German Exchange Rate Exposure at DAX and Aggregate Level, International Trade, and the Role of Exchange Rate Adjustment Costs

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Summary: This article analyses value changes of German stock market companies in response to movements of the US dollar. The approach followed in this work extends the standard means of measuring exchange rate exposure in several ways, e.g. by using multi-factor modelling instead of augmented CAPM, application of moving window panel regressions, and orthogonalization of overall market risk vis-à-vis currency risk. A further innovation lies in testing theoretical implications of exchange rate adjustment costs (hedging costs) for firm values and economic exposure. Based on time series and panel data of German DAX companies, DM/ dollar rates and macroeconomic factors, we find a rather unstable, time-variant exposure of German stock market companies. Dollar sensitivity is positively affected by the ratio of exports/GDP and negatively affected by imports/GDP. Moreover, as expected from theoretical findings, firm values and exchange rate exposure are significantly reduced by adjustment costs depending on the distance of the exchange rate from the expected long-run mean.

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1. Introduction

Are German stock values vulnerable to exchange rate movements? Classical financial theory implies that stock market values of firms should be affected by foreign exchange rate risk (Dufey 1972, Shapiro 1974). However, according to standard international portfolio choice models, optimally allocated world market portfolios hedge against exchange rate risk (Solnik 1974, Adler and Dumas 1983). To the extent that foreign exchange risk represents unsystematic risk, it can be diversified away, provided that investors and owners of equities have the same quality of information about the firm as management – a condition not likely to prevail in practice (Dufey and Giddy, 2003). Tests of predictions derived from such theoretical considerations have been facilitated by the work of Adler and Dumas (1980, 1984), who have shown that exchange rate exposure can be measured as the sensitivity of stock returns to exchange rate movements within the simple framework of linear regression models.

Econometric studies have been of limited success in identifying foreign currency exposure (see Jorion 1990 and 1991, Bodnar and Gentry 1993, He and Ng 1998, Dominguez and Tesar 2001 a,b,c, Koutmos and Martin 2003, inter alia). If found in the data, exchange rate exposure is expected to be related to international trade. However, based on data from eight countries, Dominguez and Tesar (2001 b,c), for instance, conclude that they do not find a strong connection between trade and exposure. Recent studies discuss possible reasons for this lack of significance, as there are, for instance, time-varying risks (De Santis and Gerard 1998, Tai 2000), hedging activities (Allayannis and Ofek 2001, Crabb 2002), neglected issues of competitiveness within industrial sectors (Marston 2001), potential nonlinearities (Bartram 2004) or asymmetric exposure (Koutmos and Martin 2003).

This study takes a fresh look at the subject using German data and new theoretical arguments. Due to its high international dependency, Germany is very well suited for testing the existence of exchange rate exposure. Our approach extends the literature in several ways. The usual way of measuring “residual” exchange rate exposure is based on a CAPM specification augmented by exchange rate risk. However, as many previous attempts at estimating exchange exposure based on augmented CAPM have led to insignificant results, one drawback of this specification seems to be that exchange rates do have an indirect effect on individual stocks through market returns such that the residual impact of exchange rates on stock returns in augmented CAPM specifications is partly covered by market returns. We thus suggest avoiding problems that arise due to the collinearity between market returns and exchange rates by employing orthogonalized market returns, as they represent the component of market returns that is uncorrelated with exchange rates. On the other hand, significance of exposure might be suppressed and parameter estimates may be misleading due to the omission of other relevant macroeconomic risks such as inflation and interest rate fluctuations. We therefore check robustness of results by both following the strategy of orthogonalizing the augmented CAPM specification as well as employing multifactor-modelling in the spirit of Arbitrage Pricing Theory (APT) instead of augmented CAPM. The latter is motivated by macroeconomic shocks such as divergent monetary and fiscal policies, as well as asynchronous output movements which all might drive stock returns and exchange rates in multidimensional ways such that any prediction of the prevailing impact of exchange rates on stock returns might be regime-dependent (see Gavin, 1989). Following further along these lines, we take account of time-dependency risks by running moving-window regressions. In order to exploit the longitudinal information within the data of German DAX corporations used, we propose to apply rolling-panel estimation techniques.

The role of second or higher moments caused by exchange rate adjustment costs, although at the heart of uncertainty caused by exchange rate fluctuations, has received surprisingly little attention in the literature (remarkable exceptions being Miller and Reuter 1998, Andren 2001, Priestley and Odegaard, 2002, and Bartram 2004). Theoretical analysis reveals that profits and firm values are a convex function of the exchange rate (see Franke 1991, Sercu and Vanhulle 1992, and DeGrauwe 1994, among others). Several recent research articles have been motivated by the fact that a high percentage of firms use hedging strategies (see Bodnar and Gebhard 1998, and Bartram et al., 2003, for surveys) to circumvent such costs of adjustment, and focus on hedging and reduced risk stemming from the use of forward contracts, options or other hedging strategies. The great bulk of research, however, neglects that there might be substantial costs of hedging, and that hedging costs depend on the exchange rate itself (see Dufey and Giddy, 2003, for strategies of managing corporate foreign exchange risk and related costs). The price of an option, for instance, increases convexly with the expectation for a currency's volatility because of inherent leverage effects: the more volatile, the higher the price. Our paper takes account of exchange rate adjustment costs by modelling exposure in dependence of exchange rate variation. Grounded on theoretical arguments (see Franke 1991, for instance) and empirical evidence (see Engel and Hamilton, 1990, and succeeding research), both stressing the importance of mean-reverting exchange rates, we analyse the impact of substantial deviations from expected long-run benchmarks in terms of theoretical considerations and empirical investigations.

Exchange rate exposure is estimated and predicted hypotheses are tested using performance indices from the German DAX corporations of the time 1977 to 1995, which was a period without adjustment processes following the breakdown of the Bretton Wood system in 1973 (Bartov et al. 1996), and without anticipatory distortions in the face of the forthcoming introduction of the euro in 1999.

Our intention is to derive conclusions with respect to aggregate exchange rate exposure of the German economy. We thus focus on a macroeconomic (macrofinancial) point of view, although conclusions are drawn on returns observed for individual stock companies. Econometric results show a rather unstable (regime-dependent) exposure of German stock market companies. In general (on average), German exposure is well described through the role of a net exporter, who benefits from the depreciation of domestic currency. Thus, as predicted by theoretical reasoning, estimations of time-varying exposure based on DM/US-dollar risks have a positive sign with the exception of the first half of the 1980ies, when a relatively high import dependency and a strong US dollar changed the situation. Theoretical modelling also suggests that adjustment costs play a role. We find that the larger the distance of current exchange rates from their long-mean is, the lower company values are. Results are in accordance with long-run mean reversion and confirm the negative effect of exchange rate adjustment costs on exchange rate exposure.

This paper is organised as follows. In Section 2, we present previous research. Section 3 describes the econometric modelling of exchange rate exposure, and in Section 4 we introduce the data sets employed. Section 5 presents a theoretical framework for the explanatory determinants of exposure, and informs about estimation results. Section 6 concludes.

2. Previous Research

Most studies have been of limited success in identifying foreign currency exposure. Jorion (1990) analysed the exposure to exchange rates of 287 U.S. multinationals and found that only 15 of them are significantly affected by exchange rates. Bodnar and Gentry (1993), who provided evidence based on industry data for Canada, Japan and the U.S, reported that between 20 and 35 percent of industries have statistically significant exchange rate exposures. He and Ng (1998) investigated the exchange rate exposure of Japanese corporations and found that for the period 1979 to December 1993, only 25 percent of the 171 Japanese multinationals have significant exposure. Dominguez and Tesar (2001) examine the extent of firm and industry-level exposure in a sample of industrialized and developing countries for the period 1980-1999. In the pooled eight-country sample, they found that 23 percent of firms and 40 percent of industries are exposed to at least one of their indicators of exchange rate exposure (US dollar, trade-weighted exchange rate, currency of the country's major trading partner). Koutmos and Martin (2003) analysed exchange rate exposure in nine aggregate sectors of major economies (Germany, Japan, the United Kingdom, and the United States), and confirmed existence of exposure in approximately 40 percent of the country-sector models.

Many recent empirical studies focus their research on factors that determine the extent of exposure. An evident question is whether exchange rate exposure is influenced through the channel of international trade. Previous research in this area was pioneered by Jorion (1990), who showed that a firm's exchange rate exposure is positively related to the ratio of foreign sales to total sales. This result was extended and confirmed by recent work of He and Ng (1978), Dominguez and Tesar (2001), and Allayannis and Ofek (2001), inter alia. He and Ng (1998) showed that Japanese multinationals with higher exposure levels are related to higher export shares. However, looking at international evidence, Dominguez and Tesar (2001b,c) concluded that they did not find a strong connection between trade and exposure, although there seems to be some evidence that a higher level of foreign sales corresponds to higher exposure for Germany (Dominguez and Tesar, 2001c, Table 10). Marston (2001) and Bodnar et al. (2002) have drawn attention to the fact that even a local firm which neither exports nor imports can be exposed to changes in exchange rates, for instance if it competes with foreign firms in the domestic market. Thus, as is known from the related literature on exchange-rate pass-through, an important determinant is the competitive structure of the industry in which a firm operates. Some studies have shown that the use of foreign currency derivatives (FCDs), i.e. a short-term (less than one year) hedging strategy, is related to exchange rate exposure. Allayannis and Ofek (2001) found that the use of FCDs is negatively related to the absolute value of foreign currency exposure. By controlling for hedging activity, Crabb (2002) provided evidence that previous studies often found insignificant effects because hedging mitigated currency risks. Exchange rate exposure seems to be higher when companies operate within a system of liberalized exchange rates. Bartov, Bodnar and Kaul (1996) consider the switch from fixed to floating exchange rates following the breakdown of the Bretton Woods system in 1973 and found increasing risks thereafter, whereas Bartram and Karolyi (2003) showed that the introduction of the euro in 1999 was accompanied by significant reductions in market risk exposures in and outside of Europe.

