The Interest Rate Exposure of Nonfinancial Corporations

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Abstract

Many interest rates are as volatile as exchange rates and thus represent an equally important source of risk for corporations. While this is true not only for financial institutions, but for other corporations as well, little is known about the interest rate exposure of nonfinancial firms. Consequently, this paper investigates the impact of interest rate risk on a large sample of nonfinancial corporations. It presents empirical evidence for the existence of linear and nonlinear exposures with regard to movements in various interest rate variables. The interest rate exposure is empirically determined by measures of firm liquidity, but not by financial leverage.

Keywords: Interest rates, exposure, derivatives, risk management, corporate finance, capital markets

JEL Classification: G3, F4, F3

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1 Motivation and Overview

Even though interest rates are not less volatile compared to many exchange rates and thus, *a priori*, represent an equally important source of risk, the impact of interest rate risk on the value of nonfinancial institutions has rarely been studied. As a matter of fact, the majority of the exposure studies in the literature focus on foreign exchange rate exposures (e.g. Jorion 1990), and most studies on interest rate exposures are limited to financial institutions (e.g. Choi/Elyasiani 1997) which, however, have primarily financial assets and thus are likely to show very different sensitivity with regard to interest rate changes. Interest rate risk theoretically affects the value of nonfinancial corporations as well due to changes in the cash flows and the value of their financial assets and liabilities. Moreover, interest rate movements are closely related to changes in the business cycle of the economy, and they influence – through the cost of capital – the investment behavior of firms. In addition, there may be indirect effects of interest rate risk on the competitive position of firms, impacting the size of their future cash flows and thus firm value. Motivated by the fact that the effect of interest rate risk on the value of nonfinancial institutions has gained little attention in the literature, this paper presents a comprehensive investigation of corporate interest rate exposures.

Moreover, most existing studies on interest rate exposures investigate exclusively linear relationships between changes in firm value and interest rate risk (e.g. Madura/Zarruk 1995, Prasad/Rajan 1995).[1] Since already fixed income securities exhibit a nonlinear exposure profile, corporate equities are possibly affected by interest rate movements in a more complex way as well.[2] To illustrate, nonlinearities in the corporate interest rate exposure could result if corporate cash flows are a nonlinear function of interest rates. Furthermore, most firms use predominantly linear risk management instruments (i.e. instruments with linear payoff profiles such as forward rate agreements, interest rate swaps, etc.) (Bodnar/Gebhardt 1999). Therefore, it can even be argued, that little linear (transaction)

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[1] Notable exceptions are recent studies that incorporate GARCH modeling of interest sensitivities for financial institutions (Elyasiani/Mansur 1998, Flannery et al. 1997).

[2] A nonlinear exposure results from a relationship between innovations in stock prices and interest rates that is not linear as in the classic two-factor model suggested by Stone (1974). For details see Section 4.2.

exposure is likely to be found empirically, while the remaining nonlinear part of the economic exposure may exhibit higher significance since it is often not considered corporate in risk management.

In addition, many exposure studies are based on (industry) portfolios or indices (e.g. Prasad/Rajan 1995, Bae 1990). The analysis of portfolios as opposed to firm level data is more powerful if their constituencies have similar exposures, since effects that may obstruct the identification of the exposure are reduced through diversification. If firms are heterogeneous with regard to their exposure even within the same industry, the use of stock portfolios could, however, be counterproductive. Similarly, some studies employ an index of interest rates from different countries that might exhibit diversification effects as well (e.g. Madura/Zarruk 1995).

The study of corporate interest exposures in this paper is based on a sample of 490 nonfinancial corporations which were publicly traded during the period 1987-95. The results show that nonfinancial firms exhibit interest rate exposures with regard to domestic interest rates. While a large number of firms show significant linear interest rate exposures, even more firms exhibit a significant nonlinear exposure component. The tests indicate that the nonlinear feature of the interest rate exposure is not exclusively driven by extreme observations. Partially nonparametric regressions and size bias/sign bias tests provide additional support to these findings. Consequently, the structure of the exposure appears to be an important issue for corporate risk management. With regard to exposure determinants, firm liquidity shows a significant relationship to linear and nonlinear interest rate exposures. Financial leverage, however, is not an empirically significant exposure determinant.

The paper is set up as follows. Section 2 provides the theoretical foundation of the analysis by discussing the relevance of interest rate risk for and its effect on nonfinancial firms. Subsequently, the existing empirical evidence is reviewed (Section 3), followed by the introduction of the hypotheses and regression models (Section 4). In Section 5, the data set is described, while Section 6 presents the results of the empirical study. Concluding remarks are offered in Section 7.

2 Relevance of Interest Rate Risk for Nonfinancial Corporations

The economic interest rate exposure originates from the impact of unexpected interest rate changes on firm value. The resulting effects are traditionally of foremost interest to banks and other financial institutions, since they generate significant contributions to their earnings by successfully managing interest rate risk. At the same time, companies in the financial sector can manage their interest rate risk effectively because they own primarily financial assets for which sophisticated techniques for the identification and quantification of interest rate exposures exist. Changes in interest rates are, however, also important for nonfinancial institutions. Direct effects can be identified most easily for their financial assets and liabilities, which manifest as changes in market value and interest payments, respectively, or as opportunity cost. The specific characteristics of the asset (maturity, tenor, duration, etc.) determine the type and size of the impact.

Apart from the effects on financial assets, an impact of interest rates movements on the value of real assets and projects may occur. These must also be taken into account when analyzing and managing the total effect of interest rate changes on the value of nonfinancial firms. Therefore, matching the characteristics of financial assets and liabilities does not lead to complete immunization of firm value for companies outside the financial sector. The analysis of the interest rate exposure of a corporation in its entirety is, however, obstructed by the problem of identifying and quantifying the influence of interest rate risk on real assets, since their market values are not available at regular intervals and since their future cash flows are not contractually fixed. Nevertheless, interest rate changes affect the cash flows and thus the value of these assets as well as interest rates are determinants of investment decisions and are linked to business cycles.

Because of its impact on the cost of long-term debt, long-term interest rates are especially relevant for the investment activity of industrial corporations, and also of the public and private sector – for the latter especially with regard to the purchase of real estate and the construction of private homes. Consequently, there is a tendency of a negative relationship between the development of interest rates and stock prices (Solnik 1984). Changes in long-term rates are also considered to reflect unexpected interest rate changes particularly well (Oertmann et al. 2000, Sweeney/Warga 1986). In addition, the difference between long-term rates and short-term rates is important, since this spread is a good representative of the term structure and thus acts as an indicator of business cycle development. This is because a steep term structure is often followed by high economic growth rates, while an economic slowdown is frequently preceded by a flat or inverse yield curve (Fama 1990, Fama/French 1989, Campbell 1987).

