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Abstract:

This paper empirically analyzes the impact of exchange rate uncertainty, exchange rate movements and expectations on foreign direct investment (FDI). Two competing specifications of exchange rate volatility are examined. The investigation is based on a cross-section time-series data set of U.S. outward FDI by industries to six major partner countries for the period 1984–2004. Using the standard deviation of the real exchange rate as a measure of risk it is found that exchange rate uncertainty has a discouraging effect on FDI flows across all industries. This is contrasted when applying an alternative risk specification defined as the unexplained part of real exchange rate volatility. Now, results show a clear distinction between non-manufacturing and manufacturing industries. U.S. FDI outflows in non-manufacturing industries exhibit a positive correlation with increased exchange risk, whereas this relationship is negative for manufacturing industries in the underlying sample. A real appreciation of host-country currency was associated with higher FDI flows, while expectations about an appreciation showed a negative result.

JEL-Classification: F21; F23

Keywords: Foreign direct investment, real exchange rate risk, volatility

1 Introduction

Multinational enterprises (MNE) and foreign direct investment (FDI) are important elements of global business. The growth of FDI has exceeded the growth of exports and has become the driving force for economic development in many countries. FDI allow for a more efficient allocation of resources for the investing firm in the home country. The host country, on the other hand, benefits from knowledge transfers and spillovers as well as inciting competition and increased productivity. Policy makers have recognized the special position of incoming FDI as it can play an important role in promoting economic growth.

To the fact that the exchange rate affects expected future profits, uncertainty about the future evolution of the exchange rate can influence FDI decisions. Since the end of the Bretton Woods era of fixed exchange rates the importance of exchange rates has increased in many ways. Global capital and trade flows are dependent on the valuation of currencies and exposed to related exchange risk. The decision of MNE to engage in international trade or foreign investment is based in part on the current situation of exchange markets as well as on future prospects for these markets.

Trade flow analyses have widely shown negative effects of exchange risk on the size of exports, as seen in Chowdhury (1993) and Pozo (1992)[1], and a positive correlation with home-country currency valuations or expectations. Because of the growing importance of FDI this theoretical approach has been extended to direct investment in recent years. The general analytical questions have been: Can exchange rate volatility have any impact on the location and relocation decisions of MNE? Can exchange rates and exchange rate expectations influence multinational activity? In a world of perfect capital markets though, where purchasing power parity (PPP) between currencies holds, the level of the exchange rate would not be expected to show any effect on FDI decisions. A number of theories, however, counter this assumption.

Theoretical predictions for the effect of exchange rate uncertainty on FDI are mixed across the literature. While, among others, Capel (1992), Campa (1993), and Rivoli and Salorio (1996) explain a negative relationship mainly due to a deterring effect of exchange rate uncertainty on FDI. Theories of Itagaki (1981), Cushman (1985, 1988), Broll (1992) and Broll and Zilcha (1992), Goldberg and

1 Hooper and Kohlhagen (1978), on the other hand, found no significant effect of exchange rate uncertainty on the volume of trade.

Kolstad (1995), and Aizenman and Marion (2004), for instance, explain a positive link between increased exchange rate uncertainty and the size of FDI.

In regard to theoretical predictions for the effect of the exchange rate level on FDI, existing literature again provides differing results. Under the assumption of imperfect capital markets, Froot and Stein (1991) connect exchange rate and wealth positions with FDI. In their theory FDI is positively related to a depreciation of host-country currency. A similar theoretical result comes from Blonigen (1997) who plausibly shows how a real currency depreciation in the receiving country can increase acquisition FDI to this country. Cushman (1985, 1988), on the other hand, presents diverse theoretical outcomes for the effect of the level of the real exchange rate on FDI decisions, depending on the source country of the inputs used for production, where the good is produced, and the country where the final good is sold. Along the lines of Froot and Stein (1991) and Blonigen (1997) he derives mainly a positive effect of real host-country currency depreciation on FDI. In addition he models expectations about the future evolution of the real exchange rate and finds mixed results. Contrary, Campa's (1993) theory, which follows Dixit (1989), predicts a negative relationship between real home-country currency valuation and FDI transactions to the host country.