Due to its high share of sales going to exports and its high share of imported goods, Germany is very well suited for testing exchange rate exposure. Indeed, Bartram (2004), who argued that exchange rate exposure may be partly nonlinear, identified both linear and nonlinear exposure components using data of 447 German corporations. However, at the sector level, Koutmos and Martin (2003) found significant exchange rate exposure for only one out of nine sectors in Germany. Based on returns of 12 sector indexes, Entorf and Kabbalakes (1998) detected significant (positive) exposure for chemicals, motor cars and machinery, steel production, and holdings, suggesting that exposure in Germany is mainly driven by exporting activities[1]. Glaum et. al (2000) showed that total exchange rate exposure is unstable over time. Entorf (2000) estimated a time-varying measure of overall German currency risk and showed that it significantly depends both on German exports and imports. Bartram (1999), Dominguez and Tesar (2001b) and Brunner (2003) confirmed the positive impact of foreign sales on exposure using firm level data. Brunner (2003) also tested statistical evidence of several other factors and found that particularly firm size and financial leverage ratios both lead to higher exchange rate exposure of German companies.

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[1] Entorf and Kabbalakes (1998) estimated the extent of “total” exchange rate exposure by regressing foreign exchange rates on stock returns without controlling for general market risks, whereas Koutmos and Martin (2003) estimated the “residual” effect by including the overall market factor.

3. Econometric specification: Orthogonalization issues, APT versus augmented CAPM, and time-varying measurement

As in most studies measuring exchange rate exposure, we follow Adler and Dumas (1984) who showed that the extent of corporate exposure boils down to the slope parameter δ_i^t of a regression

(1) $$r_i = \alpha_i^t + \delta_i^t d + \varepsilon_i^t$$

where r_i is the stock market return of company i, i = 1,2,…N, and d is the return of the exchange rate, i.e. the log-difference of exchange rate levels. The latter are measured in terms of the price of the foreign currency in units of the home currency. Most previous econometric studies further control for overall market risk r_m leading to a CAPM specification augmented by exchange rate movements,

(2) $$r_{it} = \alpha_i^c + \delta_i^c d_t + \beta_i^c r_{mt} + \varepsilon_{it}^c ,$$

based on time series observations. The “conditional” or “residual” effect (as it was called by Bodnar and Wong, 2003), i.e. the exposure that is different from general market exposure, measured by δ_i^c in equation (2), is then interpreted as “residual” exchange rate exposure, whereas the slope parameter δ_i^t in equation (1) would imply some measure of “total” exposure (Bodnar and Wong, 2003) that might be disturbed by some spurious effects arising when common market factors drive both exchange rates and (all) stock returns simultaneously (due to unanticipated monetary shocks, for instance).

Sensitivity of individual firm values to overall market risk (i.e. the “beta” of a firm in the context of non-augmented CAPM modelling) is covered by β_i^c. A problem with specification (2) is that overall market exposure, r_m, which in empirical studies is represented by broad market indices such as the DAX, includes several driving factors, of which exchange rate risk may be particularly important. Thus, insignificance of previous results might arise from the fact that currency risks were already included in overall risk and priced in market risk factors, leading to the misleading statistical result that collinearity between market portfolios and exchange rates prevents significant results. To circumvent a problem such as this, we apply a strategy well known from testing Arbitrage Pricing Theory (APT). McElroy and Burmeister (1988) introduced the use of the so-called “residual market factor” which implies orthogonalization of overall market risk and other risk factors which only consist of exchange rates in the present case of augmented CAPM. Thus, we first estimate an auxiliary regression to capture that particular fraction of aggregate market risk which was induced by exchange rate fluctuations:

(3) $$r_{mt} = \overline{\alpha} + \overline{\delta} d_t + \overline{r}_{mt}$$

The residual of the regression, $\overline{r}_{mt}$, represents the residual market factor, i.e. the overall market risk corrected for the influence of exchange rates. Inserting r_{mt} from equation (3) into equation (2) gives

(4) $$r_{it} = \alpha_i^o + \delta_i^o d_t + \beta_i^o \overline{r}_{mt} + \varepsilon_{it}^o ,$$

where

$$\alpha_i^o = \alpha_i^c + \beta_i^c \overline{\alpha} ,$$

$$\delta_i^o = \delta_i^c + \beta_i^c \overline{\delta} ,$$

$$\beta_i^o = \beta_i^c \text{ , and } \varepsilon_{it}^o = \varepsilon_{it}^c .$$

Thus, δ_i^o summarizes direct and indirect components of exchange rate exposure, whereas the market beta coefficient β_i^o on $\overline{r}_{mt}$ remains the same as β_i^c on r_{mt} in equation (2). Residuals, too, coincide implying the same R-squared in empirical estimations of both models.

One may argue that it is precisely the incremental effect of exchange rate movements not covered by market risk, i.e. of δ_i^c in equation (2), which is of particular interest here, because it represents the firm-specific component of conditional exchange rate exposure. However, under the aspect that a firm should be interested in hedging the risk of total potential value changes resulting from any exchange rate movements, it is of no importance whether these changes affect the common risk of all firms or the risk of the individual firm only.

On the one hand this argument applies because we are, by way of aggregating individual data, primarily interested in exchange exposure faced by the German economy as a whole, not in marginal exposure of particular firms. From this point of view, exposing the relevant currency risk by way of orthogonalization seems to be an adequate strategy which has been followed by some authors before.[2] On the other hand, both total exposure estimates and augmented CAPM specification of exposure estimation regression overlook the fact that further macroeconomic factors besides exchange rates can influence individual returns. For instance, a depreciation might be related to some expansionary monetary policy that simultaneously could have a positive impact on economic activity of domestic firms (Dornbusch, 1976). From the more general viewpoint of financial and macroeconomic theory, Gavin (1989) provided a framework that shows how exchange rates and stock returns interact, and how they react to changes in interest rates, output, and, in particular, to anticipated and unanticipated changes of monetary and fiscal policy (see also Blanchard, 1981, for a related work).[3] From the viewpoint of financial economics, a well known strategy for using controls for such disturbing macroeconomic influences is the application of "Arbitrage Pricing Theory" (APT), pioneered by Ross (1976), and already introduced by Jorion (1991) to the literature on exchange ex-

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[2] However, there seems to be some confusion as to what kind of orthogonalization should be used in econometric tests of the Adler-Dumas framework. Most applications we are aware of proceed in the manner described above (Doukas et al. 1999, Allayannis and Ofek, 2001, Griffin and Stulz, 2001, Priestley and Odegaard, 2002, Bris et al. 2004, Jayasinghe and Premaratne (2004), among others), whereas Jorion (1991) proposed orthogonalization of *exchange rates*, i.e. he employed the reverse regression by regressing exchange rates on market portfolios. The residual from this regression, i.e. orthogonalized *exchange rates,* were included in the exposure regression in addition to total market risk. This approach is counterintuitive and does not coincide with the usual way of orthogonalization known from multi-factor APT modelling. It is also misleading as it does not solve the problem of "hidden" exposure covered and priced in overall market risk. The estimated parameter on orthogonalized exchange rates, i.e. estimated exposure, is even identical to estimated exposure of unorthogonalized exchange rates of equation (2) in reversed regressions, whereas the coefficient of market risk would change its value (see (4) and substitute variables accordingly). Motivated by related work of Choi and Prasad (1995), Glaum et al. (2000) followed the path described in Jorion (1991). Not surprisingly, they did not find any significant "residual" exposure for German data. From this, they erroneously draw the conclusion that estimating "total" exchange rate exposure (in the sense of equation (1)) would be a better way of proceeding.

[3] It should be noted, however, that there are good reasons for neglecting potential problems of endogeneity in our specification, since left-hand side variables, i.e. corporate returns, are observed at the individual level, whereas explanatory variables such as exchange rate fluctuations or trade are given at the aggregate level, which is exogenous to each individual firm.

posure.[4] Thus, to test robustness of econometric results, performed estimation strategy includes the application of the multi-factor equation of the APT model[5], according to which the variation of stock returns is explained by a K-factor model of the form $r = \mu + Bf_K + \varepsilon$, where r is the vector of returns in N stock prices, and f_K is a vector of K (unanticipated) factors, of which only the (residual) market factor and exchange-rate fluctuations were used in previous augmented CAPM specifications of the exposure regressions. B is a NxK matrix of factor sensitivities to the K factors.