The relationship between GDP growth and the term structure results when interest rate expectations are determined largely by expectations about the business cycle. Expectations about business cycles and interest rates are linked insofar as recessionary developments often lead to a reduction in income and thus to lower money demand or to interest rate cuts by the central bank, inducing lower short-term interest rates. Similar considerations can be made for economic expansion periods. While economic upturns or downturns usually have a lag in their effect on many industries, they should be anticipated by professional market participants and thus be reflected in stock prices ahead of time. Empirical studies document a strong correlation between term structure variables and the business cycle as measured by GDP growth (Ragnitz 1994, Filc 1992, Harvey 1991, Deutsche Bundesbank 1991). The impact of business cycles on the sales, costs and competitive position of firms explains the empirical importance of changes in interest rates for nonfinancial corporations.

3 Empirical Evidence of Interest Rate Exposures

According to the existing evidence, the majority of corporations in the United States do not exhibit significant interest rate exposures on the basis of industry portfolios. Exceptions are the industries stone/clay/glass, utilities and banking/finance/real estate, which show a significant, negative interest rate coefficient if the regressors are not orthogonalized (Sweeney/Warga 1986, Haugen et al. 1978, Joehnk/Nielsen 1976-77). These findings are explained primarily with the lower pass-through in regulated industries, which leads to a negative effect of increases in interest rates on firm value. Other studies yield contradictory results, since a high percentage of companies with significant exposure (57%) is sometimes documented (Lynge/Zumwalt 1980), while at other times no significance of interest rate variables results for a sample of U.S. nonfinancial corporations (Bae 1990, Booth/Officer 1985). In the same vein, companies in the Canadian lumber industry do not show significant interest rate exposures in regression models with and without market index (Levi 1994).

Comparative studies identify a percentage of industry portfolios with interest rate exposures noticeable above the significance level only in Germany (16.7%), but not in the United States, Japan and the U.K. (Prasad/Rajan 1995). Other studies, however, do find significant interest rate exposures for nonfinancial corporations in France, Germany, Switzerland and the U.K. – primarily with regard to changes in long-term national interest rates, but also regarding a global interest rate index (Oertmann et al. 2000).

In the financial sector, several studies succeed in identifying a significant interest rate exposure for U.S. companies (Mitchell 1989, Scott/Peterson 1986, Martin/Keown 1977). There is some evidence that the size and the significance of the interest rate exposure depend on the estimation period (Kane/Unal 1988) and the type of institution (Chen/Chan 1989). A comparative study finds significant interest rate exposure for portfolios of Canadian, German, British and Japanese banks, but not for portfolios of U.S. banks with regard to changes in long-term national and international interest rates (Madura/Zarruk 1995).

Some of the most recent studies of the interest rate sensitivities of financial institutions are of particular interest in the context of this paper as they incorporate nonlinear interest rate effects by employing ARCH and GARCH modeling (e.g. Neuberger 1994, Song 1994). Interest rate risk appears to be compensated with a time-varying risk premium for periods of important interest rate volatility (Flannery et al. 1997). Results based on a GARCH-M model indicate a significant negative effect of the long-term interest rate on bank stock returns. The volatility and risk premium of bank stocks is empirically determined by interest rate volatility (Elyasiani/Mansur 1998).

4 Hypotheses and Methodology

4.1 Linear Interest Rate Effects

As a result of the above discussion, the empirical analysis focuses on the percentage change in the riskless, long-term interest rate as well as the spread between long-term and short-term interest rates. To allow comparisons with other studies, selected results for short-term interest rates are reported as well. Overall, increases in long-term interest rates or the interest rate spread are likely to have a negative effect on firm value, leading to the expectation of a negative interest rate exposure. As a consequence, the first hypothesis is:

H_1: Nonfinancial corporations exhibit a negative exposure with regard to interest rate risk.

Traditionally, the interest rate exposure is estimated in a two-factor Arbitrage Pricing Theory (APT) model with the market index and an interest rate variable (Stone 1974).[3] Thus, H_1 is tested estimating the following regression model with OLS:

$$R_{jt} = \alpha_j + \beta_j R_{Mt} + \chi_j R_{It} + \varepsilon_{jt}, \quad (1)$$

where R_{jt} denotes the monthly stock return of company *j* in period *t*, R_{Mt} the return on the capital market index *M* in period *t*, and R_{It} the value of the interest rate variable *I* in period *t*.

4.2 Nonlinear Interest Rate Effects

Existing empirical studies of interest exposures have investigated primarily linear exposure profiles (e.g. Madura/Zarruk 1995, Prasad/Rajan 1995). However, firm value as the present value of all future contractual and non-contractual cash flows may depend in a very complex way on changes in interest rates. As a matter of fact, Smithson/Smith/Wilford (1995, p. 144) note in the very context of measuring a firm's exposure to financial price risk that "*...in fact, the relation between the value of the firm and the interest rate is nonlinear. However, for simplicity of exposition we will presume [...] that the relation is linear...*" Since the majority of corporate cash flows are uncertain, there are many potential ways of adjustment – on the part of the company as well as its competitive environment.

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[3] This model is also referred to as augmented Capital Asset Pricing Model (CAPM). It is used e.g. by Madura/Zarruk (1995), Bae (1990), Chen/Chan (1989), Sweeney/Warga (1986), Flannery/James (1984), Lynge/Zumwalt (1980).

Further, as interest rate changes have an impact on the cash flows as well as the discount rate (cost of capital), the value of a firm may not change one-to-one with interest rates.

Moreover, some companies use risk management instruments with nonlinear payoff structures such as interest rate options, which also generate nonlinearities in the exposure if they are not used to offset an existing nonlinear exposure. But other corporate cash flows may also simply depend in a nonlinear fashion on interest rates. Finally, as a result of the large amount of information and the complexity of their impact on stock prices, market participants may be neglecting small interest rate changes to some degree while reacting (more strongly) to larger changes. As the risk management focus of most corporations is on their transaction exposure, which they tend to hedge primarily with linear hedging instruments such as forward rate agreements, interest rate futures or swaps (Bodnar/Gebhardt 1999), insignificant linear interest rate exposures might not come as too much of a surprise. Because the rest of the economic interest rate exposure is often not subject to risk management, it is more likely to find significant nonlinear interest rate exposures empirically.

While it is reasonable to make the assumption of a clear direction of the interest rate effect on firm value, the exposure can possibly have very different shapes. However, the actual relationship between changes in firm value and interest rates may be firm-specific. In addition, it is likely to be asymmetric, with positive changes having a different impact on firm value than negative changes. Consequently, the following conjecture is made:

H_2: The exposure of nonfinancial corporations with regard to interest rate changes has a nonlinear, directional component.