Empirical findings for the effect of both exchange rate uncertainty and the exchange rate level on FDI also show a large variety. Positive empirical findings for the impact of exchange rate uncertainty on FDI are presented in studies by Cushman (1985, 1988), Goldberg and Kolstad (1995), de Meńil (1999) as well as Pain and van Welsum (2003), among others. Studies reporting a negative correlation between exchange risk and FDI come from Campa (1993), Bénassy-Quéré *et al.* (2001), Urata and Kawai (2000), and Kiyota and Urata (2004) to name a few. Görg and Wakelin (2002) in contrast found no significant relationship between real exchange rate uncertainty and FDI.

Froot and Stein (1991), Cushman (1985) and Blonigen (1997) confirm their theoretical predictions of a positive correlation between host-country currency depreciation and FDI in their empirical analyses of FDI data, while Campa (1993) reports a negative link between host-country currency depreciation and FDI. Klein and Rosengren (1994) and Ito (2000) also obtain a positive effect of a dollar depreciation on U.S. FDI inflows. However, a number of studies, including Pain and van Welsum (2003) and Stevens (1998), are not able to identify a statistically significant effect of host-country currency valuation on FDI.

Following a modified version of the analytical framework applied by Kiyota and Urata (2004), this paper will investigate empirically how the volatility and the level of the real exchange rate as well as its expected future fluctuation affect U.S. outward FDI in particular.

The empirical analysis will focus on industry-specific effects, using disaggregated FDI data at industry level. This is expected to provide better insight into the coherences across different industries and through pooling produce more efficient estimation results as compared to using country-level data[2]. In addition, due to the vast variety of possible specifications of exchange rate uncertainty particular attention is given to the application of two differing measures of exchange rate risk. In accordance to Cushman (1988) an often used measure of real exchange rate risk, defined as the moving three-year standard deviation of recent annual changes in the real exchange rate, is adopted as benchmark definition. In the course of the analysis this is tested against an alternative measure of uncertainty, specified as the unexplained part of real exchange rate volatility (Kiyota and Urata 2004). Although the magnitude of any estimated coefficient that captures risk is difficult to interpret, it will allow for an interpretation of the direction and significance of the relationship between the real exchange rate uncertainty and the size of FDI flows.

The structure of the paper is as follows. Section 2 introduces the analytical methodology used for the forthcoming empirical investigation and especially the benchmark model. This section also includes a description of the underlying data. Regression results from the benchmark model as well as an application of the alternative risk specification are then presented in Section 3. Section 4 compares the performance of the two models, before Section 5 concludes with a summary of the findings in this analysis.

2 Research Design

The following section, first, introduces the empirical benchmark model. Because previous literature has implemented a variety of possible definitions of exchange rate uncertainty, in a second step one particular innovative volatility definition will be adopted in comparison to the standard deviation specification. This alternative volatility specification tries to capture the unexplained part of volatility peculiar to

2 For example Froot and Stein (1991) and Cushman (1985) analyze the effect of real exchange rates on FDI using annual national-level FDI data.

variations in real exchange rates by applying a gravity model to the volatility derivation.

2.1 Benchmark Model

The analysis is based on an annual FDI time-series cross-section dataset covering outward FDI flows from the United States to six selected partner countries. The dataset contains disaggregated data of nine industries over a period of 22 years from 1983–2004. The analytical examination follows in essence Cushman's (1988) variable specifications and a modified version of the model used in Froot and Stein (1991) and Klein and Rosengren (1994) as implemented by Kiyota and Urata (2004) for the econometric specification. Industry-specific FDI flows to the six countries are pooled to obtain a cross-section time-series dataset for each of the nine industries in which countries are treated as cross-sections. This allows to analyze industry-specific characteristics common to the different partner countries and may help to disentangle ambiguous findings observed in previous studies that were conducted at the national-level. An interpretation of estimation results focusing on industry specifics will be presented in Section 3 of this paper. FDI flows are measured as percentage of the receiving country's GDP which follows a common specification already used by Klein and Rosengren (1994), Stevens (1998), Pain and van Welsum (2003) and Kiyota and Urata (2004) for example.[3]

