Linear and Nonlinear Foreign Exchange Rate Exposures

of German Nonfinancial Corporations

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Abstract

It has been viewed as an unsolved puzzle that only for a small number of firms a significant impact of foreign exchange rate risk on firm value could be detected empirically. This paper investigates whether the results of previous studies can be explained by the fact that only the linear exposure component has been estimated or that exchange rate indices were used. For a comprehensive sample of German firms, empirical evidence is presented for the existence of significant linear and nonlinear exposures, which can be identified for bilateral as well as multilateral foreign exchange rates. The percentage of foreign sales, measures of firm liquidity and industry sectors are significant determinants of the exposure.

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1 Introduction

The foreign exchange rate exposure of nonfinancial firms is a contentious issue. Financial theory predicts an impact of foreign exchange rate risk on firm value due to corporate foreign currency cash flows originating, for example, from export and import transactions, foreign debt, cash flows of foreign subsidiaries and foreign portfolio investments. Moreover, more complicated exposures may result from the effect unexpected foreign exchange rate changes have on sales prices and quantities, production costs, market share and, thus, the competitive position of a firm. Contrary to expectations, a significant impact of foreign exchange rate risk on firm value can be found for only a small number of corporations (e.g. He/Ng 1998, Bartov/Bodnar 1994, Jorion 1990), a finding which has been perceived as the "exposure puzzle."

While many studies look at the exposure of U.S. corporations, firms in other countries (e.g. Japan, Europe, Australia) have become subject to investigation more recently. This paper presents a comprehensive study of the foreign exchange rate exposure of a large sample of German nonfinancial corporations. While German firms have not been subject to a broad empirical analysis, they lend themselves particularly well to the study of the exposure phenomenon since Germany is a very open economy that depends more than other countries, including the United States and Japan, on international business (as measured by exports or imports relative to GDP).

Several potential explanations exist for the low significance of the results of previous studies. Most importantly, existing studies investigate almost exclusively linear foreign exchange rate exposures. While the assessment of linear exposures has been motivated for hedging with forwards and futures, i.e. instruments with a linear payoff structure (Adler/Dumas 1984), there exist also risk management instruments with nonlinear payoff profiles, such as options or portfolios of options. Since financial theory predicts that the exposure of firms may have a nonlinear component due to nonlinear relationships between corporate cash flows and exchange rates (e.g. Stulz 2002, Kanas 1996a, 1996b, Giddy/Dufey 1995, Sercu/Uppal 1995, Ware/Winter 1988), the assessment of nonlinear exposures has important implications for corporate risk management. Another reason for insignificant foreign exchange rate exposures might exist in the use of foreign exchange rate indices for exposure estimation because the weighting of different foreign exchange rates in the indices is not representative for the individual firm. Additionally, the aggregation of several currencies may lead to diversification effects, which reduce the statistical significance of the exposures since changes in individual currencies may partially offset each other.

Motivated by these potential shortcomings in the empirical exposure literature, this paper offers a re-investigation of the foreign exchange rate exposure phenomenon using a new data set and improved methodologies. The study analyzes the exposure of 447 publicly traded nonfinancial corporations in Germany during the period 1981-95. The results show some significance for linear exposures of German corporations with regard to the currencies of Germany's most important trading partners. In addition, nonlinear exposures are substantially more statistically significant for all foreign exchange rates. These results persist even when excluding the largest exchange rate movements. Sign/size bias tests and partially nonparametric regressions yield supporting evidence to corroborate the nonlinear feature of the exposure. Interestingly, multilateral foreign exchange rates do not cause excessive diversification effects precluding the identification of significant exposures for German firms. The ratio of foreign sales to total sales, firm liquidity and industry classes constitute empirically significant determinants of the foreign exchange rate exposure.

The paper is organized as follows. Section 2 presents a review of the relevant literature. The hypotheses and regression models are introduced in Section 3, while the data set is described in Section 4. Section 5 presents the empirical results, and Section 6 concludes.

2 Literature Review

A study by Jorion (1990), which analyzes the influence of foreign exchange rate risk on a sample of 287 U.S. multinationals, is often referred to as the starting point for the empirical investigation of foreign exchange rate exposures. Even though companies with strong international business are selected, only a few more firms than expected by chance show a significant exposure with regard to changes in a multilateral foreign exchange rate (15 companies or 5.2% at the 5% level). The use of industry portfolios leads to results of 20% (Jorion 1991). A later study of U.S. multinational companies by Choi/Prasad (1995) finds similar results (14.9% for individual firms and 10% for industry portfolios at the 10% level). In a study of 171 Japanese multinationals, 26.3% and 53.8% show a significant foreign exchange rate exposure with regard to a multilateral exchange rate index during different time periods (He/Ng 1998). There are fewer studies that use bilateral as opposed to multilateral foreign exchange rates. In a study by Khoo (1994), the percentage of Australian mining companies with significant exposure is only little above the significance level. Doukas/Hall/Lang (1999) find that some Japanese companies exhibit significant foreign exchange rate exposures with regard to the USD (14.3%) as well as a multilateral foreign exchange rate index (14.1%).

Some empirical studies also investigate the factors that determine the size of the exposure. In general, a positive relationship between the degree of international business and the exposure is expected. According to results by Bodnar/Gentry (1993), the foreign exchange rate exposure of U.S. firms is determined empirically by the ratio of foreign assets to total assets and the use of input factors with world market price. Other studies identify the percentage of foreign sales (Simkins/Laux 1996, Jorion 1990) or firm size (Simkins/Laux 1996) as important exposure determinants for U.S. corporations. As industries differ in their characteristics, it comes as no surprise that exposure studies generally report large differences in the exposure across industry classes (e.g. Bodnar/Gentry 1993). Allayannis/Ihrig (2001) show the impact of industry competitive structure, export share and import share on the exposure.

3 Hypotheses and Methodology

3.1 Linear Foreign Exchange Rate Exposures

In comparison with other major industrialized countries, international trade relative to the size of the economy (GDP) is more important for Germany than for the other G7 countries (Figure 1).

Consequently, Germany appears an ideal laboratory to study foreign exchange rate exposures, justifying the expectation of significant foreign exchange rate effects. The most important trading partners of Germany are France, the Netherlands, Italy, the U.K., the United States, Belgium/Luxembourg, Switzerland, Austria and Japan. While the analysis of trade flows provides indications about important currencies of denomination, the currencies that economically determine the size of corporate cash flows in domestic currency (currency of determination, Dufey 1972) may be more important for the economic foreign exchange rate exposure than the currencies in which the cash flows are actually denominated (currency of denomination).

To illustrate, even a purely domestic firm may have a foreign exchange rate exposure due to import competition (Hodder 1982) or the threat of it. The currencies of determination thus have to do with the competitiveness of countries enabling its firms to determine prices and thus ultimately drive the economic exposure. The United States and Japan play an important role in international competition based on world exports shares (OECD 1996). Consequently, the U.S. Dollar and the Japanese Yen are of special interest for the exposure analysis as German corporations might be particularly strongly affected by changes in these currencies.

In addition to bilateral exchange rates, it is interesting to employ foreign exchange rate indices, as there may exist a diversification effect of multilateral foreign exchange rates. While depreciations of the German Mark are beneficial for German exports as well as for German products competing with foreign imports in Germany, firms may also rely on imported intermediate or final products. As a result, it is difficult to correctly predict the sign of the exposure for every single firm and currency. At the same time, exposures estimated based on multilateral exchange rates are expected to be less significant compared to estimations based on bilateral exchange rates.

For empirically assessing the foreign exchange rate exposure, the following regression model is estimated using OLS:

$$R_{jt} = \alpha_j + \beta_j R_{Mt} + \chi_j R_{St} + \varepsilon_{jt}, \tag{1}$$

where R_{jt} represents 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_{St} the percentage change of currency S in period t.

3.2 Nonlinear Foreign Exchange Rate Exposures

Empirical exposure studies in the literature have investigated almost exclusively linear exposure profiles. A linear exposure can result e.g. due to contractual payment obligations or claims in foreign currency (e.g. foreign currency receivables), which are fulfilled with certainty independent of the foreign exchange rate (no default risk). The value of a firm, however, could depend in a very complex way on changes in foreign exchange rates. Indeed, regression analysis with linear foreign exchange rate variables has first been suggested by Adler/Dumas (1984) to analyze the exposure of a foreign currency receivable. They demonstrated that if the foreign currency cash flow is uncertain, a regression with a linear foreign exchange rate variable determines only the part of the exposure that can be eliminated with linear risk management instruments in order to minimize the variance of the overall position. However, Adler/Dumas neither consider nonlinearities in the exposure, nor intend to estimate the entire foreign exchange rate exposure.

Corporations typically focus their risk management activities on transaction (or accounting) exposure and employ primarily linear hedging instruments (Bodnar/Gebhardt 1999, Bodnar/Hayt/Marston 1998).[1] Consequently, corporate risk management reduces some of the linear exposure, but since firms often engage only in selective hedging (Brown/Crabb/Haushalter 2001, Bodnar/Gebhardt 1999), the residual linear exposure may still be large enough to be identified empirically. In contrast, the nonlinear foreign exchange rate exposure is rarely taken into account by corporations when designing their hedging strategy (Bodnar/Gebhardt 1999, Bodnar/Hayt/Marston 1998) and thus may be empirically significant as well if it is an important component of the economic exposure. From a practical point of view, it is interesting to estimate nonlinear exposures as

[1] Only 18.1% of German nonfinancial firms consider currency options important foreign currency derivatives (Bodnar/Gebhardt 1999).

well since risk management instruments with nonlinear profiles (e.g. options) exist that can possibly be used to eliminate existing nonlinear exposures.

Financial theory offers several explanations for the existence and nature of nonlinear exposures. Nonlinear foreign exchange rate exposures result if corporate cash flows are a nonlinear function of foreign exchange rates (Stulz 2002, Sercu/Uppal 1995). As a result, the exposure is itself a function of the exchange rate. As most future corporate cash flows are uncertain (in foreign as well as in national currency), prices and quantities of sales may indeed change depending on the exchange rate. In fact, companies react and adjust in many ways to foreign exchange rate changes. In particular, multinational corporations may be able to shift manufacturing, sourcing or other activities among plants in different countries in response to movements in foreign exchange rates (Kogut/Kulatilaka 1994). As a matter of fact, it has been argued that profits are a nonlinear function of exchange rates when production and import or export decisions are flexible, leading to a nonlinear, convex economic exposure (Ware/Winter 1988).

Default risk may also be related to foreign exchange rate risk and cause a nonlinear feature of the exposure (Stulz 2002). To illustrate, a customer of a firm may default on a foreign currency payment if his home currency depreciates making the payment more expensive in local currency. Consequently, even the default risk of a local customer or supplier may be related to exchange rate risk if his business is directly or indirectly affected by currency movements. As only exchange rate movements in one direction (i.e. either appreciations or depreciations) will hurt firm performance possibly causing default, the resulting exposure is nonlinear.

More generally, both real and financial foreign currency options at the firm level induce nonlinearities in the relationship between firm value and foreign exchange rates due to their nonlinear payoff profiles, unless they are used to hedge existing nonlinear foreign exchange rate positions (Giddy/Dufey 1995, Ware/Winter 1988). In the same vein, multiple currency price lists for corporate products create a nonlinear exposure because, in effect, an option is granted to the customers of a firm (Kanas 1996a, Kanas 1996b, Giddy/Dufey 1995).