This hypothesis is tested using several types of nonlinear functions that go through the first and third (or the second and fourth) quadrant, such as the cubic functions or the sinus hyperbolicus. A general regression equation can be written as:

$$R_{jt} = \alpha_j + \beta_j R_{Mt} + \chi_j f(R_{It}) + \varepsilon_{jt}, \qquad (2)$$

where *f(.)* is a nonlinear function of the interest rate variable. A nonlinear specification implies that the effect of interest rate risk on firm value depends on the size of the interest rate shock.

In general, generic convex functions (with regard to the first quadrant) are the sinus hyperbolicus and the cubic function, whereas the inverse sinus hyperbolicus and the cubic root function are generic concave functions.[4] Concave functions may be consistent with the idea of real options mitigating the effect of large interest rate movements. However, with this functional form, small interest rate movements have a very strong effect on firm value, which does not appear very plausible. Cubic functions, on the other hand, may not be consistent with real options, however they accommodate the idea of inefficiencies of capital markets in the sense that small interest rate movements are dominated by other price relevant information. Convex and concave functions may both be seen in line with cash flows being a nonlinear function of the interest rate.

It appears difficult to justify economically a certain functional form *a priori*. However, the purpose of the regressions consists primarily in the motivation of nonlinear exposures and the estimation of some exemplary, generic functional forms. While this approach relaxes the common assumption of linear exposures, it is also still very much simplifying by pre-specifying the same, distinct, symmetric profile for all firms. Given these simplistic assumptions, the approach is conservative since the results should show less significance than if an individual exposure profile with a different, possibly asymmetric form for every firm were estimated.

Nonlinearities and asymmetries of the exposure can be investigated more generally by testing whether the exposure is dependent on the sign and the size of the interest rate shock, i.e. whether stock returns are affected differently by large positive, large negative or small interest rate changes. First, partially nonparametric regressions are employed in order to estimate the effect of interest rate risk on firm value for interest rate shocks of different size, based on the volatility of the time series as

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[4] The hyperbolic sine function describes the following relationship: $y = sinh(x) = (e^{x} - e^{-x})/2$. In contrast to the hyperbolic function, it is characterized by a positive slope in the origin. The inverse hyperbolic sine function is defined as $y = sinh^{-1}(x) = \ln(x + \sqrt{x^{2} + 1})$. Contrary to the root function, it has a positive slope in the origin.

measured by its standard deviation, without specifying a certain functional form. The model for studying interest rate exposures with this piecewise linear regression is specified as:

$$R_{jt} = \alpha_j + \beta_j R_{Mt} + \chi_j R_{It} + \delta_{j1} D_{1t} + \delta_{j2} D_{1t} R_{It} + \delta_{j3} D_{2t} + \delta_{j4} D_{2t} R_{It} + \varepsilon_{jt}$$
$$with\ D_{1t} = \begin{cases} 1\ if\ -0.5\sigma_{R_{It}} < R_{It} \leq 0.5\sigma_{R_{It}} \\ 0\ otherwise \end{cases} \quad and \quad D_{2t} = \begin{cases} 1\ if\ \ 0.5\sigma_{R_{It}} < R_{It} \\ 0\ otherwise \end{cases} \tag{3}$$

Second, sign bias tests and size bias tests are performed jointly and individually to check the linear regression model (1) for misspecifications that might prevail because the model does not capture nonlinear relationships. These diagnostic tests analyze the residuals of the regression that is employed to estimate the linear interest rate exposure. For the sign bias test, the variable Z_{It}^- is used in order to investigate the impact of positive and negative interest rate shocks on stock returns not predicted by the linear model (Engle/Ng 1993). It is a dummy variable that takes a value of one when the interest rate change R_{It} is negative or zero otherwise. The negative size bias test employs the variable $Z_{It}^- R_{It}$. It examines whether large and small negative interest rate movements have different effects on stock returns that are not captured by the model. Similarly, the positive size bias test utilizes the variable $Z_{It}^+ R_{It}$ $\left(with\ Z_{It}^+ = 1 - Z_{It}^-\right)$ and investigates differences in the effect that large and small positive interest rate changes have on stock returns. By distinguishing between negative and positive interest rate movements, potential asymmetries in the interest rate exposure are allowed for. As a result, the following model is estimated:

$$\begin{aligned} & R_{jt} = \alpha_j + \beta_j R_{Mt} + \chi_j R_{It} + \varepsilon_{jt} \\ & \frac{\varepsilon_{jt}}{\sigma_{\varepsilon_{jt}}} = \delta_j + \phi_j Z_{It}^- + \lambda_j Z_{It}^- R_{It} + \omega_j Z_{It}^+ R_{It} + \vartheta_{jt} \\ & with\ \ Z_{It}^- = \begin{cases} 1\ \ if\ R_{It} < 0 \\ 0\ \ otherwise \end{cases} \quad and \quad Z_{It}^+ = 1 - Z_{It}^- \end{aligned} \tag{4}$$

4.3 Determinants of Interest Rate Effects

In principle, nonfinancial institutions should be able to immunize firm value against changes in interest rates to some degree by matching the interest rate sensitivity of their assets and liabilities through active interest rate risk management (analogous to duration matching for financial intermediaries). However, since the majority of the future cash flows of nonfinancial institutions are not contractually fixed and since the economic life of most of their assets is undetermined, a sensible calculation of a proxy for a duration gap appears difficult for these companies.

The type and degree of the interest rate exposure depends in part on the characteristics of the assets (i.e. the industry). Consequently, banks and insurance companies are generally deemed to be especially interest rate sensitive. In addition, utility companies are expected to have interest rate exposures due to industry regulation. Further, the industries construction, industrial machinery and equipment, electrical and electronic equipment, transportation equipment and raw material/mining are perceived as cyclical and thus sensitive to interest rate risk (Wolfson/Emanuelsson 1997), while service companies are viewed as less sensitive to business cycles (Deutsche Bundesbank 1996).

The interest rate exposure of firm value is also partially related to the corporate debt/equity ratio (Hakkarainen et al. 1997, Haugen et al. 1978). Sustained increases in interest rates mean a higher cost of new debt, which negatively affects the earnings of a company and its ability to service debt. Highly levered firms have a higher expected cost of financial distress and are thus more vulnerable to interest rate risk. The hypothesis of a significant interest rate exposure of financial institutions and U.S. utility companies is, for instance, also based on the high financial leverage in these industries (Joehnk/Nielsen 1976-77). As a result, the conjecture is that firms with high leverage have a higher exposure. In contrast, it appears challenging to derive appropriate proxies for determinants of the overall interest rate exposure of nonfinancial institutions.