There is no general rule for selecting relevant macroeconomic risk factors. According to the "discounted cash flow model", which assumes that prices of assets are determined through their expected discounted dividend payments, factors have to be selected that are potentially responsible for the determination of these payments. Inspired by factors proposed by Chen et al. (1986), who pioneered the empirical approach of estimating the APT, we include a survey indicator of the German business climate, the inflation rate, the term structure, a (residual) market factor, and, in particular, the US dollar, representing the most important source of German exchange rate risk.

Since only unexpected components of macroeconomic time series can influence asset returns in efficient capital markets, we calculate unexpected variation of all variables applying ARMA- and ARIMA-filtering techniques. In order to capture the (residual) market risk that is not explained by other systematic risk factors, we follow the procedure suggested by McElroy and Burmeister (1988) described above. Therefore we include the residual market factor that now becomes the residual of an OLS-regression of the market return on the unexpected components of all involved macroeconomic variables,

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[4] The reason why this idea was widely neglected in later work might be that he used orthogonalized exchange rates (instead of orthogonalized market factor) such that significance was low and suffered from multicollinearity.

[5] We do not present estimations of a full APT model in this paper, because our focus is on time-variant rolling window regressions based on panel information. A complete model consists of the joint determination of factor sensitivities within the multi-factor model and of risk premia, which reveal whether investors have to be compensated by a higher expected return because the exchange rate risk or other risks are not diversifiable. Nonlinear seemingly unrelated regressions of the complete model have been performed in Jamin (1999) and Entorf and Jamin (2000).

including exchange rate risk. Thus, the specification of an APT exposure regression can be considered as an extended version of equation (4):

$$r_{it} = \alpha_i^a + \delta_i^a d_t + \beta_i^a \overline{r}_{mt} + \varphi_i^{a\prime} f_t^u + \varepsilon_{it}^a \,, \tag{5}$$

where *f* represents a vector of macroeconomic variables, and the superscript *u* denotes unexpected components.

Not surprisingly, testing ARIMA models for the DM/dollar return as well as for market risk factors has led to the conclusion that their (short-term) time series behaviour is well described by random walks (results not reported). Thus, we treat both returns of the DM/dollar rate as well as of the market factors as unexpected components (note missing superscripts 'u' for dollar and market returns in equation (5)). Due to this specification and the orthogonalization of the residual market factor and macroeconomic factors, CAPM in equation (4) boils down to be a simple parametric restriction of the APT version estimated in equation (5).

Some problems with the interpretation and comparisons of chosen specifications may occur. First, note that due to the orthogonalization procedure, residual market returns $\overline{r}_{mt}$ and dollar returns d_t are uncorrelated such that OLS estimates of exposure in equation (4) would be identical to total exposure estimated from equation (1) as long as no further restrictions are imposed[6], whereas standard errors are adjusted due to the better fit of the model in equation (4). Thus, the primary interest of the imposed orthogonalization procedure is to uncover potentially neglected significance of exchange rate exposure, not the level of exposure. Of course, estimated exposure itself is also of high interest for researchers and practitioners. Thus, when in equation (5) macro variables are added, standard errors of exposure might be further adjusted, but there may also exist a correlation between these variables and the exchange rate such that they may 'absorb' explanatory power from the exchange rate leading to a smaller estimate of exposure.[7]

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[6] Note, however, that SUR (seemingly unrelated regressions, see below) does not coincide with OLS estimation of total exposure (see equation (1)) and residual exposure (see equation (4)) when company-specific constants are included.

[7] We are grateful to an anonymous referee for pointing out this interpretation problem. At first glance, cleaning out all macro variables similar to the market return by individually adjusting them for their interaction with the exchange rate (i.e. by regressing their returns one by one on exchange rate returns) seems

It is thus important to check sensitivity of results dependent on the presence or absence of further macro risks. In any event, compared to orthogonalized CAPM, inclusion of other macro variables represents a conservative test for the presence of any exchange rate exposure.[8]

Our econometric modelling extends previous approaches by controlling for unobserved heterogeneity of company firm values using fixed company effects[9] which might arise due to particular features not observable in the data (management, reputation, etc.). With individual DAX companies available, we stack individual time series and run each of presented specifications (1), (2), (4) and (5) as systems of seemingly unrelated regressions (SUR). SUR considers correlations of disturbances across companies and leads to GLS estimation of the whole system. Stacking companies allows testing several hypotheses as well as estimation of aggregate exposure: 1) $\alpha_i^a = \alpha^a$ for every company i (test for unobserved heterogeneity)) , 2) $\delta_i^a = \delta^a$ for every i; non-rejection and imposing the restriction gives an estimate of aggregate stock market exposure, 3) $\beta_i^a = \beta^a$ for every i; if the restriction $\beta_i^a = \beta^a$ holds, then the universe of all German DAX companies would share a common overall market risk, and 4) if $\varphi_i^a = 0$ for every i, then APT could be restricted to augmented CAPM.

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to be a promising alternative strategy. Note, however, as this procedure would lead to exchange rates being orthogonal to all other variables in the extended APT-like regression, estimated exposure would be identical to total exposure from equation (1), i.e. there would be no additional insight with respect to the measurement of exposure. Furthermore, as this procedure would neglect orthonalization of macro variables and the market factor, now the market factor may absorb the impact of macro variables, i.e. macro variables would be correlated with the market factor. In a (non-reported) regression following the alternative in question, i.e. using individually adjusted macro factors, it turns out that all of them keep insignificant (whereas Table 2, column (4), see below, reveals their significance when the usual orthogonalization procedure is followed).

[8] In the German example, a comparison of estimates in Table 1 and Table 2 (based on total sample period, see below) reveals that the difference is rather small: Inclusion of macro risks has reduced exchange rate exposure from about 0.17 to 0.14.

[9] We do not test for random effects because our primary goal is to achieve *consistent* results of the exposure parameters needed in the second stage of the estimation procedure (to be discussed below).

Even after controlling for macroeconomic risks, unobservable macroeconomic and financial changes may result in unstable currency exposure. Moreover, exposure reflects expectations of investors which do not depend on the whole history of financial markets, but rather on limited information sets. Thus, estimations should be time-varying, and they should give much more weight on recent observations. Accordingly, we estimate equation (5) using moving window regressions, with each additional rolling sample giving a new estimate δ_{it}^{a}.[10]

Most applications of exchange rate exposure models are based on two-stage procedures, pioneered by the work of Jorion (1990). In the standard first stage, by running N time series regressions, the stock returns of a sample of N companies are regressed on the exchange rate within an augmented CAPM discussed above (see equation (2)). Second-stage specifications then consist of a cross-sectional regression of exchange rate exposure δ_{i}^{c} on averaged indicators of foreign involvement, or other determinants of exposure discussed above. We extend this procedure by performing moving APT multifactor models, thereby employing panel information of company returns. Disposing of resulting time-varying exposures δ_{it}^{a} or δ_{it}^{o} (instead of cross-sectional δ_{i}^{c}, for instance) in second-stage regressions allows us to focus on panel data and time series instead of cross sections to analyse the (macro-) economic determinants of exchange rate exposure.

4. Data

Our sample of stocks includes 28 leading German corporations comprising the DAX (the leading index of the Frankfurt stock exchange) on the 31st of March 1995.[11] They represent about 70 % of total turnover in German stocks during the sample period.[12] Monthly returns for the period from January 1977 through March 1995 are adjusted for dividends, capital increases and splits according to adjustment factors obtained from

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[10] As only unanticipated realizations enter the APT multifactor model, unexpected components of all explanatory variables are calculated using residuals from ARIMA models for each rolling sample.

[11] In order to take advantage of a balanced panel, VIAG and Henkel had to be excluded as their returns were not available for the whole estimation period.

[12] See Sauer, A. (1994), p. 102.

KKMDB, i.e the “Karlsruhe Data Base for Financial Time Series” (“Karlsruher Kapitalmarktdatenbank”).[13]

Macroeconomic risks are based on the following variables:

- Business climate: Monthly change rate of the “ifo business climate” (“ifo-Geschaeftsklimaindex”), an acknowledged German leading business cycle indicator published by CESifo (Munich).
- Inflation: Monthly rate of change in the German consumer price index (“Lebenshaltungskostenindex”) calculated by the German Federal Statistical Office (Statistisches Bundesamt).
- Term structure: Difference between the 10-year rate on German government bonds and the 1-month money market rate, both calculated by Deutsche Bundesbank (Frankfurt).
- Exchange rate: We use closing rates of the “Deutsche Mark (DM)/ US dollar” exchange rate at the Frankfurt foreign exchange market. As our objective is to examine the particular importance of the US dollar for German stock companies, we refrain from using trade-weighted averages of different currencies, as was proposed by Jorion (1990, 1991), and applied by Bodnar and Gentry (1993) and others.[14]

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[13] KKMDB was supported by the German National Science Foundation (DFG, Deutsche Forschungsgemeinschaft) to provide a file of German stock prices and performance indices for scientific use. For further information see http://finance.wiwi.uni-karlsruhe.de/Forschung/kkmdb.html.