The benchmark regression equation, that is applied separately to each of the nine industries, takes the form

$$\left(\frac{FDI}{GDP}\right)_{it} = \beta_0 + \beta_1 \ln R_{it} + \beta_2 \ln \mathrm{E}(\theta_{it}) + \beta_3 \mathrm{Sd}(\theta_{it}) + u_{it}\,, \tag{1}$$

where the left hand side gives the dependent variable, which is industry-specific FDI flow from the U.S. to partner country *i*, FDI_{it}, as proportion to country *i*'s GDP in year *t*, GDP_{it}. The explanatory variables on the right hand side include the bilateral real exchange rate of the specific partner country *i* at time *t*, R_{it}, the expected change in the real exchange rate, $\mathrm{E}(\theta_{it})$, the standard deviation of the real exchange rate, $\mathrm{Sd}(\theta_{it})$, and an error term, u_{it}. The coefficients to be estimated are the constant β_0, and the slope coefficients β_1, β_2 and β_3 for variables $\ln R_{it}$, $\ln \mathrm{E}(\theta_{it})$ and $\mathrm{Sd}(\theta_{it})$, respectively.

3 According to Klein and Rosengren (1994) scaling FDI by the GDP of the receiving country controls for changes in the size of the partner country economy that are not controlled for by the other independent variables.

The real exchange rate, R_{it}, is defined as annual nominal home-to-host currency exchange rate times the ratio of the two countries' price levels, P_{it}/P_t. According to Campa (1993), the level of the real exchange rate, R, is calculated as the annual mean of the monthly exchange rates in year t. Real exchange rate volatility, $Sd(\theta_{it})$, is measured by the three-year moving average of the standard deviation of annual percentage changes in the end-of-month real exchange rate, R_{it}, including the current year. Monthly nominal exchange rate data are taken from EconStats (2007). For the transformation of nominal exchange rates to real values producer price indices (PPI) of the home and the host countries are used, which were obtained from International Financial Statistics of the International Monetary Fund (IMF) (2004). Because data on PPI were not available in monthly frequency, this paper uses interpolated quarterly PPI data from the IMF to derive missing monthly observations. Due to the rolling three year window in the determination of the standard deviation, exchange rate data for the period 1981–2004 were used.

Following Cushman's (1988) specification of the expected future change in the real exchange rate, $E(\theta_t)$ is defined as the ratio of expected future real exchange rate level to current real exchange rate level, $E(R_{t+1})/R_t$, and denotes the expected proportional change in R over one period. For the empirical investigation this ratio is proxied for each bilateral real exchange rate separately by $R_{TREND,t} / R_t$ where $R_{TREND,t}$ is the linear prediction from the regression

$$R_t = a + bt + u_t \,, \tag{2}$$

in which the current real exchange rate, R_t, is fitted to a constant a, a time trend t, and an error term u_t. Accordingly, investors who are assumed to take primarily a long view may expect R to return to a purchasing-power-parity value for which R_{TREND} could be a reasonable estimate. If R is currently above its long-run trend value, which depicts an undervalued U.S. dollar currency, the real exchange rate is expected to fall, representing an expected real appreciation of U.S. dollar. Consequently, Cushman (1988) clearly negates the absolute and relative PPP hypotheses by implying an existing drift in the evolution of the real exchange rate over time, hence a non-constant PPP, in contrast to a time invariant constant.[4]

In equation (1) a negative sign is expected for β_1, implying decreasing FDI outflows to the partner country in reference to a real devaluation of the U.S. dol-

4 The absolute PPP hypothesis defines the real exchange rate to be invariant equal to one, whereas by the relative PPP hypothesis the real exchange rate takes a value different to one, though also remaining constant over time.

TABLE 2.1
Trends in FDI outflows (% of GDP, Average over Countries)

	1982–89	*1990–97*	*1998–2004*
All Industries	0,251	0,457	0,798
Manufacturing Total	0,161	0,175	0,224
Food	0,008	0,027	0,014
Chemicals	0,028	0,038	0,034
Primary and Fabricated Metals	0,013	0,019	0,007
Electric Machinery	0,008	0,010	0,036
Wholesale Trade	0,026	0,034	0,045
Depository Institutions	0,003	0,002	0,010
Finance, Insurance and Real Estate	0,080	0,157	0,153

Sources: Author's calculations, *Bureau of Economic Analysis* (BEA), *IMF Country Tables*

lar. Following theoretical predictions by Cushman (1988) signs for β_2 and β_3 are undetermined.

