risk benchmark returns across industries is clearly disproved.

This result confirms the earlier observation made in Table 5 while analysing industry portfolios, where insurances were found to dominate banks and non-financial companies in terms of mean (median) returns of interest rate risk benchmarks. It is thus consistent to find a large number of insurances having a mean return of their respective interest rate risk benchmarks above the corresponding sample median of all companies while the majority of non-financials tends to have values below the median.

To complete the picture, we also report descriptive statistics of the cross-sectional distributions of firm-specific contribution ratios for all of the investigated industries in Table 8 in order to assess the magnitude of interest rate risk benchmark returns relative to total shareholder return for individual firms as well. However, we face the challenge that occasionally mean total stock returns close to zero enter the denominator of the contribution ratio, leading to inflated values of this ratio. This, of course, affects the cross-sectional distributions of contribution ratios within the different industries, as can be seen from the respective minimum and maximum values and the standard deviations in Table 8. Since the median is less affected by these distortions than the

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[22] Shukla and Singh (1994, 1997) apply this test in the context of mutual fund performance measurement.

[23] Note that this test requires that the expected frequencies are sufficiently 'large' while the literature has not unanimously agreed upon what 'large' is. Daniel (1990) provides an extensive discussion of this issue. Therefore, we combine the different sectors of the banking industry into one single group to enlarge the expected frequencies, which ensures that we can validly apply the test in this case. However, considering the case of those companies having full data over the sample period, expected frequencies with respect to banks and insurance companies are quite low. Therefore, these results should be interpreted with caution.

Table 7

Contingency table: Independence of mean firm-specific interest rate risk benchmark returns and industry affiliation

For each individual company in the sample, the time series of returns of its interest rate risk benchmark is estimated, i.e. of a portfolio that is constructed to match the level, slope, and curvature exposure of the respective company, and the mean of this time series is calculated. This table compares the mean interest rate risk benchmark return of a particular company to the median value of the cross-sectional distribution of all mean interest rate risk benchmark returns. For each industry, the number of firms is reported where the corresponding firm-specific mean interest rate risk benchmark return is larger or smaller, respectively, than the median value of the cross-sectional distribution of all firm-specific mean interest rate risk benchmark returns (row labelled 'observed'). The expected values (row labelled 'expected') are derived under the null hypothesis that the median would be independent of the industry classification. Based on a comparison of observed and expected frequencies of interest rate risk benchmark returns lying above or below the overall median value, the null hypothesis of equal median values of the industry-specific cross-sectional distributions is tested using a median test. The corresponding χ^2 statistic has 2 d.f. Panel A reports results based on a sample of German firms that have at least 10 years of consecutive data. Panel B reports results based on a subsample of those companies examined in Panel A that have complete data over the entire sample period.

		Banks	Insurances	Non-Financials	Total
Panel A: Companies with at least ten years of consecutive data ($\chi^2 = 12.468^{***}$)					
> Median	observed	14	13	35	62
	(expected)	(11.41)	(7.44)	(43.15)	
≤ Median	observed	9	2	52	63
	(expected)	(11.59)	(7.56)	(43.85)	
Total		23	15	87	
Panel B: Companies with complete data ($\chi^2 = 10.510^{***}$)					
> Median	observed	4	8	16	28
	(expected)	(3.44)	(3.93)	(20.63)	
≤ Median	observed	3	0	26	29
	(expected)	(3.56)	(4.07)	(21.37)	
Total		7	8	42	

Notes:
*/**/*** denotes statistical significance at the 10%/5%/1% level.

mean, we will henceforth refer to the median value of the cross-sectional distributions of the contribution ratios.

Median values for insurances and non-financial corporations are found to be quite robust to the sample selection of individual companies and are also consistent with the values reported in Table 4 for industry portfolios. However, the median values of the cross-sectional distributions of contribution ratios within the different sectors of the banking industry appear to be quite dependent on the sample investigated. In view of our previous observation in Table 6, where mean and median values of the cross-sectional distributions of mean firm-specific interest rate risk benchmark returns were found to be unaffected by the sample selection, this result is more likely to result from differences in mean total stock returns of the respective companies which enter the contribution ratios in the denominator. Nevertheless, even for those companies that were listed over the entire sample period, we find notable realisations of firm-specific contribution ratios

Table 8

Descriptive statistics of the cross-sectional distributions of firm-specific contribution ratios

For each individual company in the sample, the time series of returns of its interest rate risk benchmark is estimated, i.e. of a portfolio that is constructed to match the level, slope, and curvature exposure of the respective company, and the mean of this time series is calculated. Likewise, the mean total stock return of the corresponding company is calculated. The contribution ratio of an individual firm is defined as the ratio (in %) of the mean interest rate risk benchmark return of this firm in the nominator and the mean total stock return of this company over time in the denominator. The table reports descriptive statistics (mean, median, standard deviation, minimum, and maximum) of the cross-sectional distribution of firm-specific contribution ratios within different industries. Panel A reports results based on a sample of German firms that have at least 10 years of consecutive data. Panel B reports results based on a subsample of those companies examined in Panel A that have complete data over the entire sample period. The column labelled 'Number' reports the number of individual companies contained in the respective industry. The time period is 1983:01–2002:12.