[14] The use of trade-weighted indices was proposed by Jorion (1990, 1991) who analysed US exposure. In the US, however, there is no single currency which is as important as the US dollar for German or European economies. In Germany, the US dollar clearly is the centre of investors’ attention, as can be seen from perpetual and recurrent comments in newspapers, “Up or down, euro leaves exporters complaining” (International Herald Tribune, May 9, 2003), “Anleger verkaufen Exportwerte. Aufwertung von Yen und Euro trüben Gewinnaussichten japanischer und europäischer Firmen” (“Investors sell shares of export-oriented companies. Appreciation of yen and euro obscure expected profit of Japanese and European firms” Frankfurter Allgemeine Zeitung, September 23, 2003). From this quotations, note the relevance of US dollars as ”euro“ always refers to US-dollar/euro. Moreover, note the high relevance of the DM/dollar rate for the euro, as it was the key currency in Europe, and its share amounted to 33.07 percent (second largest share: French Franc, 20.28 percent) of the basket of currencies constituting the ecu, i.e. the “synthetic” currency preceding the euro.

The overall German market risk is based on the DAFOX ("Deutscher Aktien-Forschungs-Index"), which is a Laspeyres performance index including all 30 DAX corporations as a subset (see Göppl and Schütz, 1993, for details). It was generated for scientific research purposes in order to dispose of a broader index of overall German stock market portfolio than the one provided by the DAX, which only consists of German blue chips (source: KKMDB).

Indicators of foreign involvement are available as shares of exported and imported goods and services in German GDP (West Germany, source: Statistisches Bundesamt). This allows us to consider the burden of (imported) input costs as well, an issue that is often neglected in empirical studies which mainly limit their focus to foreign sales.

5. Results

5.1. Direction and Magnitude of Exposure

We compare exposure estimates of orthogonalized augmented CAPM and APT-based models for different periods of time in Tables 1 to 3. Our sample consists of monthly returns of 28 DAX companies for the time period January 1977 to March 1995, leading to 6132 observations. The sample period lies well beyond the beginning of floating exchange rates in 1973 and well ahead the introduction of the euro in 1999. This selection avoids potentially misleading results due to adjustment problems after the breakdown of the Bretton Woods system described by Bartov, Bodnar and Kaul (1996), or because of anticipating investment decisions in the face of a forthcoming introduction of the euro (see Bartram and Karolyi, 2003).

In Table 1, column (1), estimates of the augmented CAPM reveal that company-specific effects turn out to be insignificant. Evidently, observed heterogeneity already covered by company-specific exposure, δ_i^o, and company-specific influences from market factors, β_i^o, render control for unobserved heterogeneity meaningless. All company estimates of exchange rate exposure have a positive sign, and 12 of them are significant. As regards market betas, individual estimates of overall market influences range between 0.79 (RWE, a former energy utility) and 1.32 (Daimler, car production).

In Table 1, column (2), we test for common exposure, identical to all DAX companies. This hypothesis is not rejected. Exposure is highly significant and estimated to be 0.172.

Thus, for the period 1977 to 1995, an increase of the DM/US dollar-exchange rate by 10 percent (i.e. a depreciation of domestic, i.e. German, currency) on average increased stock market values of German companies by 1.7 percent.

Table 1, column (3), additionally restricts individual coefficients of overall market portfolio risk to be identical for all companies. The aggregate estimate is 1.072, indicating overall offensive behaviour of German DAX companies in the long run. However, testing the restriction shows that the hypothesis of a common parameter, i.e. $\beta_i^o = \beta^o$, has to be rejected (see footnote of Table 1 for details of hypothesis testing). The estimate of exchange rate exposure, δ^o, remains almost unchanged (0.168 instead of 0.172).

Finally, specification (2) is replicated using the overall market factor r_m instead of the residual market factor $\overline{r}_m$ (Table 1, last column). Indeed, for reasons discussed in Section 3, using this specification leads to insignificance of exchange rate exposure δ_i^c. Thus, we can conclude that exchange rate exposure is an important determinant of German stock values, but that it would not show up in standard (not orthogonalized) residual exposure models based on overall market risk.

General market risk presumably has more than one dimension. Table 2 controls for further macroeconomic factors within the framework of an APT-based multifactor model. Table 2, column (1), presents unrestricted[15] estimates. Results do not differ much from corresponding column (1) of Table 1: Now 26 out of 28 company exposures have a positive sign (and 8 of them are significant instead of 12 in Table 1), and the range of market betas is almost the same as before (ranging between RWE's 0.79 and Daimler's 1.34).[16] Inspecting column (2) shows that the standard error of the aggregate exchange exposure coefficient δ^a remains the same as in Table 1 (0.014). The aggregate estimate of exchange rate exposure is somewhat smaller 0.139 (instead of 0.172 in Table 1), indicating that indeed some of the explanatory power of exchange rates is absorbed from added macro variables, as pointed out in Section 3.[17] However, exchange rate ex-

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[15] As before, tests show insignificance of company-specific fixed effects.

[16] Company-specific exposures and sensitivities to overall market factors are presented in Tables C and D of the Appendix.

[17] In a regression of dollar returns on unanticipated macro variables (results not reported elsewhere in the paper) it is found that unanticipated inflation and changes in the term structure significantly contribute to

posure remains highly significant such that any correlation with macro variables is of second order of importance when compared to the strong change of statistical significance that arises due to exclusion/inclusion of the interrelationship with the market factor (see Table 1, specifications (2) and (2’)).

Table 2, column (3), shows that sensitivity to overall market risk remains almost unchanged compared to CAPM in Table 1. In column (4), company-specific sensitivities to other macroeconomic factors are restricted to be identical to some aggregate estimate. Estimated parameters are highly significant, indicating that restricting APT to CAPM would not be justified by the data. Directions of influence are in line with usual economic reasoning. First, (non-anticipated) inflation has a negative impact on stock market returns. This might imply that investors expect a negative impact of increasing money depreciation on company profits. The negative parameter of changes of the term structure is in line with the rational expectations hypothesis of the term structure, as an increase in the term structure implies the expectation of increasing future interest rates, and therefore a heavier discounting of future profits. The parameter estimate of the ifo business climate indicator has a positive sign, confirming its role as acknowledged leading economic indicator for German companies.

Table 3 reveals that exchange rate exposure is not stable over time. To show changing parameter estimates, we divide our sample into four different, rather heterogeneous subperiods. The situation of the first period, 1977 to 1979, is characterized by a well performing German economy and appreciation of the Deutsche Mark. The DM/dollar-exchange rate fell from 2.40 at the beginning of 1977 to 1.70 in December 1979. The next six years, 1980 to 1985, are predominated by the second oil price shock and the recession in 1981/82, and a sustainable depreciation of the Deutsche Mark against the dollar, reaching its peak in March 1985, when the DM/dollar rate was 3.36. After the so-

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this correlation. Regression coefficients are positive for inflation and negative for interest rates. Signs are as expected. The positive partial correlation with inflation is in line with monetary expansions (contractions) that simultaneously increase (decrease) prices and foster depreciation (appreciation) of local currencies, whereas an increase (decrease) of the term structure anticipates rising interest rates, which in turn would lead to increasing capital imports (exports) and thus appreciation (depreciation) as a result of the interest rate parity of exchange rates. However, the only small overall impact from these variables can be seen from the very low adjusted R-squared of this regression which is only 0.041.

called Plaza Agreement reached in September 1985 by the G-5 countries (France, Japan, West Germany, the UK and US), on a need to adjust current exchange, the time span 1986 to 1990 was characterised by a now strongly depreciating dollar. The DM/dollar rate fell to 1.50 at the end of 1990. The final period, 1991 to 1995, includes the time after German unification with a relatively stable but low DM/dollar rate (fluctuating around 1.60, maximum: 1.82, minimum: 1.37).

Table 1: Estimation of exposure using (orthogonalized) augmented CAPM

Model: $r_{it} = \alpha_i^o + \delta_i^o d_t + \beta_i^o \overline{r}_{mt} + \varepsilon_{it}^o$

Explanatory variables (returns) / Parameters	(1)	(2)	(3)	(2')
	Test of common alpha[1)]	Test of common exposure[2)]	Test of common market risk[3)]	Use of r_m instead of $\overline{r}_m$
Constant α	0.0081** (0.0005) ´$\alpha_i^o = \alpha^o$´ not rejected	0.0081** (0.0005)	0.0081** (0.0005)	0.0005 (0.0005)
DM/dollar exchange rate δ	number of companies with positive exposure: 28 (significant: 12), number of companies with negative exposure: 0	0.172** (0.014) ´$\delta_i^o = \delta^o$´ not rejected	0.168** (0.014)	- 0.002 (0.014)
(Residual) Market factor β	company specific, range: 0.79 (RWE) - 1.32 (Daimler)	company specific, range: 0.79 (RWE) - 1.32 (Daimler)	1.071** (0.010) ´$\beta_i^o = \beta^o$´ rejected	company specific, range: 0.79 (RWE) - 1.32 (Daimler)
$\overline{R}^2$	0.529	0.529	0.519	0.529

Notes: Sample: 28 DAX companies, 1977:01-1995:03, (6132 observations). See the text for estimation details. **) denotes significance at 1 percent level. Restrictions are tested using F-Tests: 1) test for unobserved company effects, 2) (2) is tested against (1), 3) (3) is tested against (2). Corresponding F-statistics: [1)] F= 0.79, [2)] F=1.10, [3)] F= 5.36. Critical values: F(27, ∞, 5%) =1.46, F(27, ∞, 1%) = 1.69.