2.2 Description of the Data

The analytical investigation of the effects of exchange rate and exchange rate uncertainty on FDI flows is conducted on the basis of a dataset obtained from the Bureau of Economic Analysis (BEA) (2007) of the U.S. Department of Commerce for the years 1982–2004. It contains data on international transactions between U.S. parent companies and their foreign affiliates. The analysis concentrates on capital outflows as aggregated size, which consists of the three separate components equity capital outflows, reinvested earnings and intercompany debt outflows. Nominal FDI data were converted to real 2000 prices using the appropriate GDP deflator from IMF Country Tables.

In any case, due to severe data limitations information on selected components of total capital outflows are not available for a sufficient number of countries and industries. For this reason, I use the aggregated capital flow as a general proxy in this paper.

The long-run trends in U.S. outward FDI flows, expressed as percentage of host country GDP, are presented in Table 2.1. It can be seen that overall FDI outflows' share in GDP increased strongly from 0.25 per cent in the 1980s to 0.8 per cent during the first half of the current decade. However, across industries it shows significant differences. While FDI outflows in manufacturing industries in general increased slightly—in single industries even decreased—, a much clearer

TABLE 2.2
Development of the real exchange rates (U.S. dollar per partner country currency)

	1983	*1988*	*1992*	*1996*	*2000*	*2004*
Japan	0,00634	0,01014	0,00969	0,00979	0,00928	0,00804
Germany	0,44623	0,62323	0,69625	0,67121	0,47227	0,61177
UK	1,14794	1,56138	1,70816	1,57818	1,51655	1,72112
Canada	0,70559	0,77669	0,73493	0,70868	0,67330	0,71580
France	0,14127	0,20049	0,20816	0,19784	0,14074	0,17783
Italy	0,00046	0,00065	0,00073	0,00063	0,00048	0,00062

Sources: Author's calculations, *EconStats* (2007), *IMF Country Tables*

increase is identified among the non-manufacturing industries *Wholesale Trade*, *Depository Institutions* and *Finance, Insurance and Real Estate*. Especially to be noted, FDI outflows in the *Depository Institutions* industry display the largest gain in their share of GDP, showing a 5-fold surge from the 1990s to the beginning of the current decade.

Real exchange rate data were derived from annual average observations of the nominal bilateral exchange rates, as taken from EconStats (2007). The nominal exchange rate is denoted as the amount of home-country currency needed to purchase one unit of host-country currency. For example, it tells how many British pounds can be bought from one U.S. dollar. Due to the limited scope of this study it was not possible to obtain industry related price indices for the construction of industry-specific real exchange rates. As reasonable alternative the producer price index (PPI) for each country is used. The nominal exchange rates were then multiplied by the ratio of host country PPI to home country PPI. Here, PPI rather than consumer price index (CPI) data are used because FDI is regarded as investment in assets of firms which are more likely related to production purposes than to market priced final products. The development of the real exchange rate of the six partner countries in this sample is presented in Table 2.2. Figures show that most currencies appreciated against the U.S. dollar in real terms, with exception of Can $, over the period 1983–2004. During the first half of the 1990s all partner country currencies were stronger against the U.S. dollar than at the beginning of the sample period as well as the beginning of the current decade. Especially from the early 1980s to the beginning of the 1990s the U.S. dollar lost significantly in valuation which may in part be attributed to the Exchange Rate Mechanism (ERM) established in 1979 within the European Monetary System, whose member countries form a great part of this study. However, even after the failure of this first version of the ERM, the dollar could not regain fully its early 1980 levels.