The study investigates two partial determinants of the interest rate exposure of nonfinancial firms: financial leverage, and firm liquidity. Leverage can be perceived as the most important measurable determinant of the interest rate exposure (similar to the percentage of foreign sales for the foreign exchange exposure) as a large part of this type of exposure originates from the liability side. Firm liquidity, on the other hand, can work as a shock absorber that buffers unfavorable interest rate movements and thus reduces the expected cost of financial distress. As a result, one can expect the exposure to be negatively related to firm liquidity. The resulting hypothesis is:

H_3: The interest rate exposure is positively related to leverage and negatively related to firm liquidity.

To test H_3, a second stage, cross-section regression is estimated, using the exposure coefficients of the firm-specific time-series regression based on the long-term interest rate as regressand (as e.g. in Kwan 1991, Flannery/James 1984). The regression equation for the estimation of exposure determinants can be written as:

$$\hat{\chi}_j = \gamma_0 + \gamma_1 ED_j + \vartheta_j , \qquad (5)$$

with $\hat{\chi}_j$ and ED_j representing the estimated exposure of the time-series regression and the exposure determinants, respectively. The dependent variable is, however, not the same for the different exposure determinants. Financial leverage is related to the size and the direction of the exposure. In contrast, higher liquidity translates into lower exposure of either direction. Consequently, while leverage is regressed on the normal exposure coefficients, liquidity variables require the absolute value of the exposure coefficient as dependent variable.[5] Only one measure of liquidity is used as exposure determinant at a time because the alternative liquidity variables are highly correlated among each other.

5 Data Sources and Sample

The empirical study is based on a large sample of German nonfinancial firms during the period 1987-1995. Germany is a particularly well-suited country for this analysis because interest rate shocks are likely to be exogenous due to low inflation. The sample consists of all nonfinancial firms that are actively traded on at least one of the 8 German stock exchanges with data available on Datastream International. If interest rate risk is an important source of risk, companies with a significant exposure that do not manage interest rate risk effectively might not exist through the entire 9-year period. As a result, studying only the firms that exist at the end of the sample period possibly induces a survivor-

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[5] Combining both types of determinants (leverage, liquidity) in one regression by splitting the positive and negative exposure firms is declined due to its undesirable effect on the distribution of the error terms.

ship bias that could lower the significance of the results, as firms that were particularly sensitive to interest rate risk (and as a result ceased to exist) are not included in the analysis. This bias is avoided by determining the sample for each sub-period separately, because the sample of every sub-period includes all traded firms during that period of time.[6] Furthermore, companies are excluded for periods where they had missing data, were acquired, filed for bankruptcy or entirely changed the business objective. As a result, a total of 490 nonfinancial firms represent the sample for the empirical analysis. In the industry analysis, results for 67 financial intermediaries, i.e. 34 banks and 33 insurance companies, are included for comparison (Table 1).

The CDAX, which is obtained from the German stock exchange (Deutsche Börse AG), is the broadest value-weighted stock market performance index available for Germany. All interest rates are from Datastream International. For the short-term and long-term riskless interest rates for Germany, the middle rate of the 3-month Eurocurrency interest rate and the yield of 10-year benchmark government bonds are chosen. Averages of the yearly accounting data – i.e. book values of debt, total assets, cash/total assets, quick ratio ([cash+short-term receivables]/short-term liabilities), current ratio ([cash+short-term receivables+inventories]/short-term liabilities), and cash flow/total assets ([net income before tax+depreciation+net increase in provisions]/total assets) – originate from the annual report database by Hoppenstedt.

6 Empirical Tests and Results

6.1 Linear Interest Rate Exposure

For the analysis of the linear interest rate exposure, the relationship between changes in stock prices and interest rates is analyzed by estimating equation (1). Standard errors of the coefficients are estimated using the Newey-West correction method to correct for autocorrelation and heteroscedasticity.

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[6] Flannery et al. (1997) and Chen/Chan (1989) follow the same principle to define their sample. Elyasiani/Mansur (1998), however, argue that the effect of a survivorship bias is likely to be negligible and that the attempt to correct for it may be as bad as ignoring the effect. Similarly, Choi/Elyasiani (1997) argue that choosing firms with complete data over the sampling period may render the sample subject to survivorship bias but ensures the consistency of the data throughout the period. Prasad/Rajan (1995) suggest that not correcting for survivorship constitutes a conservative ap-

For all sub-periods, the regressions yield a percentage of nonfinancial firms with significant exposure above the 5% significance level (Table 2). The long-term interest rate (DEM10Y) shows the highest significance, with percentages of 10.2% to 21.2%. For the interest rate spread (DEMSP) and the short-term interest rate (DEM3M), 6.4% - 18.8% and 5.4% - 9.3% of all nonfinancial firms exhibit a significant exposure, respectively.[7]

As all interest rate variables are correlated with the market index, multicollinearity may be an issue. As a matter of fact, the stronger the interest rate exposure is for many firms, the more this effect will show up in the market index. However, the correlations between the interest rate variables and the market index are relatively low (0.05 - 0.47), so that there should be little concern for multicollinearity.[8] The exposure with regard to changes in long-term interest rates is more often positive than negative (other studies report similar results, e.g. Oertmann et al. 2000).[9] With regard to the interest rate spread, the signs of the exposure are frequently negative. A positive interest rate differential (normal yield curve) implies the expectation of increasing interest rates and may be reflected negatively in stock prices due to the expected consequences for investment activity.

In order to analyze the impact of interest rate risk on different industries, the percentage of firms with significant interest rate exposure per industry class is calculated. This approach is preferred over the use of industry portfolios or pooled regressions, since the interest rate exposures are possibly different with regard to size and direction, even for firms within the same industry. The sectors agriculture/forestry, industrial machinery, construction industry and companies with diversified activities are especially sensitive to changes in the long-term interest rate (Table 3). In addition, fi-

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proach, as it makes the identification of exposure less likely.

7 19.2% and between 11.5% and 15.4% of the nonfinancial firms in the DAX show a significant interest rate exposure with regard to changes in the long-term riskless interest rate and the interest rate spread, respectively.

8 The condition index and the variance inflation factor (VIF) have values in the range of 1.206-2.587 and 1.003-1.289, respectively. A condition index of 30 to 100 indicates moderate to strong collinearity. A VIF close to 1 indicates no collinearity, while VIF values exceeding 10 indicate harmful collinearity. As a result, these both measure also indicate no problem of multicollinearity.