Table 2: Estimation of exposure using APT multifactor model, 1977-1995

Model: $r_{it} = \alpha^a + \delta_i^a \, d_t + \beta_i^a \, \overline{r}_{mt} + \varphi_{1i}^a \, p_t^u + \varphi_{2i}^a \, i_t^u + \varphi_{3i}^a \, c_t^u + \varepsilon_{it}^a$

Explanatory variables (returns) / Parameters	(1)	(2)	(3)	(4)
	Test of common alpha[1)]	Test of common exposure[2)]	Test of common market risk[3)]	Full restriction[4)]
Constant α	0.0083** (0.0005) ´$\alpha_i^a = \alpha^a$´ not rejected	0.0083** (0.0005)	0.0083** (0.0005)	0.0083** (0.0005)
DM/dollar exchange rate δ	number of companies with positive exposure: 26 (significant: 8) number of companies with (insignificant) negative exposure: 2	0.139** (0.014) ´$\delta_i^a = \delta^a$´ not rejected	0.136** (0.014)	0.135** (0.014)
(Residual) Market factor β	company specific, range: 0.79 (RWE) - 1.34 (Daimler)	company specific, range: 0.79 (RWE) - 1.34 (Daimler)	1.072** (0.010) ´$\beta_i^a = \beta^a$´ rejected	1.073** (0.010)
Unexpected macro risks (inflation, term structure, business climate) $\varphi_1, \varphi_2, \varphi_3$	company specific	company specific	company specific	$\hat{\varphi}_1^a = -2.06$ * *, $\hat{\varphi}_2^a = -1.78$ * * $\hat{\varphi}_3^a = 0.33$ * *
$\overline{R}^2$	0.531	0.531	0.522	0.519

Notes: 28 DAX companies, 1977:01-1995:03 (6132 observations). See the text for estimation details. **) denotes significance at 1 percent. Restrictions are tested using F-Tests: 1) test for unobserved company effects, 2) (2) is tested against (1), 3) (3) is tested against (2), 4) (4) is tested against (3). Estimated F-statistics: [1)] F= 0.76, [2)] F=1.21, [3)] F= 5.07, [4)] F=1.39. Critical values 1)-3) F(27, ∞, 5%) = 1.46, F(27, ∞, 1%) = 1.69, specification (4): (F(91, ∞, 5%) = 1.27.

Table 3: Comparison of exposure models for different sample periods

Estimates of residual exchange rate exposure, δ

Model	1977-1995	1977-1979	1980-1985	1986-1990	1991-1995
Augmented CAPM [1] (δ^o)	0.172** (0.014)	0.027 (0.016)	- 0.268** (0.017)	0.526** (0.017)	0.384** (0.021)
APT-based[2] (δ^a)	0.139** (0.014)	0.057** (0.006)	- 0.308** (0.017)	0.296** (0.016)	0.447** (0.021)

Notes: Estimation models: [1] based on equation (4), restriction as Table 1, col. (2), [2] based on equation (5), restriction as Table 2, col. (2). *), **) denote significance at 5 and 1 percent, respectively.

Table 3 shows aggregate exposure[18] to DM/dollar movements estimated from statistically preferred specifications of previous tables, i.e. along column (2) of Tables 1 and 2. Looking at APT-based specifications, estimated exposure varied intensely from -0.308 in 1980/1985 to 0.447 during the time period 1991 to1995. The estimate of the period 1980 to 1985, i.e. the period of a very strong dollar and deep recession, was the only period with a negative exposure. The estimate (–0.308) indicates that a 10 percent increase of the DM/dollar exchange rate has led to a 3.1 percent fall of DAX stock returns. Thus, it seems as if further depreciation of the Deutsche Mark against the US dollar shied away investors during the space of 1980 and 1985, whereas other analogous times of a relatively strong dollar (or weak DM) had stimulating effects on the German economy.

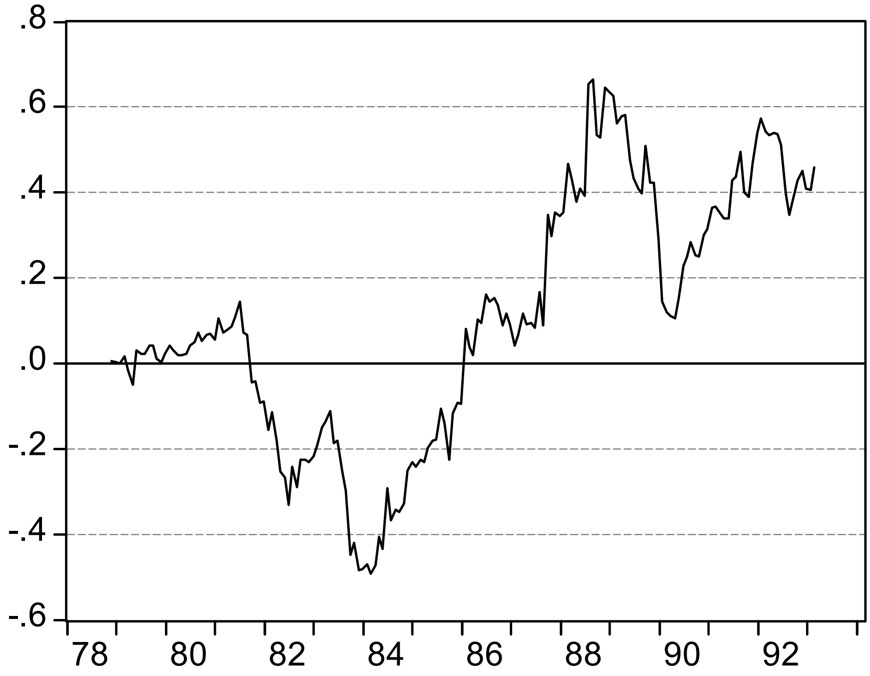
As macroeconomic factors are significantly different from zero in specification (5), we may conclude that for some periods estimates based on orthogonalized augmented CAPM may be affected by some omitted variable bias. The bias can be substantial, as can be seen from the time period 1986 - 1990, where the augmented CAPM estimate is 0.53, whereas multi-factor exposure is 0.30. However, it is not necessarily true that exposure estimates are reduced when other macro risks are included, as suspected in the previous section when discussing results of the overall sample period. Table 3 reveals that for all subperiods with the exception of 1986 to 1990 (and except the total sample period), absolute values of exposure are higher when the APT-based specification is chosen, leading to the conclusion that avoidance of some omitted macro variable bias helps to uncover significance of potential exchange rate exposure. This result is nicely visible for the period 1977 to 1979, where orthogonalized augmented CAPM leads to insignificant exposure, whereas inclusion of macro variables has revealed a highly significant estimate.

Figure 1 displays aggregate time-varying exposures from moving window regressions. The specification is based on equation (5), where company-specific exposures, δ_i^a, and company-specific macroeconomic effects, φ_i^a, are restricted to be identical to corresponding aggregate parameters δ^a and φ^a, respectively (as presented in Table 2, column (4)). These estimates do not differ significantly from statistically superior results without such a restric-

[18] Company-specific estimates are presented in Tables C,D (Appendix).

tion (compare columns (2) and (4) of Table 3).[19] Rolling samples cover a time span of 48 months. Estimated exposures of each rolling regression period are displayed at the month of the midterm period. Thus, the first observation in Figure 1 presented for December 1978 represents estimated exposure of the estimation period 1977:01 – 1980:12, the last observation dated March 1993 covers the period 1991:04 – 1995:03 (note that this last period almost coincides with the last period analysed in Table 3).

Figure 1: Time-varying exchange rate exposure in Germany



Note: Estimates of exposure, δ_t^a, are based on moving window regressions of APT-multifactor specifications, see equation (5) and Tables 2, 3. See the text for estimation details.

Figure 1 illustrates previous estimates from Table 3 in more detail. The graph nicely exhibits the time-varying nature of the German 'dance with the dollar' which implies, for instance, that an appreciating dollar (relative to Deutsche Mark) temporarily entails decreas-

[19] Attempts to estimate individual parameters for each company and for each rolling sample turned out to be unfeasible due to convergence problems of sample-specific ARIMA modelling and singularity problems.

ing company returns (as in 1980 to 1985), and at other times implied increasing values of German companies. A noticeable drop of exchange rate exposure not detectable in estimations of longer time periods happened around 1990, i.e. the time of the fall of the Iron Curtain.

Before we analyse the determinants for the time-varying exposure in more detail, we may conclude that the assumption of a stable currency exposure is not justified.[20] This result does not necessarily come as a surprise, as we already know the stylized fact that financial market parameters are not constant over time, as can be seen from the rich literature of time-variant market betas in classical CAPM-specifications.[21]

5.2. Determinants of Exposure

Costs and benefits of a weakening dollar differ between firms. Exporters like car producers suffer from appreciation of domestic currency relative to the dollar, whereas companies which ground their production on a high share of inputs factorized in US dollars (like energy utilities) would realize unexpected windfall profits. Studies analysing determinants of exposure, in particular when they are based on data at the company level, focus on foreign sales but often ignore exchange-rate dependent costs from importing inputs. As we are interested in estimating and analysing the aggregate role of exposure in Germany, we use both export shares and import shares of (West) German GDP in order to analyse the dual and ambivalent role of exchange rate movements for the German economy. From the viewpoint of a representative firm operating in a world-wide economy, we expect that in situations dominated by the interests of foreign sales (German exporters), there will be a positive impact from depreciation of the domestic (German) currency on the firm value,

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[20] This finding confirms previous results based on total exposure put forward independently of each other by Glaum et al. (2000) and Entorf (2000). The general time pattern of exposure presented there roughly coincides with the one presented in Figure 1, but levels differ and curves appear to be more erratic when they are based on total exposure.