A nonlinear exposure can also be the result of asymmetric reactions of firm value to exchange rate movements. Exporters may use greater pricing-to-market during depreciations than during appreciations as a consequence of capacity constraints in their distribution networks or quantitative trade restrictions (a dual-currency price list implies that the effect of a depreciation is fully passed-on to the foreign customer). On the other hand, pricing-to-market may actually be greater during appreciations, if firms try to build market share subject to the threat of trade restrictions (Knetter 1994). As a result of export price adjustments, the cash flow and value of an exporting firm may be a convex function of the exchange rate (Sercu/Uppal 1995). As a matter of fact, there exists some empirical evidence of asymmetries in corporate foreign exchange rate exposures (Miller/Reuer 1998).

Finally, small foreign exchange rate changes are possibly dominated by other price relevant information and, thus, are reflected less in stock prices. Large foreign exchange rate changes, however, may impact firm value more strongly and reveal the actual relationship. Overall, it appears sensible to assume a clear direction of the foreign exchange rate effect (i.e. firms either benefit or lose from an exchange rate depreciation), which does not, however, need to be linear.

Since the above theoretical arguments suggest that nonlinear exposures exist and since empirical survey evidence indicates that this is the least commonly hedged part of the exposure, it appears reasonable and interesting to study relationships between exchange rates and firm value that are not linear. As this is the first paper to investigate nonlinear exposures, we are agnostic about the nature of the nonlinearities and perform several different tests with and without structure, including nonparametric tests. As a first approach to assess nonlinear exposures, several generic types of nonlinear functions are employed that impose some structure on the form of the exposure. A general regression equation can be written as:

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

where R_{jt} represents the stock return of company j in period t, R_{Mt} the return on the capital market index M in period t, R_{St} the percentage change of currency S in period t, and $f(.)$ a nonlinear function of the exchange rate. Since the relationship between innovations in exchange rates and stock prices is not linear as in the classical model based on Adler/Dumas (1984), the effect of foreign exchange rate risk on firm value depends on the size of the exchange rate shock. A significant coefficient χ_j would suggest evidence of nonlinear foreign exchange rate exposures.

In general, different generic types of nonlinear functions consist of the cubical function, the sinus hyperbolicus, the cubical root function, and the inverse sinus hyperbolicus.[2] The former two specifications are used to estimate convex exposures, while the latter two are employed to capture concave exposures (based on their form in the first quadrant). The purpose of these regressions is not to suggest one specific exposure profile as appropriate for all firms. As a matter of fact, as the idea of nonlinear exposure relaxes the assumption of a linear relationship between firm value and exchange rates, it may indeed be realistic to expect that every firm has a different exposure profile, depending on its exports and imports, the nature of competition it is facing, its risk management strategy, the existence of real options, and its pricing policy. Thus, it is likely that the form of the exposure is not uniform across firms, but firm-specific. Moreover, the exposure may also possibly not be symmetric as implicitly assumed by these generic functions, but firms may react differently e.g. in response to currency appreciation and depreciations.

Nevertheless, it appears challenging to justify economically a certain functional form. The cubic root function may be consistent with the idea of real options mitigating the effect of large exchange rate movements. However, with this functional form small exchange rate movements have a

[2] The hyperbolic sine function describes the following relationship: $f(x) = sinh(x) = (e^x - e^{-x})/2$, and the inverse hyperbolic sine function is defined as $f(x) = sinh^{-1}(x) = ln(x + \sqrt{x^2 + 1})$. Both are characterized by a positive slope in the origin.

very strong effect on firm value, which might not appear very plausible. The cubic function, on the other hand, may not be consistent with real options, however it accommodates the idea that small exchange rate movements are dominated by other price relevant information. Moreover, it could be the result of firms adjusting export prices in response to exchange rate movements. Convex and concave functions may generally both be seen in line with cash flows being a nonlinear function of the exchange rate.

Since it is difficult to suggest a priori a certain exposure profile, the purpose of the regressions consists primarily in the motivation of nonlinear exposures and the estimation of some exemplary, generic functional forms. While these types of nonlinear functions relax the common assumption of linear exposures and, thus, may already capture the exposure more realistically, they are 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 was estimated.

In addition, more general tests are conducted that test nonlinearity without specifying the functional form of the relationship. In particular, sign bias tests, negative size bias tests, and positive size bias tests are performed. These are diagnostic tests of the regression residuals that can be used to check potential misspecifications of the linear regression model (1). The sign bias test employs the variable Z_{St}^{-} that takes a value of one when the exchange rate change R_{St} is negative or zero otherwise. It examines the impact of positive and negative exchange rate shocks on stock returns not predicted by the model. The negative size bias test considers the variable $Z_{St}^{-}R_{St}$ and thus investigates differences in the effect of large and small negative exchange rate movements on stock returns. Likewise, the positive size bias test utilizes the variable $Z_{St}^{+}R_{St}$ where $Z_{St}^{+} = 1 - Z_{St}^{-}$. It focuses on the different impact on stock returns that large and small positive exchange rate changes have and that are not captured by the model. The distinction between negative and positive exchange rate shocks allows for asymmetry in the exchange rate exposure. As a result, the following model is estimated:

$$
\begin{aligned}
&R_{jt} = \alpha_j + \beta_j R_{Mt} + \chi_j R_{St} + \varepsilon_{jt} \\
&\frac{\varepsilon_{jt}}{\sigma_{\varepsilon_{jt}}} = \delta_j + \phi_j Z_{St}^{-} + \lambda_j Z_{St}^{-} R_{St} + \omega_j Z_{St}^{+} R_{St} + \vartheta_{jt} \\
&with \;\; Z_{St}^{-} = \begin{cases} 1 & if \; R_{St} < 0 \\ 0 & otherwise \end{cases} \quad and \quad Z_{St}^{+} = 1 - Z_{St}^{-}
\end{aligned}
\tag{3}
$$

Another general specification to investigate the hypothesis of nonlinear exposures consists of partially nonparametric regressions. The model is specified as:

$$
\begin{aligned}
&R_{jt} = \alpha_j + \beta_j R_{Mt} + \chi_j R_{St} + \delta_{j1} D_{1t} + \delta_{j2} D_{1t} R_{St} + \delta_{j3} D_{2t} + \delta_{j4} D_{2t} R_{St} + \varepsilon_{jt} \\
&with \; D_{1t} = \begin{cases} 1 \; if \; -0.5\sigma_{R_{St}} < R_{St} \leq 0.5\sigma_{R_{St}} \\ 0 \; otherwise \end{cases} \quad and \quad D_{2t} = \begin{cases} 1 \; if \;\; 0.5\sigma_{R_{St}} < R_{St} \\ 0 \; otherwise \end{cases}
\end{aligned}
\tag{4}
$$

This piece-wise linear regression allows for different relationships between exchange rate risk and firm value for large (exceeding 0.5 standard deviations) negative and positive as well as intermediate exchange rate shocks. It thus accommodates asymmetry in the exposure and small exchange rate changes being unimportant for exposure.

3.3 Determinants of the Foreign Exchange Rate Exposure

With regard to exposure determinants, it is often assumed that primarily multinational firms exhibit a foreign exchange rate exposure due to their international activities. On the other hand, it is primarily companies with international business that, firstly, may be aware of their exposures and, secondly, have the means to diversify currency risk or to use operative hedging. Due to its ambivalence, the relationship between indicators of international business and foreign exchange rate exposure is an empirical question. At the same time, multinationals are typically relatively large firms, motivating the investigation of the relationship between foreign exchange rate exposure and firm size.

Firm liquidity represents effectively a hedge against foreign exchange rate risk as it can buffer adverse foreign exchange rate movements and thus reduces the expected cost of financial distress. Consequently, the relationship between (the absolute value of) the exposure and measures of firm liquidity is likely to be negative. Moreover, the foreign exchange rate exposure is expected to differ across industry sectors. In order to test these hypotheses, a second stage, cross-section regression is estimated with the exposure coefficients of the firm-specific time-series regressions as regressands. As determinants of the exposure $\hat{\chi}_j$, the ratio of foreign sales to total sales is used to assess the degree of international business activities. Firm size is represented by sales, the number of employees, and total assets. Measures of firm liquidity are cash/total assets, the quick ratio, the current ratio, and cash flow/total assets. With D_k denoting the exposure determinants and I_i the industry dummies, the regression equation for the estimation of exposure determinants can be written as:

$$\hat{\chi}_j = \gamma_0 + \sum_k \gamma_k D_{kj} + \sum_i \rho_i I_{ij} + \tau_j . \tag{5}$$

4 Sample Selection and Data Description

The empirical analysis comprises the sample period 1981-1995, which is subdivided into several consecutive 3-, 4- and 5-year periods. The choice of the length of period is based on the assumption that firms will react to their exposure with operative hedging in the long run while using financial hedging – even though possibly less complete – for shorter horizons. Since it will take between 3 to 5 years to implement operative hedges, longer intervals appear less desirable for exposure estimation. Furthermore, as the exposure is changing over time, shorter rather than longer estimation periods are desirable.

For each period, the sample consists of all German corporations that were actively traded on one of the 8 German stock exchanges with data available on Datastream International.[3] Companies are excluded from the sample for periods in which their business activity exhibited a major structural change or in which the dominance of other effects (bankruptcy, liquidation, etc.) had to be assumed. As a result, a total of 447 nonfinancial corporations represent the sample for the empirical analysis.[4] Financial institutions are not included in the general sample due to their different asset characteristics and business objectives with regard to financial risks. In the industry analysis, however, results for 67 financial intermediaries, i.e. 34 banks and 33 insurance companies, are included for comparison. Based on their core business activity, all firms are classified into 22 industry classes accounting for changes in business focus over time (Table 1).

The broadest value-weighted stock market performance index available for Germany is the CDAX, which was obtained from the German stock exchange (Deutsche Börse AG). The CDAX as well as the individual stock price series account for dividend payments, stock splits etc. The exchange rates French Franc (FRF), Dutch Guilder (NLG), Italian Lira (ITL), British Pound (GBP), U.S. Dollar (USD), Belgian Franc (BEF), Swiss Franc (CHF), Austrian Schilling (ATS) and Japanese Yen (JPY) are available from the Deutsche Bundesbank (in DEM per unit of foreign currency). Applying the procedures and data used by the Bundesbank, multilateral foreign exchange rate indices of the currencies of 18 industrialized countries (TXI), 14 EU countries (TXEU), and the EMS membership countries (TXEMS) are calculated.[5] In addition, the European Currency Unit ECU (XEU) is used as a currency index.[6]

The ratio of foreign sales to total sales, the number of employees, the book value of 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 database

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[3] By determining the sample for each subperiod separately a survivorship bias is avoided, which could possibly lower the significance of the results if firms cease to exist due to their inability to manage foreign exchange risk effectively.

[4] Since not all companies are traded or otherwise eligible in all subperiods, the total number of firms that are subject to the study is not directly observable from the sample size of the subperiods.

[5] The construction of these official multilateral foreign exchange rates is described in Deutsche Bundesbank (1989).