9 The sign of the exposure is the result of several effects and is determined by the maturity structure of net nominal assets and real assets via inflation (nominal contracting hypothesis) or changes in real interest rates (Kwan 1991, Sweeney/Warga 1986, Flannery/James 1984).

nancial intermediaries show a significant interest rate exposure.[10] Significant coefficients of the interest rate spread occur primarily in the industries agriculture/forestry, stone/clay/glass, electrical and electronic equipment, miscellaneous manufacturing, apparel/textile/leather, and wholesale trade.

6.2 Nonlinear Interest Rate Exposure

A significant nonlinear interest rate exposure can be identified for different interest rate variables. While the convex interest rate exposure is significant for many companies, concave exposure profiles appear to be of less statistical importance. Consequently, only results for convex exposures are presented (Table 4). For the polynomial of third degree, between 9.4% and 64.4% of all nonfinancial corporations exhibit a significant exposure with regard to changes in the long-term interest rate. Results with the hyperbolic sine function show even higher significance: 10.6%-69.3%. The results for the interest rate spread show percentages of firms with significant exposures of 6.7%-17.9%, which are similar to linear specifications.[11] For the short-term interest rate, convex exposures are much more significant compared to linear and concave exposures in most periods, as between 11.5% and 25.4% (39.5% and 69.8%) of all nonfinancial corporations exhibit a significant interest rate exposure for the cubic (hyperbolic sine) function.

For the comparison of the economic significance of linear and nonlinear interest rate exposures, the product of the mean regression coefficient with one and two standard deviations of the interest rate variables is calculated (Table 5). This procedure makes the coefficients comparable as it standardizes the variables across regression specifications. For interest rate changes of one standard deviation, the linear exposure has generally a bigger impact on stock prices than the nonlinear expo-

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[10] Saunders/Yourougou (1990) suggest that limiting banks in the scope of their activities leads to higher interest rate exposure. Since Germany is characterized by a universal banking system, this would imply lower interest rate risk leading to a more stable banking sector that eases the efficient transmission of monetary policy. The exposure of a portfolio of German banks towards changes in the short-term rate is indeed insignificant, but the exposure coefficients to the long-term interest rate are significant and negative. A portfolio of German nonfinancial firms shows no significant exposure to short-term interest rates as well, while the exposure to long-term rates is always positive and significant. Apparently, the exposure of German nonfinancial firms to long-term interest rates has a different sign and is typically larger than the exposure of banks (when controlling for differences in market risk).

sure. However, nonlinear exposures become more important with increasing size of the interest rate movement. On the industry level, a large number of firms being significantly affected by changes in the long-term interest rate are in the sectors chemicals, industrial machinery, paper/publishing, retail trade, transportation, and conglomerates (Table 6). For the interest rate spread, higher percentages of firms with significant exposure occur in agriculture/forestry, stone/glass/clay, electrical equipment, miscellaneous manufacturing, apparel/textile, and wholesale trade.

To investigate the relationship between linear and convex exposures, regressions with both types of variables are estimated. The results confirm the dominance of convex relative to linear exposures for the long-term interest rate, since convex specifications yield high statistical significance also in the presence of linear regressors. For the interest rate spread, however, the convex exposure is more or less equally important as its linear component. Since it is not desirable that the empirical results are entirely determined by a few extreme observations, the interest rate exposures are estimated when excluding the largest negative and positive interest rate movement. On the other hand, large interest rate movements possibly give better indications about the true relationship if other effects on stock price dominate small interest rate changes. From the results it appears that the higher significance of nonlinear exposures prevails in most cases even without the most extreme interest rate movements (Table 7). For the long-term interest rate, 63 firms have a significant nonlinear exposure, and 47 firms show a significant linear exposure during the period 1993-95 (63/47=1.3). Without the largest positive and negative interest rate movements, the nonlinear (linear) exposure is significant for 100 (46) firms (100/46=2.2).

Partially nonparametric regressions are used as a more general specification for the investigation of nonlinear relationships. This is done by estimating the intercepts and slopes for 2, 3 and 4 different size brackets of interest rate innovations in order to try different tradeoffs between the degrees of freedom and the captured complexity of the nonlinear relationship. The empirical results show

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[11] The percentages of DAX nonfinancial firms with significant coefficients are between 15.4% and 65.4% for the long-term interest rate for specifications and up to 15.4% for the interest rate spread, respectively.

that the coefficients of the interest rate variables are jointly significantly different from zero in several cases, and that F-tests including the market index can generally be rejected (Table 8). The results of the sign and size bias tests present some evidence of nonlinearities in the interest rate exposure as well (Table 9). The percentages of regressions with significant coefficients are generally above the significance level for all sign/size bias test variables, suggesting misspecification of all three types. The fact that tests of regressions without interest rate variables – and thus only with the market index – yield similar results possibly indicates that some of the interest rate effect is included in the stock market index.

6.3 Determinants of Interest Rate Exposure

Since a significant nonlinear exposure component is identified in the interest rate exposure, the regression analysis for the exposure determinants is carried out for linear as well as for nonlinear interest rate exposures (Table 10). While the coefficients are often positive, there is no significant relationship between the interest rate exposure and leverage. This might be due to the fact that financial leverage relates only to the part of the exposure that originates from the liabilities, while neglecting the impact of the assets on the interest sensitivity of firm value.[12] The coefficients of measures of firm liquidity are often negative and significant as predicted. In particular, the coefficients of cash flow/total assets are always negative and show high statistical significance.[13]

Given that the regressands are estimated coefficients rather than actual values, it is important to realize for the interpretation of results that the two-step estimation procedure causes measurement error in the regressand. Moreover, as the first and second stage is estimated over the same period of time, the errors in equation (1) and thus in equation (5) may be contemporaneously correlated. As a result, the significance of the coefficients of the exposure determinants might be biased upwards (see Flannery/James 1984). The effect may, however, be smaller than in studies of financial intermediar-

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[12] This result is consistent with survey evidence of no clear relationship between interest rate exposure and leverage of Finnish firms (Hakkarainen et al. 1997).

ies since firms in different industries are included. Furthermore, the standard errors of the estimates are corrected for autocorrelation and heteroscedasticity (using the Newey-West procedure).[14]

7 Conclusion

The results presented in this paper originate from a broad study of the interest rate exposure of nonfinancial firms. A significant interest rate exposure of nonfinancial corporations with regard to changes in the short-term and long-term riskless interest rate as well as the interest rate spread is reported. While many stocks show a significant linear interest rate exposure, a large number of firms also have an important nonlinear exposure component. In addition, there is evidence of a negative relationship between the interest rate exposure and measures of firm liquidity. In contrast, financial leverage exhibits only a weak statistical relationship to the size of the interest rate exposure of nonfinancial firms. In general, the exposure and the payoff profile of risk management instruments have to match in order to eliminate all interest rate risk to firm value. If the interest rate exposure exhibits an important nonlinear component, its assessment should be part of the exposure estimation, as it can possibly be hedged with risk management instruments that have a nonlinear payoff profile (such as options and portfolios of options). Future research may elaborate on this issue in more detail.