[21] Early evidence on beta-instability dates from the 1970s (see, for instance, Blume 1975). More recent evidence using more sophisticated tests is reported in, e.g., Bos and Newbold (1984) and Gonzales-Rivera (1997). See Table D (Appendix) for company-specific variations in our sample.

whereas the opposite would apply in situations which are characterized by a relative strong dependency on the costs coming from imports. Thus, we expect exposure to have a positive sign in situations of dominating exports, and to be negative during periods of relatively high imports. As Germany for the most part had a surplus in its trade balance, it is well described by the situation of a net exporter, and we expect a positive sign for exports and a negative sign for imports in second-stage regressions devoted to the analysis of determinants of exposure.

Some preliminary considerations confirm these expectations. Table 4 provides descriptive evidence on the relationship between exports and imports, on the one hand, and exposure estimates of different sample periods, presented in Section 5.1 (see Table 3), on the other hand. Exposure is highly positive in times of sizable export surpluses, whereas it is much lower or even negative when import comes close to exports. In particular during the period 1980 and 1985, increasing exchange rates were considered more a burden than a benefit as can be seen from the negative sign of exposure for this time period. Looking for more detailed explanations, it can be found that within a short subperiod (1980/81) the German trade balance was even negative.[22] Moreover, the beginning of the eighties were strongly influenced by the second oil shock such that any further increase of the US-dollar would be 'bad news' as it further increased the German oil bill.

Table 4: Exchange rate exposure, exports and imports for different sample periods

	1977-1979	1980-1985	1986-1990	1991-1995
Exposure δ^a (APT based, see Table 3)	0.057	-0.308	0.296	0.447
exq	0.274	0.324	0.336	0.373
imq	0.253	0.303	0.276	0.304
$(exq - imq) - (\overline{exq - imq})$	-0.030	-0.029	0.009	0.019

Note: Mean values of subperiods

[22] During 1980:3 (3rd quarter) and 1981:2, the German export share in GDP was 0.298, whereas the import share was 0.302.

Besides these immediate influences from international trade, firm values are affected by costs of adjustment. The role of adjustment costs caused by the order of magnitude of exchange rate movements has received surprisingly little attention in the literature.[23] Theoretical analysis shows that profits and firm values may be a convex function of the exchange rate (see Franke 1991, Sercu and Vanhulle 1992, and DeGrauwe 1994, among others). Convexities can arise because of costly adjustments of international portfolios, or when volatile exchange rates affect uncertainty of future prices of exported or imported goods, among others. For instance, underestimating the risk of an exchange rate change might facilitate over-expansion of foreign indebtedness exposing firms to high costs when exchange rates do change. Moreover, marketing investments in foreign markets (German car producers in the US, for instance) and other entry costs might become sunk costs when a future appreciation of the domestic currency undermines the competitiveness of exporting corporations. Motivated by the fact that a high percentage of firms use hedging strategies to circumvent such costs of adjustment[24], several recent papers focus on hedging and reduced risk stemming from the use of forward contracts, options or other hedging

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[23] Only a few articles test and estimate nonlinearities in exposure models. Whereas Miller and Reuer (1998) and Andren (2001) tested for exposure of quadratic and cubic macro-price changes with insignificant or weak results, Bartram (2004) performed several tests for nonlinearities with and without structure and confirmed the need to model nonlinear exposure by referring to significance of cubic terms. Results by Priestley and Odegaard (2002) point to the conclusion that exporters are subject to nonlinear exposure but importers are not. Our testing strategy differs from that of quoted articles in various aspects and is based on different data sets. Closest to our approach, Miller and Reuer (1998), Andren (2001) and Koutmos and Martin (2003) focus on (asymmetric) adjustment to depreciations and appreciations, but performed one-stage estimations based on (linear) dichotomous indicators of asymmetry make it necessary to analyse 9 possible outcomes for exposure such that structural interpretations are difficult to derive. Koutmos and Martin (2003) also employed conditional heteroskedasticity of error terms of estimated sector stock market returns, but they do not consider higher moments in their CAPM augmented market model.

[24] Bodnar and Gebhardt (1998) report that in comparative samples of US and German firms, 78% of German firms compared to 57% of US firms make use of derivatives in risk management. More recently, Bartram et al. (2003) present international evidence on financial derivatives usage for a sample of 7,292 non-financial firms. Across all 410 German firms in the sample, there were only 44.9 percent using derivatives in general, while 36.8 percent use currency derivatives. Corresponding international numbers for all firms of the sample from 48 countries, 59.8% and 43.6%, respectively, show that such practices seem to be less widespread in Germany than elsewhere.

strategies, but they neglect to say that there might be substantial costs of hedging, and that the cost of hedging depends on the exchange rate itself (see Giddy and Dufey, 2003, for strategies of managing corporate foreign exchange risk and related costs). The price of an option, for instance, increases convexly with the expectation for a currency's volatility because of inherent leverage effects: the more volatile, the higher the price.

This paper takes account of exchange rate adjustment costs by modelling exposure in dependence of exchange rate variation. In line with Franke (1991), who assumed the exchange rate to be mean reverting, and motivated by confirming empirical evidence found by Engel and Hamilton (1990), Frankel and Rose (1996), Sweeney (2001), inter alia, our model is based on the assumption that firms adjust their behaviour to expected long-run exchange rates. Resulting adjustment costs per foreign currency unit are assumed to increase with the absolute distance $\Delta(S,\overline{S})$ of current exchange rates, S, from expected long-run exchange rates, $\overline{S}$.

A framework that allows derivation of exchange rate exposure and its determinants, has to be based on the value of a firm, V, which can be expressed as the present value of present and future cash flows, i.e. $V=\sum_t E(CF_t)/(1+r)^t$. Provided that cash flows depend on exchange rates, S, exposure is represented by the derivative (dV/dS). With taxes, discount and growth rates being constant, exposure can instead be measured by the derivative

$$\delta \equiv \frac{dV}{dS} = \frac{d\pi}{dS} \tag{6}$$

(see Bodnar et al, 2002).[25] Thus, exposure is equal to the change in profits, π, induced by a change in the exchange rate. Motivated by considerations stated above, the profit of a firm typically consists of domestic and foreign sales, reduced by costs of domestic and imported inputs, and by costs due to exchange rate adjustment. The firm is assumed to meet its exogenously given national and international demand by producing its output in the home country. Output is separated into sales going to exports, X^*, and output sold on the home market, X. Total output, X^*+X, is produced using inputs from its home market

[25] In standard theoretical terminology, exposure is defined as dV/dS, but estimated exposure coefficients use rates of return data, i.e. estimated coefficients are more appropriately based on $d(\ln V)/d(\ln S)$.

as well as imports from abroad. Accordingly, total input costs are assumed to be decomposable into domestic and foreign inputs. So a firm's total output costs in home currency can be written $(C+SC^*)(X+X^*)$, where C (C^*) is the marginal cost of home country inputs (foreign inputs) of the firm in its home (foreign) currency (see Bodnar et al., 2002, for a similar separation of marginal costs). Thus, a simple stylized model for the profit of the (domestic) firm in its home currency is thus given as

(7) $$\pi = PX + SP^*X^* - (C+SC^*)(X+X^*) - S\,g\left(\Delta(S,\overline{S})\right)|H|,$$

where

P	=	price of the firm's product in the home market
P^*	=	price of the firm's product in the foreign market in units of the foreign currency
X	=	the quantity of the firm's product sold in the home market
X^*	=	the quantity of the firm's product sold in the foreign market
S	=	price of the foreign currency in units of the home currency (so if Germany was the home country, $S = DM/\$$)
C	=	marginal cost of domestic inputs in its home currency
C^*	=	marginal cost of foreign inputs in foreign currency
g	=	functional form of marginal adjustment costs
$H = P^*X^* - C^*(X+X^*)$	=	net hedge position

Disregarding adjustment cost (i.e. assuming $g=0$), the model predicts

(8) $$\frac{\partial \pi}{\partial S} = P^*X^* - C^*(X+X^*),$$

i.e. exchange rate exposure positively depends on foreign sales, and decreases when costs in foreign currency go up, for instance due to a higher input share of imported goods and services. Implied signs of sales going to exports and imported input costs are in line with previous empirical results in the literature (see Section 2).