[6] The weights of the currencies in the ECU reflect the relative economic importance of the member states (e.g. relative GNP and intra-European trade) and are re-examined every five years.

"Hoppenstedt Bilanzdaten – Deutsche Bilanzen" by Hoppenstedt. For each company and year, the annual report of the parent is selected that consolidates as many subsidiaries as available. Annual reports are assigned to the calendar year with the most overlap in time. Consequently, arithmetic averages of the available yearly data for each firm are calculated in each subperiod.

5 Empirical Tests and Results

5.1 Linear Foreign Exchange Rate Exposure

At the outset of the analysis, time-series regressions for each individual firm are estimated using regression model (1). Standard errors are corrected for autocorrelation and heteroscedasticity with the Newey-West method. The resulting percentage of corporations with significant foreign exchange rate exposure is above the significance level of 5% in almost all periods (Table 2). To illustrate, 29 (or 7.8%) of the 373 nonbanks in period 1991-95 had a significant exposure with regard to the U.S. Dollar; 22 of these exposures were positive and only 7 firms had a significant negative exposure. A larger number of firms with significant exposure are obtained for the following currencies where the percentage of firms with significant exposure across different time periods (i.e. 1981-85, 1986-90, 1991-95, 1992-95 and 1993-95) is in the range of 14.0%-24.8% (BEF), 11.5%-21.7% (FRF), 7.0%-13.4% (GBP), 10.1%-12.3% (NLG), 8.9%-14.0% (XEU) and 8.6%-15.5% (TXEU).

A potential reason why not more firms exhibit a significant impact of foreign exchange rate risk might exist in a strong statistical relationship between the regressors (multicollinearity). As a matter of fact, the more firms are affected by foreign exchange rate risk, the more the foreign exchange rate effect will show up in the market index inducing a strong link between the market index and foreign exchange rates. Nevertheless, all correlations between the foreign exchange rates and the CDAX (which are, however, a measure of the linear association between the variables only) turn out to be not very high.

The observation that the USD and the JPY appear not to be of greater importance than the currencies of other major trading partners can be interpreted as an indication that the exposure is not primarily driven by the currencies of determination. The sign of the exposure is often positive, but there are also several cases with significantly negative exposures. Contrary to expectations, a comparison of bilateral and multilateral foreign exchange rates does not reveal excessive diversification effects of currency indices precluding the identification of significant exposures.

In order to analyze the impact of foreign exchange rate changes on different industries, the percentage of firms with significant foreign exchange rate exposure is calculated by industry class (Table 3). This is preferred over the use of industry portfolios as firms differ even within the same industry with regard to size and direction of their exposure (Allayannis 1997). The U.S. Dollar is chosen as a foreign exchange rate variable for this analysis as it is generally viewed as having a dominating impact on the performance of the German economy. This might result from the volatility of the DEM/USD foreign exchange rate, the function of the USD as a currency of determination in many industries as well as the importance of the United States as a trading partner. Across all periods, a significant USD exposure is found to be strongest in the following industries: chemicals, primary metal industries, industrial machinery, construction, retail trade, and transportation. Industrial diversification apparently does not reduce the foreign exchange rate sensitivity substantially, as conglomerates exhibit significant exposures as well. As expected, financial firms in banking and insurance are also exposed to foreign exchange rate changes.

As other studies often analyze the exposure of the companies in the national stock market indices, results for the companies that have been part of the German stock market index DAX are calculated as well (Table 4). In order to make the results comparable with nonlinear exposures, which are studied in the next section, the exposure coefficients are multiplied with one standard deviation of the U.S. Dollar. The data shows that about half of the coefficients are positive, and that there are substantial differences in the linear foreign exchange rate exposure across firms even within industries. Many of the companies with significant exposures are in the sectors chemicals, banking and industrial conglomerates. Across time periods, between 7.7% and 16.7% of the DAX nonfinancial firms show a significant dollar exposure, which is similar to the findings for the entire sample. DAX companies are very large companies (size is one of the selection criteria for index membership), which may be more likely to have international business and thus large exposures, but there may also be economies of scale for corporate risk management.

5.2 Nonlinear Foreign Exchange Rate Exposure

In order to examine nonlinear structures in the foreign exchange rate exposure, regressions for alternative types of nonlinear foreign exchange rate variables are estimated. With convex specifications, a large number of firms exhibit a significant foreign exchange rate exposure. In all periods, the percentage of firms with significant exposure is well above the significance level and often exceeds 20%. Generally, convex exposure profiles are statistically more significant than linear specifications, while concave specifications are typically not statistically more significant than linear ones. Therefore, only results for convex exposures are reported (Table 5).[7] For the individual currencies, the proportions of firms with significant exposures in the sample are: 11.5%-28.0% (ATS), 40.8%-69.0% (BEF), 8.6%-16.3% (CHF), 27.9%-67.5% (FRF), 10.5%-63.3% (GBP), 10.2%-37.5% (ITL), 12.1%-25.5% (JPY), 13.2%-61.8% (NLG), and 13.1%-23.1% (USD).

Interestingly, while there is only weak significance of linear foreign exchange rate exposure of German firms vis-à-vis changes in the Yen, high significance is obtained with nonlinear specifications for the JPY as well. The currency indices show percentages of firms with significant exposures of 15.5%-43.6% (XEU), 21.4%-31.0% (TXEMS), 14.7%-40.6% (TXEU), and 11.8%-19.3% (TXI). Similar to linear foreign exchange rate exposures, the results do not indicate that primarily the currencies of determination as opposed to the currencies of denomination are relevant for the economic foreign exchange rate exposure.

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[7] All tables show results for the cubical function, but some currencies show even higher significance with the sinus hyperbolicus (GBP: 11.9%-66.2%, ITL: 7.0%-65.7%, JPY: 25.6%-53.6%, USD: 11.5%-54.6%), which may allow for stronger effects of small exchange rate movements compared to the cubic function.

In addition to the statistical significance, which is generally higher for the nonlinear exposure component than for the linear one, the economic importance of the exposures has to be considered. In order to compare the economic significance of linear and nonlinear exposures, the mean exposure coefficient across all nonfinancial firms is multiplied with one and two standard deviations of the exchange rate, respectively (Table 6). To illustrate, a depreciation of the U.S. Dollar of one standard deviation during the period 1991-95 increased stock prices on average by 0.29%. In most cases, linear exposures have a stronger bearing on stock prices than nonlinear ones, which however become more important with increasing size of the exchange rate movement.

The high significance of the convex foreign exchange rate exposure of the entire sample is also reflected in highly significant U.S. Dollar exposures in most of the industry sectors (Table 7). Especially during the period 1991-95, many industries are strongly affected by changes in the foreign exchange rate. Especially the industry sectors public utilities/mining, chemicals, stone/clay/glass, transportation equipment, retail trade and conglomerates show high USD exposures. Financial institutions are also subject to nonlinear foreign exchange rate risk.

The analysis of the nonlinear foreign exchange rate exposure of the DAX companies shows slightly higher percentages of firms with significant exposure per period as compared to the entire sample and substantially higher percentages compared to linear exposures (Table 8). Up to one third of the DAX nonfinancial firms have a significant USD exposure. Foremost companies in the industries chemicals, transportation equipment, wholesale trade, transportation, banking, and conglomerates are sensitive to nonlinear changes in the USD.

To investigate the relationship between linear and convex exposures further, regressions with both types of variables (linear and nonlinear) are estimated (Table 9). The results confirm the finding that the foreign exchange rate exposure exhibits an important nonlinear structure, since the nonlinear exposure component is of stronger statistical significance than the linear one. In order to check the robustness of the results, regressions are estimated for which the largest positive and negative exchange rate movement for each currency is excluded to investigate how much the results are influenced by extreme observations (Table 10). For the CHF, 32 firms had a significant nonlinear and 21 firms had a significant linear exposure during the period 1991-95 (32/21=1.5). Without the largest positive and negative Swiss Franc movements, the nonlinear (linear) exposure is significant for 41 (18) firms (41/18=2.3).

While nonlinear exposures lose significance, the number of firms with significant foreign exchange rate exposure generally remains higher for nonlinear specifications compared to linear ones, suggesting that the results are not exclusively driven by few extreme market movements. Moreover, as small exchange rate movements are possibly dominated by other effects on stock price, large changes of the exchange rate, which are part of the data set as well, might actually better reveal the relationship between exchange rate risk and stock returns.

Sign bias tests and size bias tests provide some evidence in support of nonlinear exposures as well, since the linear regression model appears to be misspecified in several cases (Table 11).[8] To illustrate, the coefficients for the sign bias variable, the positive size bias variable and the negative size bias variable are significant for 4.3%, 8.6% and 9.7%, respectively, for regressions with the Japanese Yen during the period 1991-95. Interestingly, residuals from a regression with the market index as only regressor, i.e. without an exchange rate variable, show a similar pattern, which might indicate that the market largely captures the exchange rate effect already.

Finally, the nonlinear feature of the exposure is assessed with partially nonparametric regressions. Since there is a tradeoff between the number of subsamples of exchange rate changes and the degrees of freedom, regressions are run for alternatively 2, 3 and 4 subsamples. F-tests including the coefficient of the market typically lead to the rejection of the null (5% significance level), and the hypothesis that the coefficients of all exchange rate variables are equal to zero can be rejected in

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[8] F-tests show that the nonlinear variable significantly adds to the linear model in several cases.

several cases as well (Table 12). For instance, for the period 1991-95, F-tests including (excluding) the market index are significant for 46.1% (6.7%) of the regressions with nonfinancial firms for the U.S. Dollar.

5.3 Determinants of Foreign Exchange Rate Exposure

In order to estimate the determinants of the foreign exchange rate exposure, the estimated exposure coefficients of the broadest foreign exchange rate index TXI are used as exogenous variables in a cross-sectional regression. The percentage of foreign sales, measures of firm size and firm liquidity as well as industry dummy variables are employed as regressors to explain the foreign exchange rate exposure. The industry dummy variables are defined such that the effect is measured relative to the largest sector (industrial machinery). Only one measure of size and liquidity is used at a time because the alternative size and liquidity variables are highly correlated among each other.

Furthermore, the dependent variable is not the same for the different exposure determinants. Foreign sales are expected to be (positively) related to the size and the direction of the exposure. By the same token, firm size is assumed to be related to the degree of international business and is thus assumed to have an impact on the direction of the exposure as well. In contrast, firm liquidity should not be related to the sign, but only the size of the exposure, as liquidity is expected to reduce exposures of either direction. Consequently, liquidity variables require the absolute value of the exposure coefficient as dependent variable. Combining all three types of determinants 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. Standard errors of the estimates are corrected for autocorrelation and heteroscedasticity with the Newey-West procedure.

As in Jorion (1990), the regression coefficient of the percentage of foreign sales is positive in many cases, and positive and significant in the periods 1981-85 and 1986-90 (Table 13). In later periods, the coefficients are negative, but not or only marginally significant. Thus, firms that generate a large share of their sales abroad seem to exhibit systematically higher exposures than firms with low foreign sales. The coefficients of total assets are negative in most periods, but only slightly significant in 1986-90 for the nonlinear specification.[9] Doukas/Hall/Lang (1999) and Simkins/Laux (1996) document a negative relationship between firm size and exposure as well, while He/Ng (1998) find a positive relationship. The results indicate further that industry sectors matter significantly for foreign exchange rate exposure across all specifications corroborating the results of Tables 3 and 7. Especially the sectors agriculture/forestry, rubber/plastics, stone/glass/clay, primary metal, paper/publishing, leather/textile, construction and retail trade show significant industry effects for the exchange rate exposure.