TABLE 2.3
Summary Statistics

	Obs	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*
$(FDI/GDP)_i$	1188	0,106	0,310	-0,343	3,450
$\ln R_i$	132	-2,413	2,813	-7,752	0,550
$\ln E(\theta_i)$	132	0,010	0,139	-0,284	0,321
$Sd(\theta_i)$	132	0,085	0,038	0,020	0,200
$(K/GDP)_{i,t-1}$	1188	0,008	0,022	-0,007	0,207
$\ln(ULC/ULC_i)$	132	0,128	0,220	-0,351	0,787
$\ln(i/i_i)$	132	0,026	0,399	-0,909	1,333

Sources: Author's calculations

Only recently in 2004 the U.S. dollar revalued again against all currencies, but Japan yen.

The noticeable trends interestingly indicate a likely positive connection of home country currency depreciation and increasing FDI outflows during the sample period, which would be in contrast to theoretical predictions by Cushman (1988) and Froot and Stein (1991), for instance. Estimation results presented in Section 3 of this paper will shed light on this controversial issue.

Table 2.3 presents summary statistics for the variables used in the regression. For space reasons due to substantial information on industry-specific correlations of variables an appropriate overview is detained in this paper.

2.3 Econometric Issues

A problem often found in time-series data is serial correlation of the disturbance terms. This means successive observations are likely to be interdependent, linked by a common element in the disturbance of each observation in group *i*. One reason for this can be seen in the inertia peculiar to most economic time series, for instance due to some cyclical pattern, in which a variable shows successive movements into the same direction over a particular period of time before reversing. In the presence of autocorrelation in the error terms the usual Ordinary Least Squares (OLS) estimators will no longer posses minimum variance among all linear unbiased estimators.[5] They will become inefficient and lead to possibly invalid t, F and χ^2 statistics.[6] Based on the data at hand, a simple test for serial correlation

5 Note, that I use serial correlation and autocorrelation synonymously in the context of time series in this paper, whereas, cross-sectional correlation refers to panel data.

6 On this, see Gujarati (2003, pp. 442-445) for a more detailed examination of the theoretical consequences of autocorrelation.

in the idiosyncratic errors of a linear panel-data model, as discussed by Wooldridge (2001), was performed for all industries on basis of the benchmark model from Section 4.1. The null hypothesis of no first-order autocorrelation was generally not rejected, except for *All Industries* and *Finance, Insurance and Real Estate*, indicating that the error terms within the time series of these two industries exhibit serial correlation which will be taken into account by the choice of an appropriate estimation method. Tests for first-order autocorrelation in panel data are also conducted for the alternative volatility specification in Section 3.2. Results on these tests will be discussed in the corresponding section.

Another important consideration in panel-data analysis is the possible existence of heteroscedasticity. That is, the conditional variance of each disturbance term, conditional on the chosen values of the explanatory variables, is not constant but shows unequal spreads. For panel data this refers to a non-constant conditional variance of the error terms across different groups of the sample at one point in time. In the underlying sample, countries could exhibit different sensitivities to changes in fundamental factors, therefore introducing cross-sectional heteroscedasticity of the error terms in the model. The consequences of applying standard OLS as estimation method in this situation are explained by Gujarati (2003). It would lead to estimators that are no longer best and do not have minimum variance in the class of unbiased estimators. To examine the existence of a potential heteroscedastic error structure across panels I conducted a likelihood-ratio test following closely a proposed procedure described by Wiggins and Poi (2001). Using a maximum likelihood method the model is first fitted with panel-level heteroscedasticity and in a second step with the restriction of homoscedasticity of the error terms. Based on the likelihood values of both estimations a likelihood-ratio test (LRT) will tell whether adding additional parameters, which are the covariances between the panels, gives a significant improvement in fit of the model to the underlying dataset. The likelihood ratio test statistic is defined as

$$LR \equiv 2[L1 - L2]\,,^{7} \tag{3}$$

where *L1* denotes the log-likelihood function of the unrestricted and *L2* the log-likelihood function of the restricted estimator. The test statistic, *LR*, approximately follows a chi-square distribution. By constraining the variance of the error term to be the same for all panels the degrees of freedom, that is the number of constraints, for determining the significance of the LRT statistic is given by the num-

7 Information on hypothesis testing using maximum likelihood methods is taken from Greene (1993, pp. 364-370) and Wooldridge (2001, pp. 397-398).

ber of groups/panels minus one. The null hypothesis that the parameters of the benchmark model satisfy the imposed constraint had to be rejected for all industries across all model specifications addressed later in this paper, which includes the benchmark model, the alternative volatility specification and the augmented model. The result of these tests states the existence of heteroscedasticity between panels in the dataset at hand.