Turning to $g \neq 0$, adjustment costs depend on the amount of foreign currencies to be managed. As currencies from foreign sales can be used to finance expenditures in foreign currency, the relevant hedging position is the difference between foreign output sales and foreign input costs, H. For reasons of convenience, H is taken in absolute terms implying that any cost function g weighs hedging of imports and hedging of exports in a symmetric way. Now exchange rate exposure defined as the partial derivative of the profit function with respect to the exchange rate consists of three main components, namely exported sales, foreign input costs, and an adjustment cost factor, $f(S)|H|$, with $f(S)$ defined as $f(S) \equiv (g'(S)S + g(S))$:

(9) $$\frac{\partial \pi}{\partial S} = P^* X^* - C^*(X + X^*) - f(S)|H| = H - f(S)|H|.$$

When, in accordance to standard approaches of modelling adjustment cost, a quadratic form is chosen, i.e.

(10) $$g(S) = \lambda (S - \overline{S})^2,$$

with $\lambda \geq 0$ representing an adequate adjustment parameter, then the adjustment cost component in equation (9) would boil down to the quadratic function

(11) $$f(S)|H| = \lambda\, m(S)|H|,$$

where $m(S) \equiv (3S^2 - 4S\overline{S} + \overline{S}^2)$.

Previous theoretical arguments lead to the econometric specification of second-stage regressions. Exposures δ_{it}, estimated from moving-window regressions in the first step, depend on foreign sales and imported inputs as well as on a nonlinear component, $f(S)|H|$. As no individual data are available and since the primary intention is to estimate aggregate parameters, aggregate export shares in GDP, exs, and import shares, ims, are used as explanatory trade determinants of exchange rate exposure. Moreover, we assume quadratic adjustment costs implying that the component $\lambda\, m(S)|H|$ (see equation (11)) has to be added to the econometric model. The component is linear in the parameter λ, which can thus be estimated in a linear regression model. In our econometric specification, $\overline{S}$ is replaced by the mean value of the sample period (which was 2.083 DM/ \$). Moreover, corporate-specific fixed effects control for unobserved heterogeneity (management strategies such as individually different hedging practices, for instance).[26] We stack individual time series and base second stage regressions on the econometric specification (12), i.e.

(12) $$\delta_{it} = \gamma_{0i} + \gamma_{1i} exs_t + \gamma_{2i} ims_t + \lambda_i \, m(S_t) \left| H_t \right| + \varepsilon_{it} .$$

Equations for companies i = 1,…,28 are estimated as a system of seemingly unrelated regressions. Realisations of δ_{it} are obtained from moving-window first-stage panel regressions under consideration of company-specific APT factors (see equation (5)). As exposures δ_{it}^{a} are estimated from moving windows, point estimates are allocated midway of each window, as displayed in Figure 1 (hence explanatory variables are matched to the same centre point of each window).

Time series variation of exports and imports enables identification of trade parameters, γ_1 and γ_2. Imposing the restrictions $\gamma_{1i} = \gamma_1$ and $\gamma_{2i} = \gamma_2$ for all companies i[27], column (1) of Table 5 confirms the hypothesis that an increasing importance of exports ceteris paribus leads to rising exposure, whereas a relative growth of imports diminishes it. Estimated parameters are surprisingly high at first glance: Looking at the estimate 6.84 for export share in column (1), an increase of the export share by one percentage point would lead to an increase of exposure by almost 0.07 on average. However, exports and imports almost always move in the same direction (both positively depend on fluctuations of world trade and the German integration in global business cycles; the correlation coefficient amounts to 0.54), such that the usual "ceteris paribus condition" has limited appeal in historical situations.[28] However, columns (2) to (4) show that signs of exports and imports do not arise as a spurious result of some multicollinearity between both variables: Including only exports leads to a positive sign, using imports as sole regressor reveals a negative impact,

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[26] Company-specific effects are significant for all specifications presented in Table 5.

[27] Without this restriction, all 28 estimates of γ_{1i} are positive, of which 24 are significant. As regards estimated parameters on imports (γ_{2i}), 28 are negative, of which 26 are significant (5%-level). Testing $\gamma_{1i} = \gamma_1$ and $\gamma_{2i} = \gamma_2$ leads to the result of an invalid restriction at the 1% level (F=4.11, critical value = 1.51). In spite of this result, Table 5 is limited to the presentation of restricted estimation results in order to focus on aggregate evidence concerning the overall German economy.

[28] Note also the high variation among companies ranging between – 0.90 and 1.26: see Table B, Appendix.

and also the positive sign of $(exs - ims)$ confirms expected results.[29] The much higher R-squared in the latter case compared to columns (2) and (3) shows that even univariate measurement of interacting exports and imports is superior to models with either of both variables. Table 5, column (5), informs about the effect of aggregate foreign involvement, calculated as the sum of exports and imports in German GDP. In line with previous results found in the literature, it can be concluded that the higher total foreign involvement is, the higher aggregate exposure of firms is. This specification, however, has only small explanatory power (note the very low R-squared).

The next step is to test whether exposure is line with the hypothesis of (quadratic) adjustment costs, caused by departing from expected long-run dollar values. Column (6) reveals that effects are as expected. The adjustment parameter (see equations (10), (11)) has the expected negative sign and is estimated as $\hat{\lambda} = 1.61$. The high importance of adjustment costs for profits and thus for exchange exposure can be seen from the adjusted R-squared that rises from 0.341 (column (1) when only exports and imports are included to 0.519 in the presence of the adjustment cost component.

The estimation of company-specific adjustment parameters λ_i (column (7)) reveals significant heterogeneity at the firm level.[30] A relative high influence can be observed for corporations mainly belonging to the car industry as well as to the steel and metals sector, whereas the impact seems to be less important for energy utilities, banking and insurance companies.[31] Thus, though company-specific conclusions can only be tentative given data restrictions, exchange rate adjustment costs appear to be more important for export-oriented firms, whereas import-oriented (in particular oil-dependent) firms and corporations mainly operating in the home country seem to be less sensitive to large deviations from

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[29] An F-Test rejects the hypothesis $\gamma_1 = -\gamma_2$ at the 1% level (F=98.16, critical values at the 5% / 1% level = 3.84 / 6.64).

[30] The F-statistic of the hypothesis $\lambda_i = \lambda$ is $F = 6.88$ suggesting consideration of firm-specific adjustment processes (critical values at the 5% / 1% level = 1.51/ 1.77).

[31] All estimated parameters at the firm level have a negative sign. BMW, Daimler, Degussa, Deutsche Babcock, Karstadt, Kaufhof, MAN, Metallgesellschaft, Preussag, and Thyssen all have parameter estimates below -2.00, whereas estimates for Allianz, Bayerische Vereinsbank, Hypo-Vereinsbank, Lufthansa, RWE, and VEBA are above -1 (detailed results not reported elsewhere).

the long-run mean of the exchange rate. This conclusion is confirmed in columns (8) and (9) reporting results for subsamples of DAX corporations. In column (8), the sample is restricted to strongly export-oriented companies of the German car and truck industries and (former) producers of metal, steel and machinery (BMW, Daimler-Chrysler, Degussa, Deutsche Babcock, MAN, Mannesmann, Metallgesellschaft, Preussag, Thyssen and Volkswagen). The high importance of adjustment cost for this group of firms can be seen from the parameter –2.12, whereas the same parameter estimate is only –0.38 for a subgroup of more import-oriented utilities (RWE, VEBA) and banking and insurance companies (Allianz, Bayerische Vereinsbank, Commerzbank, Deutsche Bank, Dresdner Bank, Hypo-Vereinsbank) forming the sample in Table 5, column (9).

Summing up, econometric results confirm theoretical predictions. In line with the individual behaviour of profit maximizing companies, overall exchange rate exposure increases with rising foreign trade and decreases (and might become more negative) with higher input costs. Thus, in an export-oriented economy like Germany where exports exceed imports exchange rate exposure is expected to be positive, as indeed was the case with the exception of a short period during the first half of the 1980ies (where exposure estimates turn out to be negative). Our results also confirm the hypothesis of significant adjustment costs. Estimates are in accordance with costly adjustment to long-run mean values of exchange rates, and are thus in line with the notion of mean-reverting exchange rates, at least seen from the viewpoint of decision-making financial investors.

Table 5: Determinants of German Dollar Exposure

Model: $\delta_{it}^{a} = \gamma_{0i} + \gamma_{1i} exs_t + \gamma_{2i} ims_t + \lambda_i \, m(S_t)\left|H_t\right| + \varepsilon_{it}$

Explanatory determinants	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)[1]	(9)[2]
Exports/GDP (exs)	6.84** (0.22)	2.88** (0.14)	–	–	–	4.98** (0.32)	4.82** (0.16)	5.90** (0.87)	6.58** (0.64)
Imports/GDP (ims)	-10.47** (0.34)	–	-4.82** (0.24)	–	–	-6.58** (0.50)	-6.60** (0.25)	-3.38* (1.36)	-10.17** (0.99)
(exs – ims)		–	–	7.26** (0.20)	–	–	–	-	-
(exs + ims)	–	–	–	–	0.30** (0.06)	–	–	-	-
Adjustment cost factor, $m(S_t)\left\|H_t\right\|$		–	–			-1.61** (0.08)	(company specific)	-2.12** (0.23)	-0.38* (0.16)
$\overline{R}^2$	0.341	0.104	0.122	0.299	0.046	0.519	0.565	0.612	0.525

Notes: All estimates include fixed-company effects and are based on seemingly unrelated regressions. Estimation period: 1979:1 – 1992:4; sample in cols. (1) to (5): 28 DAX companies (1568 quarterly observations), [1]) subsample in col. (6): 10 export-oriented companies (560 observations), [2]) subsample in col. (7): 8 non-export companies (448 observations). (Asymptotic) standard errors are given in parentheses. *) and **) denote t-values above 1.96 and 2.58 (conventional 5% and 1% significance levels).