For the linear and nonlinear exposure, the coefficients of the variable cash flow/total assets as a measure of firm liquidity are mostly negative as predicted and often significant (Table 14).[10] This is opposite the positive (negative) relationship between exposure and quick ratio (dividend payout ratio) reported by He/Ng (1998) for Japanese firms (which are, however, based on the raw exposure coefficient). Significant differences in exposure across industries can be identified for agriculture/forestry, public utilities/mining, chemicals, stone/glass/clay, miscellaneous manufacturing, paper/publishing, construction, wholesale trade, transportation, real estate, and other services.

6 Conclusion

The results presented in this paper originate from a comprehensive study of the foreign exchange rate exposure of 447 German nonfinancial corporations during the period of 1981-95. Due to the international dependence of its economy, Germany is extremely well suited as subject for this kind of study. Indeed, many German firms exhibit a significant exposure for different foreign exchange rate indices as well as for the bilateral foreign exchange rates of Germany's most important trading

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9 Results for total sales and the number of employees as proxies for firm size are similar.

10 The variables cash/total assets, quick ratio and current ratio yield similar signs, but less significant coefficients. Results using the log-odds transformation, as implemented by Dominguez/Tesar (2001), are similar but not more efficient.

partners. In addition to linear foreign exchange rate exposures, a significant nonlinear exposure component can be identified for all different foreign exchange rates and periods.

Nonlinearities in the exposure may originate from corporate cash flows that are a nonlinear function of the exchange rate. Consequently, the assumption of a uniform, symmetric and linear exposure that is implicit in the classical approach for exposure estimation appears to be unrealistic and simplifying. Nonlinear regression specifications, sign and size bias tests as well as partially nonparametric regressions reveal some empirical evidence in support of a nonlinear characteristic of the foreign exchange rate exposure.

The empirical evidence does not indicate that the economic foreign exchange rate exposure is primarily driven by the currency of determination. In line with previous studies, the ratio of foreign sales to total sales is identified as important explanatory variable for foreign exchange rate exposures. Thus, firms with more international sales exhibit systematically larger and more significant foreign exchange rate exposures. In addition, firm liquidity variables, especially cash flow/total assets, are significantly negatively related to the exposure. Moreover, industry sectors are important determinants of the foreign exchange rate exposure.

The results of this study motivate important implications for corporate risk management. Given that a simple linear relationship between financial risks and firm value cannot be assumed in general, the structure of the economic exposure has to be taken into account for exposure estimation. Only when considering potential nonlinear exposure components, corporate financial exposures can be estimated and hedged properly. As the choice of hedging tools is determined by the exposure profile, nonlinear foreign exchange rate exposures suggest the use of hedging instruments with nonlinear payoff profiles such as financial and/or real options.

References

Adler, M., Dumas, B., 1984. Exposure to Currency Risk: Definition and Measurement. Financial Management 13 (2), 41-50.

Allayannis, G., 1997. The Time-Variation of the Exchange Rate Exposure: An Industry Analysis. University of Virginia Working paper.

Allayannis, G., Ihrig, J., 2001. Exposure and Markups, Review of Financial Studies, Vol. 14 (3), 805-835.

Amihud, Y., 1994. Exchange Rates and the Valuation of Equity Shares. In: Amihud, Y., Levich, R.M. (Eds.), Exchange Rates and Corporate Performance, Irwin, 49-59.

Bartov, E., Bodnar, G.M., 1994. Firm Valuation, Earnings Expectations, and the Exchange Rate Exposure Effect. Journal of Finance 44 (5), 1755-1785.

Bartov, E., Bodnar, G.M., Kaul, A., 1996. Exchange Rate Variability and the Riskiness of U.S. Multinational Firms: Evidence from the Breakdown of the Bretton Woods System. Journal of Financial Economics, 105-132.

Bartram, S.M. 1999. Corporate Risk Management, Uhlenbruch.

Bodnar, G.M., Gebhardt, G., 1999. Derivatives Usage in Risk Management by U.S. and German Non-Financial Firms. Journal of International Financial Management and Accounting 30 (3), 153-187.

Bodnar, G.M., Gentry, W.M., 1993. Exchange Rate Exposure and Industry Characteristics: Evidence from Canada, Japan, and the USA. Journal of International Money and Finance 12 (1), 29-45.

Bodnar, G.M., Hayt, G.S., Marston, R.C., 1998. 1998 Wharton Survey of Financial Risk Management by US Non-Financial Firms, Financial Management 27 (4), 70-91.

Brown, G.W., Crabb, P.R., Haushalter, D., 2001. Are Firms Successful At "Selective" Hedging?, University of North Carolina Working paper.

Choi, J.J., Prasad, A.M., 1995. Exchange Risk Sensitivity and Its Determinants: A Firm and Industry Analysis of U.S. Multinationals. Financial Management 24 (3), 77-88.

Chow, E.H., Lee, W.Y., Solt, M.E., 1997. The Exchange-Rate Risk Exposure of Asset Returns. Journal of Business 70 (1), 105-123.

Deutsche Bundesbank, 1989. Aktualisierung der Außenwertberechnungen für die D-Mark und fremde Währungen. Monatsbericht der Deutschen Bundesbank 41 (4), 44-52.

Dominguez, K.M.E., Tesar, L.L., 2001. Trade and Exposure, American Economic Review 91 (2), 367-370.

Doukas, J., Hall, P.H., Lang, L.H.P., 1999. The Pricing of Currency Risk in Japan. Journal of Banking and Finance 23(1), 1-20.

Dufey, G., 1972. Corporate Finance and Exchange Rate Variations. Financial Management 1 (2), 51-57.

Giddy, I.H., Dufey, G., 1995. Uses and Abuses of Currency Options. Journal of Applied Corporate Finance 8 (3), 49-57.

Glaum, M., M. Brunner, and H. Himmel. 2000. The DAX and the Dollar: The Economic Exchange Rate Exposure of German Corporations, Journal of International Business Studies 31 (4), 715-724.

Griffin, J.M., and R.M. Stulz. 2001. International Competition and Exchange Rate Shocks: A Cross-Country Industry Analysis of Stock Returns, Review of Financial Studies 14 (1), 215-241.

He, J., Ng, L.K., 1998. The Foreign Exchange Exposure of Japanese Multinational Corporations. Journal of Finance 53 (2), 733-753.

Hodder, J.E., 1982. Exposure to Foreign Exchange-Rate Movements. Journal of International Economics 13 (11), 375-386.

IMF, 1997. International Financial Statistics. CD-ROM 9/97.

Jorion, P., 1990. The Exchange-Rate Exposure of U.S. Multinationals. Journal of Business 63 (3), 331-345.

Jorion, P., 1991. The Pricing of Exchange Rate Risk in the Stock Market. Journal of Financial and Quantitative Analysis 26 (3), 363-376.

Kanas, A., 1996a. Exchange Rate Economic Exposure when Market Share Matters and Hedging Using Currency Options. Management International Review 36 (1), 67-84.

Kanas, A., 1996b. Exchange Rate Economic Exposure, Business Exposure and Hedging Using Currency Options. Journal of Multinational Financial Management 6 (2/3), 1-19.

Khoo, A., 1994. Estimation of Foreign Exchange Rate Exposure: An Application to Mining Companies in Australia. Journal of International Money and Finance 13 (3), 342-363.

Knetter, M.M., 1994. Is Export Price Adjustment Asymmetric? Evaluating the Market Share and Marketing Bottlenecks Hypothesis. Journal of International Money and Finance 13 (1), 55-70.

Kogut, B., Kulatilaka, N., 1994. Operating flexibility, global manufacturing, and the option value of a multinational network. Management Science 40 (1), 123-139.

Levi, M.D., 1994. Exchange Rates and the Valuation of Firms. In: Amihud, Y., Levich, R.M. (Eds.), Exchange Rates and Corporate Performance, Irwin, 37-48.

Miller, K.D., Reuer, J.J., 1998. Asymmetric Corporate Exposures to Foreign Exchange Rate Changes. Strategic Management Journal 19 (12), 1183-1191.

OECD, 1996. OECD Economic Outlook 59, June, OECD (Paris).

Sercu, P., Uppal, R., 1995. International Financial Markets and the Firm. Chapman (London).

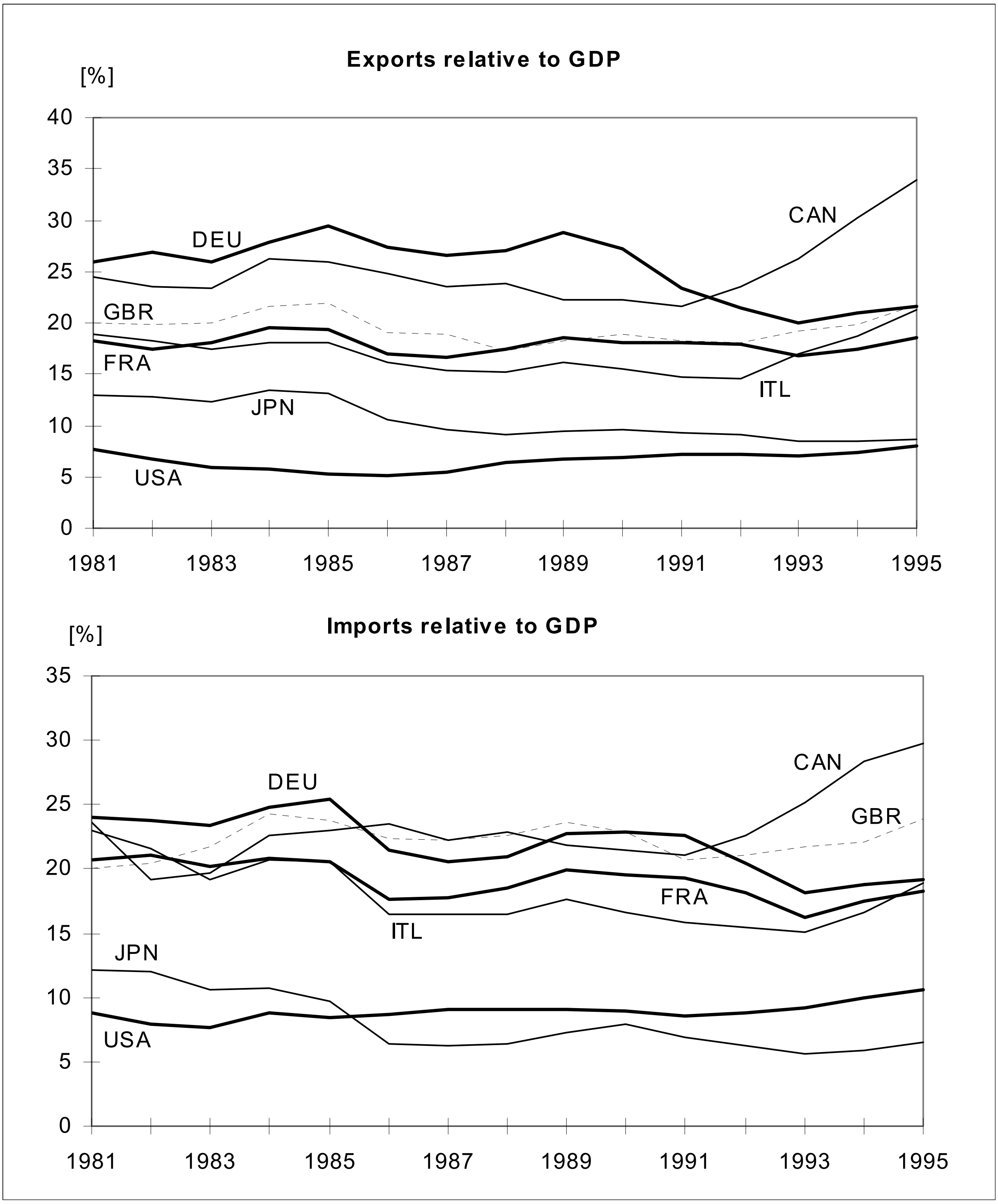
Simkins, B.J., Laux, P., 1996. Derivatives Use and the Exchange Rate Risk of Investing in Large U.S. Corporations. Proceedings of the 2nd International Finance Conference, Georgia Institute of Technology.