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[13] The coefficients of other measures of firm liquidity (cash/total assets, quick ratio, current ratio) are often negative as well but less significant.

[14] Flannery/James (1984) suggest the simultaneous estimation of the first and second stage using seemingly unrelated regressions (SUR) methodology, which is employed by Kwan (1991). Choi/Elyasiani (1997) use a modified SUR methodology for the two-step estimation procedure. Given the large cross-section, this approach is, however, computationally infeasible in the present study.

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Table 1: Sample size and industry classification

The table reports the number of firms in the sample by sub-period and industry class. Samples are determined for each sub-period separately in order to avoid a survivorship bias. Across all periods, a total of 490 nonfinancial corporations and 67 financial intermediaries are studied.

Industry	**3-year periods**			**4-year period**	**5-year period**
	1987-89	**1990-92**	**1993-95**	**1992-95**	**1991-95**
Agriculture, forestry, and fishing	1	2	3	2	2
Public utilities, mining	13	26	26	23	23
Chemicals	16	22	20	19	19
Rubber and plastics	4	9	10	10	9
Stone, clay, glass, and concrete products	14	23	19	19	19
Primary metal industries	4	14	13	13	13
Industrial machinery and equipment	22	51	53	50	47
Transportation equipment	10	14	15	15	14
Electrical and electronic equipment, optical and precision instruments	19	26	30	29	27
Miscellaneous manufacturing industries	4	14	15	14	13
Paper and wood products, publishing and printing	7	15	16	16	14
Apparel and textile products, leather and leather products	9	33	30	29	29
Food and kindred products, tobacco	14	44	38	36	34
Construction	6	8	12	11	9
Wholesale trade	5	16	20	18	16
Retail trade	9	15	19	16	16
Transportation and communication	2	16	15	12	12
Banking	27	31	31	30	29
Insurance	20	29	31	31	29
Real estate	4	23	22	20	19
Diversified investment offices and conglomerates	16	29	30	28	27
Other services	0	10	14	12	11
All nonfinancial firms	**179**	**410**	**420**	**392**	**373**
All financial intermediaries	**47**	**60**	**62**	**61**	**58**

Table 2: Linear interest rate exposure

The table reports the percentage of nonfinancial firms that show a significant linear interest rate exposure χ_j for different interest rate variables and time periods (5% level). For each period, the left column refers to negative, the middle column to positive and the right column (bold figures) to all exposures, respectively.

Percentage of nonfinancial firms with significant exposure (5% level)															
	3-year periods									**4-year period**			**5-year period**		
	1987-89			**1990-92**			**1993-95**			**1992-95**			**1991-95**		
	-	**+**	**±**	**-**	**+**	**±**	**-**	**+**	**±**	**-**	**+**	**±**	**-**	**+**	**±**
$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{It} + \varepsilon_{jt}$															
Long-term rate	1.1	11.2	**12.3**	4.1	17.1	**21.2**	1.4	9.8	**11.2**	0.8	9.4	**10.2**	0.5	13.1	**13.7**
Interest rate spread	5.6	3.4	**8.9**	2.2	16.6	**18.8**	14.8	0.7	**15.5**	5.4	3.3	**8.7**	4.0	2.4	**6.4**
Short-term rate	3.4	5.0	**8.4**	2.7	6.6	**9.3**	4.5	3.6	**8.1**	3.6	1.8	**5.4**	5.1	2.4	**7.5**

Table 3: Linear interest rate exposure by industry

The table reports the percentage of firms that show a significant linear interest rate exposure χ_j with regard to the long-term interest rate variable (DEM10Y) for different industries and time periods (5% level). For each period, the left column refers to negative, the middle column to positive and the right column (bold figures) to all exposures, respectively. R^2 indicates the average of this statistic for all regressions in the period in %; aR^2 is the adjusted R^2 statistic.

$$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{DEM10Yt} + \varepsilon_{jt}$$

Percentage of nonfinancial firms with significant exposure (5% level)

	1987-89			**1990-92**			**1993-95**		
	-	**+**	±	**-**	**+**	±	**-**	**+**	±
Agriculture/forestry	0.0	0.0	**0.0**	0.0	50.0	**50.0**	0.0	33.3	**33.3**
Public utilities/mining	7.7	0.0	**7.7**	7.7	11.5	**19.2**	0.0	7.7	**7.7**
Chemicals	0.0	12.5	**12.5**	4.5	4.5	**9.1**	0.0	10.0	**10.0**
Rubber/plastics	25.0	0.0	**25.0**	11.1	0.0	**11.1**	0.0	0.0	**0.0**
Stone/clay/glass	0.0	7.1	**7.1**	0.0	21.7	**21.7**	0.0	15.8	**15.8**
Primary metal	0.0	0.0	**0.0**	0.0	28.6	**28.6**	0.0	7.7	**7.7**
Industrial machinery	0.0	22.7	**22.7**	3.9	29.4	**33.3**	1.9	13.2	**15.1**
Transp. equipment	0.0	10.0	**10.0**	0.0	28.6	**28.6**	0.0	6.7	**6.7**
Electr. equipment	0.0	10.5	**10.5**	0.0	3.8	**3.8**	0.0	10.0	**10.0**
Misc. manufacturing	0.0	0.0	**0.0**	0.0	21.4	**21.4**	6.7	6.7	**13.3**
Paper/publishing	0.0	0.0	**0.0**	0.0	13.3	**13.3**	0.0	6.2	**6.2**
Textile/leather	0.0	0.0	**0.0**	3.0	9.1	**12.1**	3.3	10.0	**13.3**
Food/tobacco	0.0	0.0	**0.0**	6.8	20.5	**27.3**	2.6	2.6	**5.3**
Construction	0.0	33.3	**33.3**	0.0	25.0	**25.0**	0.0	8.3	**8.3**
Wholesale trade	0.0	20.0	**20.0**	6.2	6.2	**12.5**	5.0	5.0	**10.0**
Retail trade	0.0	0.0	**0.0**	6.7	6.7	**13.3**	0.0	21.1	**21.1**
Transportation	0.0	0.0	**0.0**	0.0	12.5	**12.5**	6.7	6.7	**13.3**
Banking	3.7	14.8	**18.5**	12.9	12.9	**25.8**	12.9	0.0	**12.9**
Insurance	10.0	0.0	**10.0**	20.7	6.9	**27.6**	6.5	3.2	**9.7**
Real estate	0.0	0.0	**0.0**	8.7	26.1	**34.8**	0.0	0.0	**0.0**
Conglomerates	0.0	37.5	**37.5**	3.4	20.7	**24.1**	0.0	20.0	**20.0**
Other services				20.0	10.0	**30.0**	0.0	14.3	**14.3**
R^2		**39.3**			**27.3**			**18.5**	
aR^2		**35.6**			**22.9**			**13.6**	

Table 4: Nonlinear interest rate exposure

The table reports the percentage of nonfinancial firms that show a significant interest rate exposure χ_j for different interest rate variables and time periods (5% level). For each period, the left column refers to negative, the middle column to positive and the right column (bold figures) to all exposures, respectively.