As a further issue, the error terms of different cross-sections are assumed to be contemporaneously correlated due to a common element. It seems reasonable to presume a common element in the error terms of the different cross-sections because global macroeconomic shocks specific to an industry may well affect the same industry in all countries in a similar way.

As a result of these issues, usual OLS estimates would be inefficient in the presence of both serial correlation (within panel) and cross-sectional correlation (across panel) as well as heteroscedasticity. For this reason, I follow Kiyota and Urata (2004) in using the Feasible Generalized Least Squares (FGLS) estimation method to allow for these error term characteristics[8]. Autocorrelation is controlled for by including a panel-specific autoregressive process with one lag (AR1) for the error terms. In the benchmark model this applies to every industry except All Industries and Finance, Insurance and Real Estate, as mentioned above. Because the true variances and covariances of the error terms are unknown, the FGLS estimation consists of two stages. The FGLS method first estimates the model by OLS disregarding the problems of heteroscedasticity and/or serial correlation. In a second step the obtained residuals from this model are used to form the estimated variance-covariance matrix of the error terms which is used for the transformation of the original variables in the final estimation. By applying OLS to the transformed variables, which is GLS, the obtained estimators will be best linear unbiased estimators (BLUE) and therefore satisfy the assumptions of the classical linear regression model (CLRM).

8 For further information on FGLS, see Gujarati (2003, pp. 394-400).

3 Estimation Results

3.1 Benchmark Model Estimates

For the underlying cross-sectional time-series dataset containing information on capital outflows from the U.S. to the six partner countries Japan, Germany, United Kingdom, Canada, France and Italy for the period 1983–2004 estimation results are presented in Table 3.1. For the subsequent presentation and interpretation FDI as proportion of GDP will be referred to as with the terms FDI or FDI flows for simplicity.

Table 3.1 presents estimation results for the benchmark model. The effect of the current level of the real exchange rate, *R*, on U.S. FDI outflows is positive and highly significant in seven of nine industries[9], which is at odds with theoretical predictions of Cushman (1988) and Froot and Stein (1991) as well as several empirical findings[10], but in line with, for example, Campa (1993) and Görg and Wakelin (2002). During the research period a real depreciation of the U.S. dollar was on average associated with an increase in U.S. outward FDI flows in seven industries. No significant relationship, however, can be found for the *Food* industry and the *Electric Machinery* industry. As pointed out by Görg and Wakelin (2002), the contradicting result for *R* found in their study and here could be due to the more recent underlying time period covered compared to Cushman (1988) or Froot and Stein (1991). FDI transactions have been constantly increasing during the last decades, which also includes outward FDI from the United States. This appears to have coincided with a real depreciated of the U.S. dollar against other main currencies during this period, leading to this adverse result. As Klein and Rosengren (1994) noted, another possible source for a positive relationship between the real exchange rate and FDI could be that FDI represents tariff-jumping.

In the presence of a strong currency the threat of protectionism rises and would predict increasing FDI flows in order to avoid higher tariffs in the receiving country. Although, tariffs are not subject to this study the results may indicate validly such a coherence as put forward by the two authors.

9 Calculations were also performed with pure FDI flows, FDI_i, which yielded identical signs and sensitivities for the explanatory variables.

10 A negative effect was found by Klein and Rosengren (1994), Ito (2000), Sazanami *et al.* (2003), and Bénassy-Quéré *et al.* (2001) among others.