Stulz, R.M., 2002. Derivatives, Risk Management, and Financial Engineering. Southwestern Publishing Co. (Cincinnati), forthcoming.

Ware, R., Winter, R., 1988. Forward Markets, Currency Options and the Hedging of Foreign Exchange Risk. Journal of International Economics 25 (3/4), 291-302.

Williamson, R. 2001. Exchange Rate Exposure and Competition: Evidence from the Automotive Industry, Journal of Financial Economics 59 (3), 441-475.

Figure 1: The importance of foreign trade for the G7 countries



Source: IMF (1997)

Table 1: Sample size and industry classification

The table reports the number of firms in the sample by subperiod and industry class. Samples are determined for each subperiod separately in order to avoid a survivorship bias. Across all periods, a total of 447 nonfinancial corporations and 67 financial intermediaries are studied.

Industry	5-year period			4-year period	3-year period
	1981-85	1986-90	1991-95	1992-95	1993-95
Agriculture, forestry, and fishing	1	1	2	2	3
Public utilities, mining	14	13	23	23	26
Chemicals	14	16	19	19	20
Rubber and plastics	3	4	9	10	10
Stone, clay, glass, and concrete products	13	13	19	19	19
Primary metal industries	4	4	13	13	13
Industrial machinery and equipment	15	19	47	50	53
Transportation equipment	4	8	14	15	15
Electrical and electronic equipment, optical and precision instruments	11	14	27	29	30
Miscellaneous manufacturing industries	1	3	13	14	15
Paper and wood products, publishing and printing	3	6	14	16	16
Apparel and textile products, leather and leather products	4	7	29	29	30
Food and kindred products, tobacco	14	13	34	36	38
Construction	5	5	9	11	12
Wholesale trade	2	5	16	18	20
Retail trade	6	7	16	16	19
Transportation and communication	2	2	12	12	15
Banking	25	26	29	30	31
Insurance	20	20	29	31	31
Real estate	2	2	19	20	22
Diversified investment offices and conglomerates	11	15	27	28	30
Other services	0	0	11	12	14
Nonfinancial firms	129	157	373	392	420
Financial intermediaries	45	46	58	61	62

Table 2: Linear foreign exchange rate exposure

The table reports the percentage of nonfinancial firms that show a significant linear foreign exchange rate exposure χ_j for different foreign exchange 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 to all exposures, respectively. ATS = Austrian Schilling, BEF = Belgian Franc, CHF = Swiss Franc, FRF = French Franc, GBP = British Pound, ITL = Italian Lira, JPY = Japanese Yen, NLG = Dutch Guilder, USD = U.S. Dollar, XEU = European Currency Unit ECU, TXEMS = currency index of EMS membership countries, TXEU = currency index of 14 EU countries, TXI = currency index of 18 industrialized countries.

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

	5-year period									4-year period			3-year period		
	1981-85			1986-90			1991-95			1992-95			1993-95		
	-	+	±	-	+	±	-	+	±	-	+	±	-	+	±
ATS	3.9	4.7	8.5	10.8	1.9	12.7	1.3	4.3	5.6	2.0	5.6	7.7	2.1	3.6	5.7
BEF	20.9	3.9	24.8	0.6	13.4	14.0	11.0	13.1	24.1	9.2	14.5	23.7	8.8	12.9	21.7
CHF	7.8	2.3	10.1	3.8	1.3	5.1	0.8	4.8	5.6	1.0	3.3	4.3	1.4	5.2	6.7
FRF	9.3	12.4	21.7	1.9	10.8	12.7	5.1	6.4	11.5	5.4	6.1	11.5	6.0	6.0	11.9
GBP	2.3	4.7	7.0	5.1	5.7	10.8	3.8	9.7	13.4	3.3	8.7	12.0	1.7	6.0	7.6
ITL	11.6	3.1	14.7	1.3	3.8	5.1	4.8	5.1	9.9	3.8	5.1	8.9	6.0	7.1	13.1
JPY	4.7	3.1	7.8	3.2	3.2	6.4	1.1	4.8	5.9	1.8	3.6	5.4	1.9	4.3	6.2
NLG	8.5	1.6	10.1	1.3	10.2	11.5	9.1	3.2	12.3	8.7	2.6	11.2	7.9	2.4	10.2
USD	3.9	4.7	8.5	6.4	10.2	16.6	1.9	5.9	7.8	3.6	3.8	7.4	3.6	4.3	7.9
XEU	9.3	4.7	14.0	3.2	5.7	8.9	2.9	7.5	10.5	4.1	6.6	10.7	4.8	4.8	9.5
TXEMS	14.7	3.9	18.6	1.9	6.4	8.3	2.7	5.1	7.8	3.8	4.3	8.2	7.4	5.0	12.4
TXEU	9.3	6.2	15.5	3.8	7.0	10.8	2.9	5.6	8.6	3.8	5.4	9.2	5.7	5.5	11.2
TXI	7.8	3.9	11.6	6.4	8.9	15.3	1.6	5.9	7.5	2.0	4.1	6.1	3.3	5.2	8.6

Table 3: Linear USD exposure by industry

The table reports the percentage of firms that show a significant linear foreign exchange rate exposure χ_j with regard to the U.S. Dollar 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 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.

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

	1981-85			1986-90			1991-95		
	-	+	±	-	+	±	-	+	±
Agriculture/forestry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Public utilities/mining	0.0	0.0	0.0	15.4	0.0	15.4	0.0	4.3	4.3
Chemicals	7.1	7.1	14.3	6.2	12.5	18.8	0.0	10.5	10.5
Rubber/plastics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.2	22.2
Stone/clay/glass	0.0	0.0	0.0	15.4	0.0	15.4	5.3	0.0	5.3
Primary metal	0.0	0.0	0.0	0.0	25.0	25.0	7.7	7.7	15.4
Industrial machinery	0.0	13.3	13.3	0.0	21.1	21.1	2.1	4.3	6.4
Transp. equipment	0.0	0.0	0.0	0.0	12.5	12.5	0.0	0.0	0.0
Electr. equipment	0.0	0.0	0.0	7.1	0.0	7.1	3.7	22.2	25.9
Misc. manufacturing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paper/publishing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	7.1
Textile/leather	0.0	0.0	0.0	0.0	42.9	42.9	3.4	3.4	6.9
Food/tobacco	7.1	0.0	7.1	7.7	7.7	15.4	0.0	0.0	0.0
Construction	0.0	40.0	40.0	0.0	0.0	0.0	0.0	22.2	22.2
Wholesale trade	0.0	0.0	0.0	0.0	20.0	20.0	0.0	0.0	0.0
Retail trade	33.3	0.0	33.3	42.9	0.0	42.9	0.0	0.0	0.0
Transportation	0.0	50.0	50.0	0.0	50.0	50.0	0.0	0.0	0.0
Banking	20.0	0.0	20.0	23.1	0.0	23.1	13.8	3.4	17.2
Insurance	10.0	0.0	10.0	0.0	0.0	0.0	0.0	17.2	17.2
Real estate	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.3	10.5
Conglomerates	9.1	0.0	9.1	0.0	13.3	13.3	3.7	11.1	14.8
Other services							0.0	0.0	0.0
R^2		22.3			38.7			17.1	
aR^2		19.5			36.6			14.2	

Table 4: Linear USD exposure of DAX companies

The table reports the exposure coefficients χ_j of the DAX companies multiplied by 1 standard deviation of the exchange rate variable for different periods. *, ** and *** indicate the 10%, 5% and 1% significance level, respectively.

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

	1981-85	1986-90	1991-95
BASF	0.147	0.657	0.197
Bayer	0.824***	1.203	0.051
Henkel		-0.927**	0.294
Hoechst	0.601*	1.217*	0.005
Schering	0.655	1.765*	0.743
Continental	0.320	-0.535	0.075
Deutsche Babcock	1.034	0.775	1.947**
Linde	0.519	0.263	0.282
BMW	0.205	1.086	1.237
Daimler Benz	0.614	-0.103	-0.009
Volkswagen	-0.779	0.961	-0.425
Nixdorf		-0.794	
Siemens	0.079	0.324	-0.670**
Feldmühle Nobel			-0.004
Karstadt	-0.744	-1.426	-0.240
Kaufhof	-1.808***	-2.875***	-0.919
Deutsche Lufthansa	-0.144	1.783***	0.809
Bayer. Hypo.	-0.848	-1.225**	-0.104
Bayer. Vereinsbank	-1.231***	-0.084	-0.339
Commerzbank	-1.110*	-0.781	0.328
Deutsche Bank	-1.105***	-0.356	-0.278
Dresdner Bank	-1.580***	-1.099	0.348
Allianz Holding	-0.779*	-0.222	-0.441
Münchner Rück	0.802	-1.510*	-0.427
Degussa	0.221	0.773	0.901**
MAN	-0.135	1.455	0.660
Mannesmann	-0.673	1.888	0.136
Metallgesellschaft	0.147	1.086	0.720
Preussag	1.149	1.413	1.331*
RWE	-0.514	-0.563	-0.866**
Thyssen	-0.529	2.145***	-0.060
VEBA	-1.364**	-0.325	-0.951*
VIAG			0.048
SAP			-0.646

Table 5: Nonlinear foreign exchange rate exposure

The table reports the percentage of nonfinancial firms that show a significant nonlinear foreign exchange rate exposure χ_j for different foreign exchange 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 to all exposures, respectively. ATS = Austrian Schilling, BEF = Belgian Franc, CHF = Swiss Franc, FRF = French Franc, GBP = British Pound, ITL = Italian Lira, JPY = Japanese Yen, NLG = Dutch Guilder, USD = U.S. Dollar, XEU = European Currency Unit ECU, TXEMS = currency index of EMS membership countries, TXEU = currency index of 14 EU countries, TXI = currency index of 18 industrialized countries.

$$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{St}^3 + \varepsilon_{jt}$$