Percentage of nonfinancial firms with significant exposure (5% level)															
	3-year periods									4-year period			5-year period		
	1987-89			1990-92			1993-95			1992-95			1991-95		
	-	+	±	-	+	±	-	+	±	-	+	±	-	+	±
Panel (a)	$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{It}^3 + \varepsilon_{jt}$														
Long-term rate	2.2	8.9	**11.2**	22.2	42.2	**64.4**	2.9	10.2	**13.1**	1.0	8.4	**9.4**	1.1	11.3	**12.3**
Interest rate spread	3.9	2.8	**6.7**	2.2	9.3	**11.5**	16.4	1.4	**17.9**	7.4	2.3	**9.7**	7.0	2.7	**9.7**
Short-term rate	16.8	6.1	**22.9**	14.1	11.2	**25.4**	11.7	6.9	**18.6**	6.9	4.6	**11.5**	7.0	4.6	**11.5**
Panel (b)	$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j sinh(R_{It}) + \varepsilon_{jt}$														
Long-term rate	2.8	7.8	**10.6**	24.9	44.4	**69.3**	4.3	10.7	**15.0**	3.3	10.5	**13.8**	2.7	12.1	**14.7**
Interest rate spread	3.4	2.8	**6.1**	2.2	14.9	**17.1**	16.2	1.2	**17.4**	6.4	3.3	**9.7**	5.6	2.7	**8.3**
Short-term rate	67.0	2.8	**69.8**	26.1	25.1	**51.2**	27.6	18.1	**45.7**	24.2	15.3	**39.5**	24.9	17.7	**42.6**

Table 5: Economic significance of linear and nonlinear exposures

The table reports the mean exposure coefficient multiplied by one (Panel (a)) and two (Panel (b)) standard deviations of the interest rate variable, respectively. Exposures are estimated by regressions of interest rates and the market index on stock returns. Nonlinear exposures are estimated with the cubic function.

	Linear exposure					**Nonlinear exposure**				
		3 years		**4 years**	**5 years**		**3 years**		**4 years**	**5 years**
	1987-89	**1990-92**	**1993-95**	**1992-95**	**1991-95**	**1987-89**	**1990-92**	**1993-95**	**1992-95**	**1991-95**
Panel (a): Mean regression coefficient multiplied by 1 standard deviation of the risk factor										
Long-term rate	0.6720	0.7062	0.5692	0.5585	0.6301	0.2230	0.0346	0.1245	0.1168	0.1217
Interest rate spread	-0.1711	0.8379	-0.7962	-0.2015	-0.0771	-0.0423	0.1505	-0.4004	-0.2110	-0.1102
Short-term rate	0.3760	0.2674	-0.1510	-0.1022	-0.1284	-0.0586	0.0007	-0.0201	-0.0154	-0.0191
Panel (b): Mean regression coefficient multiplied by 2 standard deviations of the risk factor										
Long-term rate	1.3441	1.4123	1.1384	1.1170	1.2602	1.7840	0.2764	0.9961	0.9346	0.9737
Interest rate spread	-0.3423	1.6757	-1.5925	-0.4029	-0.1543	-0.3383	1.2039	-3.2030	-1.6883	-0.8818
Short-term rate	0.7520	0.5347	-0.3021	-0.2044	-0.2567	-0.4691	0.0056	-0.1608	-0.1231	-0.1525

Table 6: Nonlinear interest rate exposure by industry

The table reports the percentage of nonfinancial firms that show a significant interest rate exposure χ_j with regard to the long-term interest rate variable (DEM10Y) for different industries and time periods (5% level). For each period, the left column refers to negative, the middle column to positive and the right column (bold figures) to all exposures, respectively. R^2 indicates the average of this statistic for all regressions in the period in %; aR^2 is the adjusted R^2 statistic.

$$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R^3_{DEM10Yt} + \varepsilon_{jt}$$

	Percentage of nonfinancial firms with significant exposure (5% level)								
		1987-89			**1990-92**			**1993-95**	
	-	**+**	±	**-**	**+**	±	**-**	**+**	±
Agriculture/forestry	0.0	0.0	**0.0**	0.0	100	**100**	0.0	0.0	**0.0**
Public utilities/mining	15.4	0.0	**15.4**	26.9	30.8	**57.7**	3.8	3.8	**7.7**
Chemicals	0.0	12.5	**12.5**	18.2	50.0	**68.2**	0.0	15.0	**15.0**
Rubber/plastics	25.0	0.0	**25.0**	22.2	44.4	**66.7**	0.0	10.0	**10.0**
Stone/clay/glass	0.0	0.0	**0.0**	13.0	47.8	**60.9**	0.0	15.8	**15.8**
Primary metal	0.0	0.0	**0.0**	14.3	71.4	**85.7**	0.0	7.7	**7.7**
Industrial machinery	4.5	13.6	**18.2**	13.7	52.9	**66.7**	0.0	15.1	**15.1**
Transp. equipment	0.0	20.0	**20.0**	7.1	64.3	**71.4**	0.0	6.7	**6.7**
Electr. equipment	0.0	5.3	**5.3**	23.1	30.8	**53.8**	3.3	10.0	**13.3**
Misc. manufacturing	0.0	0.0	**0.0**	7.1	50.0	**57.1**	6.7	6.7	**13.3**
Paper/publishing	0.0	28.6	**28.6**	13.3	46.7	**60.0**	12.5	6.2	**18.8**
Textile/leather	0.0	0.0	**0.0**	24.2	33.3	**57.6**	3.3	6.7	**10.0**
Food/tobacco	0.0	0.0	**0.0**	38.6	36.4	**75.0**	0.0	0.0	**0.0**
Construction	0.0	0.0	**0.0**	0.0	50.0	**50.0**	0.0	16.7	**16.7**
Wholesale trade	0.0	0.0	**0.0**	18.8	25.0	**43.8**	10.0	0.0	**10.0**
Retail trade	0.0	22.2	**22.2**	66.7	13.3	**80.0**	10.5	15.8	**26.3**
Transportation	0.0	50.0	**50.0**	18.8	31.2	**50.0**	13.3	26.7	**40.0**
Banking	3.7	3.7	**7.4**	48.4	22.6	**71.0**	12.9	0.0	**12.9**
Insurance	5.0	5.0	**10.0**	65.5	17.2	**82.8**	6.5	6.5	**12.9**
Real estate	0.0	0.0	**0.0**	30.4	43.5	**73.9**	0.0	0.0	**0.0**
Conglomerates	0.0	18.8	**18.8**	17.2	48.3	**65.5**	0.0	20.0	**20.0**
Other services				30.0	30.0	**60.0**	0.0	21.4	**21.4**
R^2		**39.0**			**27.3**			**18.4**	
aR^2		**35.3**			**22.9**			**13.5**	