TABLE 3.1

Regression Results: Benchmark Model, Dependent Variable U.S. Outward FDI: $(FDI/GDP)_i$

	All Industries	*Manufacturing Total*	*Food*	*Chemicals*
$\ln R_i$	0,091 ***	0,020 ***	0,001	0,002 **
	[0,018]	[0,003]	[0,001]	[0,001]
$\ln E(\theta_i)$	0,016	-0,033	-0,009	-0,045 **
	[0,142]	[0,096]	[0,011]	[0,019]
$Sd(\theta_i)$	-1,130 **	-1,177 ***	-0,088 *	-0,156 *
	[0,487]	[0,418]	[0,050]	[0,085]
Contant	0,761 ***	0,309 ***	0,018 ***	0,045 ***
	[0,131]	[0,040]	[0,006]	[0,009]
Log-Likelihood	-6,638	78,738	307,581	245,803
AIC	21,276	-149,476	-607,162	-483,606
Wald chi²(3)	31,080 ***	65,410 ***	5,160	13,680 ***

	Primary and Fabricated Metals	*Electric Machinery*	*Wholesale Trade*	*Depository Institutions*	*Finance, Insurance and Real Estate*
$\ln R_i$	0,001 ***	0,000	0,004 ***	0,001 ***	0,022 ***
	[0,000]	[0,001]	[0,001]	[0,000]	[0,004]
$\ln E(\theta_i)$	-0,004	0,023	-0,019	0,007	-0,048
	[0,010]	[0,015]	[0,019]	[0,007]	[0,036]
$Sd(\theta_i)$	-0,078 *	-0,209 ***	-0,104	-0,185 ***	-0,362 **
	[0,045]	[0,056]	[0,086]	[0,035]	[0,183]
Contant	0,017 ***	0,031 ***	0,049 ***	0,021 ***	0,178 ***
	[0,005]	[0,006]	[0,009]	[0,003]	[0,027]
Log-Likelihood	319,247	292,664	244,914	339,238	107,786
AIC	-630,494	-577,327	-481,829	-670,477	-207,573
Wald chi²(3)	15,040 ***	16,660 ***	28,650 ***	42,100 ***	34,150 ***

Note: Standard errors in brackets. *,**,*** denote statistical significance at the 10, 5, 1 per cent level respectively.

Sources: Author’s calculations

The expected future change in the real exchange rate, E(θ), shows very weak results for an effect on FDI outflows compared to the current level of the real exchange rate, *R*. The estimated coefficient is statistically significant only in the *Chemicals* industry. The reported effect is negative, stating that an expected future real devaluation (i.e. higher E(θ)) of the U.S. dollar was on average accompanied by decreased U.S. FDI outflows of MNE operating in the chemical sector. Apparently, this expectations variable generally seems inapplicable to explain locational decisions of MNE as predicted theoretically by Cushman (1988).

Exchange rate risk, Sd(θ), measured as the standard deviation of the monthly real exchange rate over the preceding three years including the current, exhibits a statistically significant negative relationship with U.S. FDI outflows in eight industries, including *All Industries*. Thereby, statistical significance in the *Food*, *Chemicals* and *Primary and Fabricated Metals* industries is only achieved at the ten per cent confidence level. The coefficient for Sd(θ) in the *Wholesale Trade* industry is statistically not different from zero, though showing a negative sign too. In general, declining uncertainty about the future movements of the real exchange rate on average corresponded with increasing U.S. FDI outflows for the period 1983–2004. These findings confirm a discouraging effect of exchange rate volatility on FDI which is in accordance to empirical analyses of Bénassy-Quéré *et al.* (2001) and Urata and Kawai (2000).

The overall goodness of fit for the regressions, as indicated by the Wald criterion, is mostly highly significant at the one per cent critical level for all industries except *Food*. U.S. FDI outflows in the *Food* industry are explained only poorly by variations in or uncertainty of the real exchange rate, with all estimated coefficients jointly insignificant. This leads to the conclusion that this industry is most likely less affected by real exchange rate characteristics then other industries, based on the examined research period.

3.2 Alternative Definition of Uncertainty

Unlike the majority of previous studies that use variances or standard deviations of exchange rates as a measure of uncertainty, a different approach is chosen by Kiyota and Urata (2004). Both authors use a measure of volatility which only captures the part of real exchange rate volatility not explained by the failures of the law of one price. The failures of the law of one price are explained by factors known to investors, such as distance and national border. Kiyota and Urata (2004) argue that the part of exchange rate volatility explained by these factors can not be treated as ‘volatile’. After excluding the impacts from the failures of the law of one price, the authors predict a negative effect of the ‘true’ exchange rate volatility on FDI flows to the host country.