	Number	Mean	Median	Std.-Dev.	Min.	Max.
Panel A: Companies with at least ten years of data						
Banks (composite)	23	21.41	45.88	238.83	−1022.50	360.08
International banks	5	76.26	72.57	36.48	38.47	131.12
Regional banks	9	−74.29	36.72	356.80	−1022.50	99.59
Mortgage banks	9	86.64	42.94	109.17	8.08	360.08
Insurances	15	548.65	67.44	1794.21	29.42	7030.80
Non-Financials	87	−97.55	23.68	1344.08	−12386.22	1424.80
Panel B: Companies with complete data						
Banks (composite)	7	109.71	85.89	116.50	30.56	360.08
International banks	3	86.31	89.35	46.40	38.47	131.12
Regional banks	1	32.48	32.48	N/A	32.48	32.48
Mortgage banks	3	158.85	85.89	176.46	30.56	360.08
Insurances	8	86.54	65.12	58.46	43.57	221.84
Non-Financials	42	28.10	29.68	59.46	−92.03	337.31

which even partly exceed 100%, meaning that the average return of a firm's interest rate risk benchmark is larger than the corresponding mean total stock return.

Finally, we also check whether the magnitude of the contribution ratio of a company is independent of its industry affiliation, using the same test employed earlier in Table 7. To this end, we determine for each individual company having at least ten years of consecutive data (for those companies with complete data over the sample period), whether its contribution ratio is above or below the median contribution ratio of all firms, which is 33.0% (35.9%). Put differently, for the median company, the mean interest rate risk benchmark return over the period 1983 to 2002 amounts to about one-third of mean total stock returns. The number of companies per industry having a contribution ratio above or below the median value is reported in Table 9. The χ^2 test statistic of 18.459 (12.701) follows from the comparison of observed and expected frequencies and has two degrees of freedom. The corresponding p-value is 0.010% (0.175%) meaning that the hypothesis of equal median contribution ratios across the different industries is again clearly disproved. Obviously, the observed absolute frequencies reported in Table 9 are largely consistent with those reported earlier in Table 7, where we investigated the hypothesis of equal medians of the cross-sectional distributions of mean interest rate risk benchmark returns.

Table 9

Contingency table: Independence of firm-specific contribution ratios and industry affiliation

For each individual company in the sample, the time series of returns of its interest rate risk benchmark is estimated, i.e. of a portfolio that is constructed to match the level, slope, and curvature exposure of the respective company, and the mean of this time series is calculated. Likewise, the mean total stock return of the corresponding company is calculated. The contribution ratio of an individual firm is defined as the ratio (in %) of the mean interest rate risk benchmark return of this firm in the nominator and the mean total stock return of this company over time in the denominator. This table compares the contribution ratio of a particular company to the median value of the cross-sectional distribution of all contribution ratios. For each industry, the number of firms is reported where the corresponding contribution ratio is larger or smaller, respectively, than the median value of the cross-sectional distribution of all firm-specific contribution ratios (row labelled 'observed'). The expected values (row labelled 'expected') are derived under the null hypothesis that the median would be independent of the industry classification. Based on a comparison of observed and expected frequencies of contribution ratios lying above or below the overall median value, the null hypothesis of equal median values of the industry-specific cross-sectional distributions is tested using a median test. The corresponding χ^2 statistic has 2 d.f. Panel A reports results based on a sample of German firms that have at least 10 years of consecutive data. Panel B reports results based on a subsample of those companies examined in Panel A that have complete data over the entire sample period.

		Banks	Insurances	Non-Financials	Total
Panel A: Companies with at least ten years of consecutive data (χ^2 = 18.459***)					
> Median	observed	15	14	33	62
	(expected)	(11.41)	(7.44)	(43.15)	
≤ Median	observed	8	1	54	63
	(expected)	(11.59)	(7.56)	(43.85)	
Total		23	15	87	
Panel B: Companies with complete data (χ^2 = 12.701***)					
> Median	observed	5	8	15	28
	(expected)	(3.44)	(3.93)	(20.63)	
≤ Median	observed	2	0	27	29
	(expected)	(3.56)	(4.07)	(21.37)	
Total		7	8	42	

Notes:
*/**/*** denotes statistical significance at the 10%/5%/1% level.