	5-year period									4-year period			3-year period		
	1981-85			1986-90			1991-95			1992-95			1993-95		
	-	+	±	-	+	±	-	+	±	-	+	±	-	+	±
ATS	12.4	6.2	18.6	21.7	6.4	28.0	4.3	7.2	11.5	3.8	8.4	12.2	4.0	9.5	13.6
BEF	47.3	21.7	69.0	13.4	27.4	40.8	25.5	19.0	44.5	25.5	17.6	43.1	25.2	16.7	41.9
CHF	10.9	5.4	16.3	3.8	5.7	9.6	2.4	6.2	8.6	3.8	5.9	9.7	7.1	7.6	14.8
FRF	11.6	16.3	27.9	36.3	31.2	67.5	30.3	21.7	52.0	28.8	19.1	48.0	29.5	17.9	47.4
GBP	7.8	6.2	14.0	10.8	14.6	25.5	28.2	35.1	63.3	26.5	35.7	62.2	3.8	6.7	10.5
ITL	12.4	9.3	21.7	4.5	5.7	10.2	15.3	22.3	37.5	15.6	21.7	37.2	12.1	17.9	30.0
JPY	6.2	10.1	16.3	4.5	7.6	12.1	5.9	10.7	16.6	6.6	9.2	15.8	8.8	16.7	25.5
NLG	8.5	4.7	13.2	22.9	38.9	61.8	17.2	5.1	22.3	16.6	4.6	21.2	18.8	5.7	24.5
USD	6.2	7.0	13.2	5.1	8.3	13.4	5.4	7.8	13.1	13.5	4.3	17.9	13.3	9.8	23.1
XEU	10.1	5.4	15.5	13.4	18.5	31.8	18.0	24.4	42.4	18.4	25.3	43.6	16.2	11.7	27.9
TXEMS	13.2	11.6	24.8	10.2	15.3	25.5	9.9	11.5	21.4	10.5	12.0	22.4	20.0	11.0	31.0
TXEU	9.3	5.4	14.7	7.6	14.0	21.7	15.5	23.1	38.6	16.6	24.0	40.6	10.0	9.0	19.0
TXI	5.4	7.8	13.2	4.5	10.8	15.3	3.8	8.0	11.8	6.9	7.4	14.3	10.0	9.3	19.3

Table 6: 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 foreign exchange rate variable, respectively. Exposures are estimated by regressions of the market index and the exchange rate on stock returns. ATS = Austrian Schilling, BEF = Belgian Franc, CHF = Swiss Franc, FRF = French Franc, GBP = British Pound, ITL = Italian Lira, JPY = Japanese Yen, NLG = Dutch Guilder, USD = U.S. Dollar, XEU = European Currency Unit ECU, TXEMS = currency index of EMS membership countries, TXEU = currency index of 14 EU countries, TXI = currency index of 18 industrialized countries.

Panel (a): 1 standard deviation of the exchange rate										
	Linear exposure					Nonlinear exposure				
	5-years			4-years	3-years	5-years			4-years	3-years
	1981-85	1986-90	1991-95	1992-95	1993-95	1981-85	1986-90	1991-95	1992-95	1993-95
ATS	-0.0934	-0.3936	0.0783	0.0804	0.1291	-0.0297	-0.0563	0.0410	0.0473	0.0656
BEF	-0.4822	0.5798	-0.0932	-0.0666	-0.1013	-0.0112	0.0293	-0.0075	-0.0109	-0.0188
CHF	-0.1205	-0.0906	0.2442	0.1949	0.1884	-0.0564	0.0179	0.0515	0.0531	0.0133
FRF	-0.0244	0.1116	0.0210	0.0409	-0.0574	0.0028	-0.0083	-0.0122	-0.0173	-0.0272
GBP	-0.0305	-0.0122	0.2839	0.3347	0.2936	0.0004	0.0278	0.0049	0.0080	0.0749
ITL	-0.2366	0.3289	-0.0054	0.0112	0.0112	-0.0063	0.0162	0.0057	0.0113	0.0293
JPY	0.0126	0.0285	0.2179	0.0801	0.2529	0.0392	0.0419	0.0700	0.0411	0.0789
NLG	-0.3316	0.2818	-0.3378	-0.3461	-0.4318	-0.0275	0.0172	-0.0712	-0.0929	-0.1208
USD	-0.0199	0.3344	0.2878	-0.0369	0.0675	-0.0498	0.0680	0.0304	-0.0671	-0.0203
XEU	-0.1894	0.1232	0.0753	0.0973	-0.0200	-0.0208	0.0220	0.0028	0.0058	-0.0396
TXEMS	-0.2734	0.3141	-0.0364	-0.0270	-0.0925	-0.0071	0.0034	-0.0035	-0.0015	-0.0306
TXEU	-0.1883	0.1710	0.0548	0.0716	-0.0196	-0.0155	0.0254	0.0046	0.0093	-0.0018
TXI	-0.1101	0.2529	0.2595	0.0782	0.1063	-0.0126	0.0777	0.0629	0.0091	0.0044
Panel (b): 2 standard deviations of the exchange rate										
ATS	-0.1868	-0.7873	0.1565	0.1608	0.2583	-0.2376	-0.4501	0.3281	0.3787	0.5245
BEF	-0.9644	1.1596	-0.1865	-0.1331	-0.2025	-0.0899	0.2347	-0.0601	-0.0868	-0.1503
CHF	-0.2409	-0.1811	0.4883	0.3898	0.3768	-0.4512	0.1430	0.4118	0.4246	0.1061
FRF	-0.0489	0.2232	0.0420	0.0817	-0.1148	0.0221	-0.0660	-0.0976	-0.1388	-0.2177
GBP	-0.0611	-0.0243	0.5677	0.6694	0.5872	0.0031	0.2223	0.0390	0.0642	0.5993
ITL	-0.4731	0.6578	-0.0108	0.0225	0.0225	-0.0506	0.1294	0.0453	0.0907	0.2341
JPY	0.0251	0.0569	0.4358	0.1601	0.5057	0.3133	0.3350	0.5597	0.3287	0.6313
NLG	-0.6632	0.5636	-0.6757	-0.6923	-0.8637	-0.2202	0.1376	-0.5693	-0.7428	-0.9664
USD	-0.0398	0.6688	0.5755	-0.0738	0.1350	-0.3982	0.5442	0.2428	-0.5371	-0.1626
XEU	-0.3787	0.2463	0.1505	0.1945	-0.0401	-0.1666	0.1758	0.0220	0.0468	-0.3169
TXEMS	-0.5468	0.6283	0.1096	0.1432	-0.0393	-0.0571	0.0275	-0.0277	-0.0124	-0.2447
TXEU	-0.3766	0.3419	-0.0728	-0.0540	-0.1851	-0.1238	0.2035	0.0367	0.0740	-0.0142
TXI	-0.2201	0.5057	0.5189	0.1564	0.2125	-0.1005	0.6215	0.5030	0.0731	0.0354

Table 7: Nonlinear USD exposure by industry

The table reports the percentage of nonfinancial firms that show a significant nonlinear foreign exchange rate exposure χ_j with regard to the U.S. Dollar 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 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.

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

	1981-85			1986-90			1991-95		
	-	+	±	-	+	±	-	+	±
Agriculture/forestry	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	50.0
Public utilities/mining	21.4	7.1	28.6	15.4	0.0	15.4	13.0	4.3	17.4
Chemicals	0.0	21.4	21.4	6.2	12.5	18.8	0.0	21.1	21.1
Rubber/plastics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.2	22.2
Stone/clay/glass	0.0	15.4	15.4	15.4	0.0	15.4	5.3	0.0	5.3
Primary metal	0.0	0.0	0.0	0.0	25.0	25.0	7.7	0.0	7.7
Industrial machinery	0.0	6.7	6.7	0.0	15.8	15.8	4.3	6.4	10.6
Transp. equipment	0.0	25.0	25.0	0.0	12.5	12.5	0.0	14.3	14.3
Electr. equipment	0.0	0.0	0.0	7.1	0.0	7.1	7.4	11.1	18.5
Misc. manufacturing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paper/publishing	0.0	0.0	0.0	0.0	16.7	16.7	0.0	0.0	0.0
Textile/leather	25.0	0.0	25.0	0.0	14.3	14.3	6.9	0.0	6.9
Food/tobacco	7.1	7.1	14.3	0.0	0.0	0.0	11.8	11.8	23.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	11.1
Wholesale trade	0.0	0.0	0.0	0.0	20.0	20.0	0.0	0.0	0.0
Retail trade	33.3	0.0	33.3	28.6	0.0	28.6	6.2	6.2	12.5
Transportation	0.0	0.0	0.0	0.0	50.0	50.0	0.0	16.7	16.7
Banking	32.0	0.0	32.0	11.5	0.0	11.5	3.4	13.8	17.2
Insurance	10.0	0.0	10.0	0.0	10.0	10.0	3.4	20.7	24.1
Real estate	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.3	10.5
Conglomerates	9.1	0.0	9.1	0.0	13.3	13.3	7.4	18.5	25.9
Other services							0.0	0.0	0.0
R^2		22.3			38.5			17.1	
aR^2		19.6			36.3			14.2	

Table 8: Nonlinear USD exposure of DAX companies

The table reports the exposure coefficients χ_j of the DAX companies multiplied by 1 standard deviation of the exchange rate variable for different periods. *, ** and *** indicate the 10%, 5% and 1% significance level, respectively.

$$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{USDt}^3 + \varepsilon_{jt}$$

	1981-85	1986-90	1991-95
BASF	0.093	0.044	0.060
Bayer	0.257***	0.224	0.069
Henkel		-0.444***	0.184**
Hoechst	0.219***	0.187	0.051
Schering	0.252***	0.577*	0.253**
Continental	0.150	-0.218	-0.333
Deutsche Babcock	0.244	0.188	0.196
Linde	0.090	0.229	-0.018
BMW	0.085	0.509	0.413**
Daimler Benz	0.144**	-0.057	0.009
Volkswagen	-0.207	0.268	0.034
Nixdorf		-0.363	
Siemens	-0.046	0.182	-0.190***
Feldmühle Nobel			-0.066
Karstadt	-0.140	-0.509	0.245*
Kaufhof	-0.534***	-1.176***	-0.046
Deutsche Lufthansa	-0.201	0.805***	0.284**
Bayer. Hypo.	-0.360*	-0.298	-0.016
Bayer. Vereinsbank	-0.248**	0.067	-0.064
Commerzbank	-0.161	-0.311	0.086
Deutsche Bank	-0.259**	-0.208	-0.108*
Dresdner Bank	-0.435***	-0.238	-0.015
Allianz Holding	-0.107	0.292	-0.112
Münchner Rück	0.289	-0.288	-0.041
Degussa	-0.063	0.103	0.063
MAN	-0.064	0.667**	0.099
Mannesmann	-0.213*	0.539	0.009
Metallgesellschaft	-0.059	0.521	0.168
Preussag	0.226	0.355	0.249
RWE	-0.070	-0.117	-0.196**
Thyssen	-0.220	0.470*	-0.056
VEBA	-0.376***	-0.161	-0.251***
VIAG			0.015
SAP			-0.159