6. Conclusions

This article analyses value changes of stock market companies in response to exchange rate movements, with special focus on exposure of the German stock market in the face of variations of the US dollar. Due to its high involvement in international trade, the German case is very well suited for testing the presence of currency exposure. The approach followed in this work extends the standard way of measuring exchange rate exposure in several ways, e.g. by using multi-factor modelling instead of augmented CAPM, application of moving window panel regressions, orthogonalization of overall market risk vis-à-vis currency risk. An important innovation lies in deriving and testing theoretical implications of exchange rate adjustment costs for firm values and exposure.

As a first result, it is shown that the usual way of measuring exchange rate exposure by estimating so-called residual exposure coefficients in an augmented CAPM framework would often lead to insignificant results due to some collinearity between exchange rate risk and overall market risk. An application of alternative orthogonalization techniques reveals significant exposure for both individual DAX companies and the aggregate German stock market. Consideration of further macro risks confirms significance of exposure and shows robustness of results. Based on time series data for German DAX companies, DM/dollar rates and macroeconomic factors, we find a time-variant exposure of German stock market companies. Linking estimated exposure to German trade, we conclude that, in general (on average), German exposure is well described through the role of a net exporter, who benefits from the depreciation of domestic currency. Accordingly, estimations of time-varying exposure based on dollar risks have a positive sign with exception of the first half of the 1980ies, when a relatively high import dependency and a strong US Dollar changed the situation.

Our results confirm the hypothesis of significant adjustment costs. Estimates are in accordance with long-run mean reversion. Deviations of exchange rates from their expected long-run values have a significant impact on overall German stock market exposure. We find that the larger the distance of exchange rates from their expected value is, the lower company values are.

Future work should focus on the micro view of exchange rate exposure and its determinants. Factor costs, adjustment processes and profits depend on individual markets and foreign trade activities. Valuable insights are expected from combining results from modelling imperfect competition and exchange rate pass-through, leading to the analysis of individual profit margins (and hence exchange rate exposure) in terms of markup of prices over marginal costs, which would result in testing the role of further determinants such as concentration ratios, market shares, or company specific hedging activities.

7. References

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Table A: Descriptive Statistics: Stock values, returns and macroeconomic factors, monthly data, 1977:01 – 1995:03

	DAX company returns (r_{it})	Average company returns ($\overline{r}_{\bullet t}$)	DM/US-$	DM/US-$, returns	Interest rate term structure	Inflation	Business Climate (ifo)	Market risk (DAFOX)	DAFOX, returns
Mean	0.006855	0.006855	2.034474	-0.002287	0.009337	0.030984	0.930831	402.4090	0.007517
Median	0.007217	0.009790	1.874063	-0.003938	0.014100	0.029400	0.940000	396.8200	0.009532
Maximum	0.319689	0.141223	3.356831	0.103722	0.036000	0.074600	1.079000	809.7240	0.137507
Minimum	-0.411905	-0.249551	1.393340	-0.090260	-0.037600	-0.010000	0.745000	132.3030	-0.245858
Std. Dev.	0.070578	0.052028	0.435809	0.034898	0.017685	0.016935	0.075759	215.0022	0.048610
Observations	6132	219	219	219	219	219	219	219	219

Table B: Descriptive Statistics of exposure, trade and DM /US-Dollar, 1979-1992, quarterly data.

	δ_{it}^{a}	$\overline{\delta_{\bullet t}^{a}}$	$\left\|\delta_{it}^{a}\right\|$	*EX / GDP*	*IM / GDP*	*EX / GDP - IM / GDP*	*DM / $*
Mean	0.144	0.144	0.312	0.332	0.292	0.050	2.083
Median	0.120	0.118	0.247	0.331	0.293	0.056	1.895
Maximum	1.258	0.803	1.258	0.388	0.327	0.077	3.357
Minimum	-0.897	-0.514	0.000	0.271	0.251	-0.009	1.393
Std. Dev.	0.375	0.313	0.252	0.029	0.019	0.021	0.468
Observations	1568	56	1568	56	56	56	56

Table C: Exchange Rate Exposure of German DAX companies

Company	1977-1995	1977-1979	1980-1985	1986-1990	1991-1995
ALLIANZ AG	0.032	-0.182	-0.379*	0.011	0.226
BASF AG	0.076	0.150	-0.242*	0.089	0.283*
BAYER AG	0.034	0.049	-0.254**	0.051	0.190
BMW AG	0.197*	-0.154	-0.153	0.318	0.452*
BAYER. VEREINS-BANK AG	0.094	0.006	-0.328**	0.271	0.148
COMMERZBANK AG	0.058	0.128	-0.589**	0.540**	-0.023
CONTINENTAL AG	0.135	-0.240	-0.310	0.442	0.260
DAIMLER-BENZ AG	0.278**	0.032	-0.333**	0.559**	0.612**
DEGUSSA AG	0.368**	0.215	-0.236	0.738**	0.632**
DEUTSCHE BANK AG	0.153*	0.065	-0.400**	0.580**	0.139
DRESDNER BANK AG	-0.046	0.224*	-0.681**	0.225	0.012
DEUTSCHE BAB-COCK AG	0.190	0.029	-0.363	0.659**	0.361
HOECHST AG	0.024	0.030	-0.352**	0.001	0.383**
BAYER. HYPO-THEKEN- UND WECHSELBANK AG	0.144	0.080	-0.338*	0.481**	0.063
KARSTADT AG	0.202	0.259	-0.351	0.347	0.577**
KAUFHOF AG	0.232*	0.283	-0.340*	0.529*	0.402*
LINDE AG	0.158*	-0.132	-0.255	0.210	0.471**
LUFTHANSA AG	0.191	0.171	0.149	0.101	0.144
MAN AG	0.123	-0.217	-0.459**	0.118	0.879**
MANNESMANN AG	0.144	0.057	-0.397**	0.276	0.517**
METALLGESELL-SCHAFT AG	0.132	-0.009	-0.223	-0.049	0.601
PREUSSAG AG	0.427*	-0.064	-0.099	0.538	0.793**
RWE AG	0.031	0.040	-0.270*	0.085	0.190
SCHERING AG	0.163	0.389	-0.219	0.134	0.270
SIEMENS AG	0.223*	0.212*	-0.264**	0.435**	0.329**
THYSSEN AG	0.198	0.376	-0.208	0.162	0.650**
VEBA AG	-0.009	0.036	-0.407**	0.197	0.028
VOLKSWAGEN AG	0.067	-0.242	-0.353	0.298	0.094

Note: Estimations according to specification (5), unrestricted version (see Table 2, column (1)).

Table D: Market Betas (overall market risk)

Company	1977-1995	1977-1979	1980-1985	1986-1990	1991-1995
ALLIANZ AG	1.316	1.150	1.439	1.280	1.301
BASF AG	0.864	0.706	0.936	0.836	1.123
BAYER AG	0.876	1.046	1.020	0.872	0.881
BMW AG	1.193	1.544	1.048	1.316	1.253
BAYER. VEREINS-BANK AG	1.044	1.078	0.868	1.104	1.002
COMMERZBANK AG	1.111	1.070	1.529	0.972	0.929
CONTINENTAL AG	0.922	1.313	1.196	0.780	0.800
DAIMLER-BENZ AG	1.341	1.027	1.299	1.310	1.333
DEGUSSA AG	0.945	0.912	0.969	0.860	1.222
DEUTSCHE BANK AG	1.159	0.945	1.363	1.060	1.028
DRESDNER BANK AG	1.166	0.786	1.470	1.139	0.907
DEUTSCHE BAB-COCK AG	1.090	0.981	1.207	1.014	1.580
HOECHST AG	0.862	0.843	0.995	0.764	1.170
BAYER. HYPO-THEKEN- UND WECHSELBANK AG	1.097	0.911	1.015	1.119	1.033
KARSTADT AG	0.858	1.035	0.660	0.984	0.875
KAUFHOF AG	0.951	1.404	0.732	0.901	1.490
LINDE AG	1.008	1.338	0.990	0.980	1.192
LUFTHANSA AG	0.934	1.075	0.711	1.070	1.048
MAN AG	1.129	1.366	1.175	1.098	1.204
MANNESMANN AG	1.181	1.336	1.081	1.133	1.338
METALLGESELL-SCHAFT AG	1.174	1.683	0.844	1.280	1.645
PREUSSAG AG	1.108	1.388	0.958	1.140	1.116
RWE AG	0.785	0.688	0.614	0.830	1.021
SCHERING AG	0.967	1.203	1.137	0.953	0.833
SIEMENS AG	1.177	1.007	1.217	1.194	1.066
THYSSEN AG	1.028	1.174	1.134	1.005	1.263
VEBA AG	0.810	0.757	0.744	0.811	0.932
VOLKSWAGEN AG	1.277	1.869	1.332	1.307	1.351

Note: Estimations according to specification (5), unrestricted version (see Table 2, column (1)).