The results presented in this section largely support earlier findings in the context of industry portfolios. Mean returns of interest rate risk benchmarks tend to be higher for insurances than for banks and non-financial firms where the latter group was found to mostly have the lowest mean returns. In this respect, we confirm that returns of interest rate risk benchmarks are not independent of the industry to which a firm belongs. With respect to mean interest rate risk benchmark returns, we find no clear evidence of a survivorship bias. In contrast, the analysis of contribution ratios shows that the sample selection can affect the results. Still, even for those firms that existed over the whole sample period, we find firms where the mean interest rate risk benchmark return exceeds the respective mean total stock returns.

6. Summary

In this study, we investigate the reward an investor should receive for being exposed to changes in the term structure when investing in German equity securities and particularly in the stocks of financial institutions. In general, prior research focused mainly on either the influence of interest rate risk on stock return variability or on the question of whether interest rate risk is priced in equity markets. Astonishingly, few studies combined these two questions in order to quantify the magnitude of interest rate risk rewards and their contribution to total stock returns, which is exactly the gap this paper aims to fill.

Consistent with the investor's perspective taken here, we investigate the issue employing an out-of-sample benchmark portfolio approach which has been previously applied in the context of mutual fund performance measurement. We assume that a benchmark portfolio having the same exposure to changes in the term structure as a particular company should be rewarded with the same compensation for its interest rate risk. This hypothesis has been exemplarily confirmed for a sample of government bonds where benchmark returns closely match the original return series.

Our key findings from investigating the time series of returns of the respective interest rate risk benchmarks of German stocks are the following: i) Regardless of the industry considered, interest rate risk benchmark returns of stock portfolios are consistently significantly larger than zero. This applies to the majority of individual companies as well. This finding suggests that investors should expect to receive a positive reward for being exposed to the risk of term structure changes. ii) Returns of interest rate risk benchmarks of non-financial corporations are significantly lower compared to those of financial institutions, which indicates that financial institutions have a higher exposure to interest rate risk. iii) By solely investing in a portfolio having the interest rate risk of either a broad German banking or insurance stock portfolio, an investor will have earned about or even more than 70% of the total return of the respective portfolio, while the associated investment risk will have been significantly lower. iv) Interest rate risk benchmarks of German insurance companies earn a significantly higher return than the corresponding portfolios of German banks. This contradicts the hypothesis that banks — because of maturity transformation — should profit the most from an on average positive slope of the term structure. This — in contrast — means that insurance companies seemingly face the largest interest rate risk exposure. Possible explanations of this observation are that insurers face difficulties in measuring the economic interest rate sensitivity of many of their liabilities and, due to the market's pressure to offer attractive returns on insurance policies, invest in more risky fixed-income securities.

The analysis of individual firm data largely confirms the results already discussed in the context of industry portfolios. Using two different sample selection criteria, we find that no obvious survivorship bias influences our results.

Standard financial theory suggests that if investors do want to earn the reward being paid for a particular interest rate risk exposure, they can create this exposure by themselves. However, based on the assumption that the same risk earns the same return in different segments of the capital market, our results suggest that a large part of the stock returns, of financial institutions in particular, might consist of rewards for bearing interest rate risk.

Appendix

Sample companies (financials)

Corporation	Corporation
International Banks	*Mortgage Banks* (*cont'd*)
Bayerische Hypotheken- und Wechselbank	Eurohypo
Commerzbank	Nürnberger Hypothekenbank
Dresdner Bank	Rheinhyp Rheinische Hypothekenbank
Deutsche Bank	Württembergische Hypothekenbank
HypoVereinsbank	Wüstenrot & Württembergische
Regional Banks	*Insurances*
Baden-Württembergische Bank	Aachener und Münchener Lebensversicherung
Berliner Bankgesellschaft	AMB Generali Holding
Comdirect Bank	Allianz Holding
Direktanlagebank	Allianz Lebensversicherung
DSL Bank	AXA Konzern
DVB Bank	AXA Leben
HSBC Trinkaus & Burkhardt	Berliner Lebensversicherung
IKB Deutsche Industriebank	DBV Winterthur
ING BHF Bank	Ergo Versicherungsgruppe
Merkur Bank	Gerling
Oldenburgische Landesbank	Hannover Rück
Vereins- und Westbank	Kölnische Rückversicherungsgesellschaft
	Mannheimer Holding
Mortgage Banks	Münchener Rück
Aareal Bank	Nordstern Allgemeine Versicherung
Allgemeine Hypothekenbank Rheinboden	Nürnberger Beteiligungs AG
Berlin-Hannoversche Hypothekenbank	Thuringia Versicherung
BHW	Vereinte Versicherungen
Depfa	Volksfürsorge Holding
Deutsche Hypothekenbank Hannover	Württembergische Lebensversicherungen

Note: If a company changed its name during the sample period, only the most recent name is reported.

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