Table 7: Ratio of firms with nonlinear and linear interest rate exposure

The table presents the ratio of the number of nonfinancial firms with significant nonlinear and linear exposure (5% level) from regressions of interest rates and the market index on stock returns. While results in Panel (a) are based on all data, the largest positive and negative interest rate change is excluded for regressions in Panel (b).

	3-year periods									**4-year period**			**5-year period**		
	1987-89			**1990-92**			**1993-95**			**1992-95**			**1991-95**		
	-	**+**	±	**-**	**+**	±	**-**	**+**	±	**-**	**+**	±	**-**	**+**	±
All interest rate movements															
Long-term rate	2.5	0.7	**0.9**	6.1	2.6	**3.3**	3.1	1.1	**1.3**	4.1	1.1	**1.4**	5.4	0.9	**1.1**
Interest rate spread	0.6	0.8	**0.7**	1.0	0.9	**0.9**	1.1	1.7	**1.1**	1.2	1.0	**1.1**	1.4	1.1	**1.3**
Short-term rate	19.7	0.6	**8.3**	9.7	3.8	**5.5**	6.1	5.0	**5.6**	6.7	8.5	**7.3**	4.9	7.4	**5.7**
Largest positive and negative interest rate movement excluded															
Long-term rate	4.1	0.4	**0.9**	11.5	2.1	**2.8**	3.4	1.9	**2.2**	3.9	1.4	**1.7**	7.0	1.2	**1.5**
Interest rate spread	0.6	1.0	**0.8**	1.1	1.0	**1.0**	1.1	0.8	**1.0**	1.2	0.8	**1.1**	1.0	1.0	**1.0**
Short-term rate	19.7	1.0	**3.8**	6.1	1.4	**2.0**	1.3	5.7	**2.9**	1.5	2.5	**2.0**	1.6	2.4	**1.9**

Table 8: Partially nonparametric regressions

The table reports the percentage of nonfinancial firms where the coefficients of all regressors (including and excluding the market index, respectively) are significantly different from 0 (F-Test on the 5% level) for different interest rates and time periods.

$$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{It} + \delta_{j1} D_{1t} + \delta_{j2} D_{1t} R_{It} + \delta_{j3} D_{2t} + \delta_{j4} D_{2t} R_{It} + \varepsilon_{jt}$$

$$with\ D_{1t} = \begin{cases} 1\ if\ -0.5\sigma_{R_{It}} < R_{It} \leq 0.5\sigma_{R_{It}} \\ 0\ otherwise \end{cases} \quad and \quad D_{2t} = \begin{cases} 1\ if\ \ 0.5\sigma_{R_{It}} < R_{It} \\ 0\ otherwise \end{cases}$$

	Percentage of nonfinancial firms with significant F-test for dummy variables / all variables (5% level)				
		3-year periods		**4-year period**	**5-year period**
	1987-89	**1990-92**	**1993-95**	**1992-95**	**1991-95**
Long-term rate	9.5 / 70.9	6.8 / 51.7	7.1 / 31.0	7.4 / 37.2	4.6 / 44.5
Interest rate spread	5.0 / 66.5	7.6 / 53.7	6.9 / 31.0	4.8 / 39.8	5.4 / 44.0
Short-term rate	2.2 / 67.6	6.6 / 50.7	4.5 / 26.2	4.3 / 35.2	3.8 / 42.6

Table 9: Sign and size tests of regression residuals

The table reports the percentage of nonfinancial firms with significant coefficients ($\phi_j, \lambda_j, \omega_j$) of the sign/size test regression for different interest rates and time periods (5% level).

$$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{It} + \varepsilon_{jt}$$

$$\frac{\varepsilon_{jt}}{\sigma_{\varepsilon_{jt}}} = \delta_j + \phi_j Z_{It}^{-} + \lambda_j Z_{It}^{-} R_{It} + \omega_j Z_{It}^{+} R_{It} + \vartheta_{jt}$$

$$\text{with } Z_{It}^{-} = \begin{cases} 1 & \text{if } R_{It} < 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{and} \quad Z_{It}^{+} = 1 - Z_{It}^{-}$$

Percentage of nonfinancial firms with significant coefficients (5% level)

		3-year periods			**4-year period**	**5-year period**
		1987-89	**1990-92**	**1993-95**	**1992-95**	**1991-95**
Long-term rate	ϕ_J	7.8	5.9	10.7	7.4	8.6
	λ_j	9.5	8.3	11.7	7.9	7.0
	ω_j	14.5	23.7	12.1	10.7	12.6
Short-term rate	ϕ_J	8.9	10.7	12.6	6.6	7.2
	λ_j	3.4	15.6	4.0	2.8	1.9
	ω_j	8.9	10.0	19.0	13.5	11.8

Table 10: Determinants of the interest rate exposure

The table reports the regression coefficients γ_1 of alternative exposure determinants ED_j (i.e. financial leverage, firm liquidity) for different periods. Regressions with financial leverage are based on the normal exposure estimates, while regressions with firm liquidity (cash flow/total assets) use the absolute value of the exposure estimates as regressand. *, ** and *** indicate the 10%, 5% and 1% significance level, respectively.

	1987-89	**1990-92**	**1993-95**	**1992-95**	**1991-95**
	$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{DEM10Yt} + \varepsilon_{jt}$			$\hat{\chi}_j = \gamma_0 + \gamma_1 ED_j + \vartheta_j$	
Leverage	-0.0159	0.1548	0.1198	0.1372	0.1237
Cash flow / total assets	-0.1010	-0.3207**	-0.4250***	-0.5016***	-0.4745***
	$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R^3_{DEM10Yt} + \varepsilon_{jt}$			$\hat{\chi}_j = \gamma_0 + \gamma_1 ED_j + \vartheta_j$	
Leverage	-0.0173	0.0008	-0.0004	0.0005	0.0007
Cash flow / total assets	-0.0025	-0.0008	-0.0096***	-0.0097***	-0.0102***