Table 9: Linear and nonlinear foreign exchange rate exposure

The table reports the percentage of nonfinancial firms with significant linear (χ_j) and nonlinear (η_j) exchange rate exposure (5% level) for different currencies and time periods. ATS = Austrian Schilling, BEF = Belgian Franc, CHF = Swiss Franc, FRF = French Franc, GBP = British Pound, ITL = Italian Lira, JPY = Japanese Yen, NLG = Dutch Guilder, USD = U.S. Dollar, XEU = European Currency Unit ECU, TXEMS = currency index of EMS membership countries, TXEU = currency index of 14 EU countries, TXI = currency index of 18 industrialized countries.

$$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{St} + \eta_j R_{St}^3 + \varepsilon_{jt}$$

	5-year period						4-year period		3-year period	
	1981-85		1986-90		1991-95		1992-95		1993-95	
	χ_j	η_j	χ_j	η_j	χ_j	η_j	χ_j	η_j	χ_j	η_j
ATS	7.8	17.8	11.5	12.1	5.1	11.0	5.1	9.4	7.6	11.2
BEF	10.9	17.8	11.5	22.9	18.8	24.9	22.7	29.8	23.3	30.0
CHF	3.1	5.4	8.3	12.1	5.9	10.2	4.3	9.9	7.4	9.8
FRF	14.0	17.8	5.7	26.8	9.1	24.7	10.5	24.5	10.5	25.7
GBP	7.0	10.9	7.6	14.6	8.3	20.9	8.9	21.4	7.9	10.2
ITL	12.4	14.7	7.6	8.9	8.6	19.8	7.9	20.7	5.2	17.1
JPY	7.0	11.6	4.5	8.9	7.5	16.1	9.7	17.9	8.6	19.0
NLG	9.3	7.0	8.3	25.5	7.8	17.2	8.4	17.3	8.1	17.6
USD	7.0	7.8	7.6	7.0	8.3	14.5	10.7	18.6	10.7	16.4
XEU	9.3	7.0	7.6	24.2	9.7	24.1	8.2	23.7	8.1	18.6
TXEMS	12.4	13.2	12.7	21.7	9.4	15.0	8.9	15.8	10.5	15.7
TXEU	7.0	8.5	7.6	21.7	9.9	26.0	9.7	25.0	6.0	10.2
TXI	7.8	6.2	8.3	8.3	7.8	11.5	7.9	12.5	6.7	12.9

Table 10: Ratio of firms with nonlinear and linear foreign exchange rate exposure

The table presents the ratio of the number of nonfinancial firms with significant nonlinear and linear exposure (5% level) from regressions of exchange rates and the market index on stock returns. While results in Panel (a) are based on all data, the largest positive and negative exchange rate change is excluded for regressions in Panel (b). ATS = Austrian Schilling, BEF = Belgian Franc, CHF = Swiss Franc, FRF = French Franc, GBP = British Pound, ITL = Italian Lira, JPY = Japanese Yen, NLG = Dutch Guilder, USD = U.S. Dollar, XEU = European Currency Unit ECU, TXEMS = currency index of EMS membership countries, TXEU = currency index of 14 EU countries, TXI = currency index of 18 industrialized countries.

	5-year period									4-year period			3-year period		
	1981-85			1986-90			1991-95			1992-95			1993-95		
	-	+	±	-	+	±	-	+	±	-	+	±	-	+	±
Panel (a): All exchange rate movements															
ATS	3.2	1.3	2.2	2.0	3.4	2.2	3.3	1.7	2.1	1.9	1.5	1.6	1.9	2.6	2.4
BEF	2.3	5.6	2.8	22.3	2.0	2.9	2.3	1.5	1.8	2.8	1.2	1.8	2.9	1.3	1.9
CHF	1.4	2.3	1.6	1.0	4.4	1.9	3.0	1.3	1.5	3.8	1.8	2.3	5.1	1.5	2.2
FRF	1.2	1.3	1.3	19.1	2.9	5.3	5.9	3.4	4.5	5.3	3.1	4.2	4.9	3.0	4.0
GBP	3.4	1.3	2.0	2.1	2.6	2.4	7.4	3.6	4.7	8.0	4.1	5.2	2.2	1.1	1.4
ITL	1.1	3.0	1.5	3.5	1.5	2.0	3.2	4.4	3.8	4.1	4.3	4.2	2.0	2.5	2.3
JPY	1.3	3.3	2.1	1.4	2.4	1.9	5.4	2.2	2.8	3.7	2.6	2.9	4.6	3.9	4.1
NLG	1.0	2.9	1.3	17.6	3.8	5.4	1.9	1.6	1.8	1.9	1.8	1.9	2.4	2.4	2.4
USD	1.6	1.5	1.6	0.8	0.8	0.8	2.8	1.3	1.7	3.8	1.1	2.4	3.7	2.3	2.9
XEU	1.1	1.1	1.1	4.2	3.2	3.6	6.2	3.3	4.0	4.5	3.8	4.1	3.4	2.4	2.9
TXEMS	0.9	3.0	1.3	5.4	2.4	3.1	3.7	2.3	2.7	2.8	2.8	2.7	2.7	2.2	2.5
TXEU	1.0	0.9	0.9	2.0	2.0	2.0	5.3	4.1	4.5	4.4	4.4	4.4	1.8	1.6	1.7
TXI	0.7	2.0	1.1	0.7	1.2	1.0	2.4	1.4	1.6	3.5	1.8	2.3	3.0	1.8	2.2
Panel (b): Largest positive and negative exchange rate movement excluded															
ATS	1.3	3.9	1.7	1.5	1.5	1.5	1.5	1.3	1.3	1.4	1.6	1.5	1.8	1.7	1.8
BEF	1.6	5.4	2.2	8.5	1.9	2.2	4.7	3.1	3.6	3.7	2.3	2.7	4.0	1.9	2.4
CHF	2.6	1.0	2.0	1.3	2.5	1.4	3.1	2.0	2.3	3.1	2.2	2.5	3.2	2.2	2.6
FRF	1.8	2.1	1.9		3.5	4.0	1.0	1.3	1.2	0.9	1.2	1.1	1.0	1.5	1.3
GBP	2.3	3.0	2.8	3.0	1.2	2.2	2.9	1.4	1.6	3.6	1.3	1.6	1.6	1.0	1.2
ITL	1.4	3.8	1.9	1.7	1.8	1.8	3.3	5.6	4.1	2.9	5.1	3.8	2.0	3.1	2.5
JPY	1.1	2.0	1.5	1.0	2.8	2.1	3.4	0.8	1.6	1.8	0.8	1.3	2.1	2.1	2.1
NLG	2.3	2.3	2.3	1.3	0.9	1.0	1.9	0.8	1.6	1.7	1.2	1.6	2.3	1.2	2.0
USD	1.6	2.0	1.8	0.9	1.3	1.1	4.8	1.1	2.4	2.6	1.1	1.5	3.9	1.4	2.1
XEU	1.4	1.4	1.4	2.3	1.7	2.0	4.0	3.8	3.9	4.8	3.2	3.9	2.5	2.7	2.7
TXEMS	1.5	4.6	2.4	0.6	1.6	1.2	3.8	3.6	3.7	3.6	3.3	3.5	2.9	2.7	2.8
TXEU	0.9	2.2	1.3	1.6	1.3	1.5	2.4	1.6	1.9	2.1	1.7	1.9	3.5	2.8	3.2
TXI	1.6	2.0	1.7	1.0	1.7	1.5	2.2	1.4	1.7	1.6	1.1	1.3	2.1	1.7	1.8

Table 11: Sign and size tests of regression residuals

The table reports the percentage of nonfinancial firms with significant coefficients (ϕ_j, λ_j, ω_j) of the sign/size bias test regression for different currencies and time periods (5% level). ATS = Austrian Schilling, BEF = Belgian Franc, CHF = Swiss Franc, FRF = French Franc, GBP = British Pound, ITL = Italian Lira, JPY = Japanese Yen, NLG = Dutch Guilder, USD = U.S. Dollar, XEU = European Currency Unit ECU, TXEMS = currency index of EMS membership countries, TXEU = currency index of 14 EU countries, TXI = currency index of 18 industrialized countries.

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

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

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

	5-year period									4-year period			3-year period		
	1981-85			1986-90			1991-95			1992-95			1993-95		
	ϕ_j	λ_j	ω_j	ϕ_j	λ_j	ω_j	ϕ_j	λ_j	ω_j	ϕ_j	λ_j	ω_j	ϕ_j	λ_j	ω_j
ATS	8.5	7.8	7.0	3.8	7.0	5.7	4.8	7.0	7.5	4.6	7.4	7.1	6.7	11.4	6.2
BEF	7.8	5.4	9.3	4.5	11.5	11.5	5.1	8.6	8.8	4.6	8.7	10.2	6.2	13.3	8.8
CHF	7.8	7.8	8.5	5.1	14.6	10.8	4.6	8.8	8.8	4.8	10.5	10.2	7.1	13.6	8.8
FRF	8.5	7.0	9.3	4.5	9.6	10.8	4.8	8.6	9.1	4.3	8.7	8.4	6.2	13.6	7.9
GBP	8.5	9.3	9.3	4.5	14.6	12.1	5.1	8.0	8.8	3.3	9.4	9.7	6.2	12.1	8.3
ITL	7.8	6.2	7.0	4.5	13.4	13.4	5.4	8.8	9.1	3.8	9.2	8.4	6.4	13.6	9.3
JPY	7.8	8.5	9.3	3.8	15.3	13.4	4.3	8.6	9.7	4.8	7.4	9.7	6.4	13.6	9.0
NLG	3.1	7.0	10.9	4.5	15.3	11.5	5.1	8.8	10.2	5.1	9.2	10.2	6.7	12.6	8.3
USD	7.8	7.0	7.0	5.1	16.6	12.7	3.8	8.3	10.5	4.1	7.9	9.9	6.7	11.7	10.0
XEU	7.8	7.0	9.3	4.5	14.6	13.4	4.3	9.1	7.5	3.6	9.2	8.4	6.2	13.6	8.8
TXEMS	8.5	7.0	7.8	5.1	12.7	10.8	4.6	8.8	8.8	3.8	9.2	8.2	6.2	13.6	9.0
TXEU	8.5	7.8	8.5	4.5	14.6	12.7	4.6	9.1	9.4	3.8	8.9	8.7	6.2	12.9	8.8
TXI	7.8	8.5	6.2	4.5	15.3	14.6	4.8	7.8	9.4	4.3	8.9	10.5	7.1	12.4	9.0

Table 12: Partially nonparametric regressions

The table reports the percentage of nonfinancial firms where the coefficients of the regressors (excluding and including the market index, respectively) are significantly different from 0 (F-Test at the 5% level) for different currencies and time periods. ATS = Austrian Schilling, BEF = Belgian Franc, CHF = Swiss Franc, FRF = French Franc, GBP = British Pound, ITL = Italian Lira, JPY = Japanese Yen, NLG = Dutch Guilder, USD = U.S. Dollar, XEU = European Currency Unit ECU, TXEMS = currency index of EMS membership countries, TXEU = currency index of 14 EU countries, TXI = currency index of 18 industrialized countries.

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

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

		5-year period		4-year period	3-year period
	1981-85	1986-90	1991-95	1992-95	1993-95
ATS	4.7 / 51.9	3.8 / 88.5	4.3 / 43.2	5.4 / 35.7	4.3 / 24.5
BEF	6.2 / 57.4	3.8 / 91.7	8.0 / 47.7	6.9 / 39.5	6.9 / 30.0
CHF	3.9 / 53.5	4.5 / 88.5	7.5 / 45.0	7.4 / 38.5	7.1 / 32.4
FRF	7.0 / 63.6 *	7.6 / 89.2	4.8 / 43.4	5.6 / 38.3	8.8 / 30.5
GBP	3.1 / 51.9	7.6 / 90.4	7.0 / 45.6	6.4 / 39.0	6.0 / 29.0
ITL	6.2 / 65.9 *	1.9 / 87.9	9.4 / 45.8	6.1 / 40.3	5.7 / 28.8
JPY	4.7 / 53.5	2.5 / 89.2	5.4 / 43.2	4.8 / 36.5	4.5 / 27.9
NLG	4.7 / 54.3	5.7 / 87.3	7.0 / 47.5	5.9 / 39.5	6.7 / 31.7
USD	9.3 / 61.2	7.0 / 89.8	6.7 / 46.1	6.6 / 40.1	5.5 / 29.8
XEU	7.8 / 56.6	5.1 / 89.2	6.7 / 43.2	8.7 / 40.1	6.4 / 31.0
TXEMS	4.7 / 57.4	6.4 / 88.5	4.0 / 42.4	5.9 / 39.3	5.7 / 28.1
TXEU	3.9 / 58.1	5.1 / 89.8	5.1 / 45.6	6.4 / 37.8	6.0 / 29.0
TXI	4.7 / 56.6	7.6 / 90.4	6.2 / 45.3	3.1 / 39.3	4.5 / 28.3

** results based on regressions with 2 subsamples only*

Table 13: Determinants of the foreign exchange rate exposure

The table reports the regression coefficient of different determinants D_k (i.e. the percentage of foreign sales, total assets) and industry dummies I_i of the foreign exchange rate exposure for different periods. *, ** and *** indicate the 10%, 5% and 1% significance level, respectively.

Panel (a) $R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{TXIt} + \varepsilon_{jt}$ $\hat{\chi}_j = \gamma_0 + \sum_k \gamma_k D_{kj} + \sum_i \rho_i I_{ij} + \tau_j$

	1981-85	1986-90	1991-95	1992-95	1993-95
Constant	-0.0430	1.5194	0.5180	0.1670	0.6121
Foreign sales	1.3979*	1.8885***	-0.2714	-0.4849*	-0.2937
Total assets	-0.0175	-0.0880	-0.0071	0.0038	-0.0139
Agriculture/forestry		-0.5292***	-0.5371***	-0.1935	-0.0151
Public utilities/mining	0.2016	0.3678	0.0195	-0.0635	-0.6587
Chemicals	-0.1082	-0.0320	0.1923	0.4657**	0.2287
Rubber/plastics	0.3338	-0.9837***	0.8059	0.6831	0.1612
Stone/clay/glass	-0.1628	-0.7803**	-0.3200	-0.2791	-0.4600*
Primary metal	-0.9835***	0.7491**	-0.5883	-0.5333	-0.7772
Transp. equipment	-0.6039*	0.2155	0.1902	0.0539	0.0643
Electr. equipment	-0.0522	-0.4458*	0.1610	0.1498	0.0753
Misc. manufacturing	-0.2947	-0.0904	-0.4550**	-0.6521***	-0.6693***
Paper/publishing	-0.1556	0.4271	0.1397	0.2714	-0.0142
Textile/leather	-0.0314	0.5599*	-0.0712	0.1195	0.1521
Food/tobacco	0.2480	0.4694	-0.2593	-0.3539	-0.5748*
Construction	-0.2264	-0.1678	0.8981***	0.7717***	0.4983
Wholesale trade		0.4960	-0.0632	-0.0227	-0.2234
Retail trade	0.2104	-0.8845**	0.2771	0.0934	-0.2987
Transportation		0.2567	-0.2538	-0.1042	-0.3194
Real Estate		-0.2545			
Conglomerates	-0.6128	0.2439	0.2359	0.2467	-0.0479
Other services			-0.0138	0.3266	0.4444

(continued)

Table 13: Determinants of the foreign exchange rate exposure (continued)

Panel (b)	$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R^3_{TXIt} + \varepsilon_{jt}$		$\hat{\chi}_j = \gamma_0 + \sum_k \gamma_k D_{kj} + \sum_i \rho_i I_{ij} + \tau_j$		
	1981-85	1986-90	1991-95	1992-95	1993-95
Constant	0.1140	0.5871	0.0001	-0.2247	-0.0367
Foreign sales	0.1444	0.4005**	0.0018	-0.0923	-0.0087
Total assets	-0.0072	-0.0332*	0.0031	0.0148	0.0066
Agriculture/forestry		-0.2640***	-0.0840**	-0.0800*	-0.0769
Public utilities/mining	0.0965	0.0282	0.0676	0.0080	-0.1762
Chemicals	0.0000	0.0604	-0.0031	0.0167	-0.0565
Rubber/plastics	0.1366***	-0.2042***	0.2182**	0.1575	-0.0146
Stone/clay/glass	-0.0015	-0.0959	-0.1125**	-0.1233**	-0.2424***
Primary metal	-0.0384*	0.1756	-0.1228	-0.1676	-0.3658
Transp. equipment	-0.0639*	0.1032	0.1006	0.0466	0.0471
Electr. equipment	0.0091	0.0396	-0.0083	-0.0363	-0.0696
Misc. manufacturing	-0.0111	0.0754	-0.0504	-0.1238**	-0.2457***
Paper/publishing	-0.0847***	0.3418***	-0.0228	-0.0004	-0.0467
Textile/leather	-0.0355	0.1995***	-0.0524	-0.0386	-0.1023
Food/tobacco	0.0312	0.0816	-0.0683	-0.1157*	-0.2190**
Construction	-0.0605**	0.0455	0.0377	0.0189	-0.0346
Wholesale trade		0.2033	-0.0913	-0.1167*	-0.0940
Retail trade	0.0048	-0.1992**	0.1509	0.1145	-0.0126
Transportation		0.0974	0.0538	0.0703	0.0380
Real Estate		-0.0859			
Conglomerates	-0.0873**	0.0865	0.0957*	0.0621	-0.0096
Other services			-0.1066***	-0.0505	-0.0041

Table 14: Determinants of the absolute foreign exchange rate exposure

The table reports the regression coefficient of determinants D_k (i.e. cash flow/total assets) and industry dummies I_i of the absolute value of the foreign exchange rate exposure for different periods. *, ** and *** indicate the 10%, 5% and 1% significance level, respectively.

Panel (a)	$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R_{TXIt} + \varepsilon_{jt}$		$\left|\hat{\chi}_j\right| = \gamma_0 + \sum_k \gamma_k D_{kj} + \sum_i \rho_i I_{ij} + \tau_j$		
	1981-85	1986-90	1991-95	1992-95	1993-95
Constant	0.7911***	0.9583***	0.9196***	1.0163***	1.2407***
Cash flow / total assets	-1.9881*	0.4344	-1.2665***	-1.1542***	-1.8395***
Agriculture/forestry	-0.5071***	-0.8310***	-0.2495***	-0.2402	0.1250
Public utilities/mining	-0.1766	-0.2327	-0.2009**	-0.3221***	-0.2762**
Chemicals	-0.1922	-0.1486	-0.2363**	-0.2783**	-0.4039***
Rubber/plastics	-0.1110	-0.4353**	0.4549	0.2689	0.2782
Stone/clay/glass	-0.0739	-0.0847	-0.2431***	-0.2505*	-0.2416
Primary metal	-0.1183	0.2446	0.0117	0.0691	0.0699
Transp. equipment	0.1178	-0.2483	-0.0553	-0.0958	-0.2602
Electr. equipment	-0.1992	-0.0626	0.0033	-0.0711	-0.2494
Misc. manufacturing	-0.2291*	-0.4066	-0.1319	-0.1057	-0.0332
Paper/publishing	-0.6556***	-0.1053	-0.2385*	-0.2369*	-0.4147***
Textile/leather	-0.2486	0.2755	0.0479	0.0851	0.1444
Food/tobacco	0.1190	0.0824	-0.0432	-0.1130	-0.1067
Construction	-0.0983	-0.4331**	0.2301*	0.0970	0.0460
Wholesale trade	-0.4352***	-0.2942	-0.3034***	-0.3519***	-0.1547
Retail trade	0.0050	0.2257	0.1657	0.2346	0.1462
Transportation	1.2453***	0.4047**	-0.1065	-0.2489*	-0.4242***
Real Estate	-0.3056*	-0.5587**	0.0184	-0.0022	-0.2990**
Conglomerates	-0.1652	-0.0792	-0.0608	-0.1860	-0.2167**
Other services			-0.4671***	-0.3152**	-0.2874**

(continued)

Table 14: Determinants of the absolute foreign exchange rate exposure (continued)

Panel (b)	$R_{jt} = \alpha_j + \beta_j R_{CDAXt} + \chi_j R^3_{TXIt} + \varepsilon_{jt}$		$\left|\hat{\chi}_j\right| = \gamma_0 + \sum_k \gamma_k D_{kj} + \sum_i \rho_i I_{ij} + \tau_j$		
	1981-85	1986-90	1991-95	1992-95	1993-95
Constant	0.0981***	0.2309***	0.1961***	0.2446***	0.3238***
Cash flow / total assets	-0.2214	0.0793	-0.1149*	-0.1711**	-0.2578**
Agriculture/forestry	-0.0227	-0.1076**	-0.1465***	-0.1638***	-0.1820***
Public utilities/mining	-0.0177	-0.0983	-0.0659**	-0.1021**	-0.0885*
Chemicals	-0.0185	-0.0361	-0.0719***	-0.0902**	-0.1094***
Rubber/plastics	0.0605***	-0.0553	0.1339**	0.0452	0.0193
Stone/clay/glass	0.0028	-0.0100	-0.0561	-0.0538	-0.0887***
Primary metal	-0.0726***	0.1400***	0.0157	0.0062	0.0481
Transp. equipment	0.0110	-0.0465	0.0315	0.0210	-0.0324
Electr. equipment	-0.0143	0.0409	-0.0110	-0.0334	-0.0600
Misc. manufacturing	-0.0722***	0.0201	-0.0725**	-0.1002**	-0.0790**
Paper/publishing	-0.0357*	0.1201	-0.0722**	-0.0714*	-0.1024**
Textile/leather	-0.0136	0.0528	-0.0442*	-0.0662	-0.0538
Food/tobacco	0.0310	-0.0374	-0.0459*	-0.0659	-0.0775**
Construction	-0.0087	-0.1072**	-0.0739**	-0.0666	-0.0839*
Wholesale trade	-0.0093	0.0451	-0.0241	-0.0593*	-0.0580
Retail trade	0.0352*	-0.0027	-0.0078	-0.0278	0.0162
Transportation	0.0374**	0.0433	0.0240	-0.0401	-0.1078***
Real Estate	-0.0594***	-0.1398***	-0.0274	-0.0267	-0.1349***
Conglomerates	-0.0094	-0.0181	0.0110	-0.0412	-0.1057***
Other services			-0.1099***	-0.1063***	-0.1796***