The hypothesis of the *law of one price* applied to the international marketplace states that if international arbitrage is possible, a currency must have the same purchasing power in every country (Mankiw 2002, pp. 138-139). Failures to this principle can occur because of several reasons. First, many goods are not easily traded, and thus arbitrage is not possible to equalize prices. Second, similar tradable goods are not always perfect substitutes leading to price differences due to diverse consumer preferences. Furthermore, any imperfection in international markets can result in a deviation of the real exchange rate from purchasing power parity, violating the law of one price.

For analyzing the effect of the unexplained part of real exchange rate volatility on FDI flows regression equation (1) from the benchmark model is altered to incorporate the alternative volatility specification. The changed regression equation, which again is applied separately to each industry, is of the following form

$$\left(\frac{FDI}{GDP}\right)_{it} = \beta_0 + \beta_1 \ln R_{it} + \beta_2 \ln \mathrm{E}(\theta_{it}) + \beta_3 VOL_{it} + u_{it}\,, \tag{4}$$

where the previously used standard deviation of future changes in the real exchange rate, $\mathrm{Sd}(\theta_{it})$, is now replaced by the unexplained part of real exchange rate volatility, VOL_{it}, for partner country i in year t.

Values for the country-specific unexplained part of real exchange rate volatility, VOL_{it}, are derived from equations (5) and (6) in the following way. The unexplained part of real exchange rate volatility, VOL_{it}, is obtained by calculating the absolute difference between the actual variance of the real exchange rate, $\mathrm{var}(R_{it})$, and the part of the volatility explained by the failures of the law of one price, $\mathrm{v\hat{a}r}(R_{it})$,

$$VOL_{it} = \left|\mathrm{var}(R_{it}) - \mathrm{v\hat{a}r}(R_{it})\right| . \tag{5}$$

The actual real exchange rate variance, $\mathrm{var}(R_{it})$, is measured by the variance of percentage changes in the real exchange rate for the period of the preceding two years not including the current by using monthly data.

As described by Kiyota and Urata (2004) real exchange rate volatility explained by the failures of the law of one price, $\mathrm{v\hat{a}r}(R_{it})$, is based on information known to market participants and therefore does not represent *uncertainty* per se, but rather a predictable factor. Concentrating on the unexplained part of exchange rate volatility allows to specifically exploit effects caused by unknown, hardly predictable, economic factors.

According to Engel and Rogers (1996), who analyzed price dispersions among locations, distance and border are significant determinants for price variations. They found that distance is helpful in explaining price differences across locations in the same country, showing a positive relationship. Borders between locations accordingly lead to a further increase in the volatility of prices. Kiyota and Urata (2004) use this approach to determine the explained part of real exchange rate volatility and estimate a gravity equation of the form

$$var(R_{it}) = \alpha_0 + \alpha_1 \ln Dist_i + \alpha_2 \ln(GDP_t GDP_{it}) + \mu_{it} , \qquad (6)$$

where the subscript i denotes the host country, $Dist_i$ is the distance in kilometers between the capital cities of the USA and the respective partner country i and μ_{it} is an error term.[11] Following Kiyota and Urata (2004) the border effect is proxied by including the GDP of the home and the host country, GDP_t and GDP_{it}, respectively. The two authors estimate this equation using a random-effects model with year dummies to control for further country-specific random effects and macroeconomic shocks. The fitted values of this regression form the explained part of real exchange rate volatility, $\hat{var}(R_{it})$, as included in equation (5). Figure 3.1 plots the actual real exchange rate variance, $var(R_{it})$, against the predicted variance, $\hat{var}(R_{it})$ from equation (6) for a visual comparison. Noticeable is a roughly flat line at the bottom of the graph which depicts the variance of the US$/Can$ real exchange rate. This remarkably low variance could be seen as an affirmation of gravity theory in that it attests to the assumption of increasing exchange rate uncertainty the larger the distance between two countries is. In the case of Canada the common border with the USA seems to decrease the according risk substantially.

Along the lines of Section 2.3 a simple test for first-order autocorrelation is conducted on basis of the alternative volatility specification. The result is identical to the benchmark model in that the LRT statistic showed no signs of first-order serial correlation for most industries, with the exception of *All Industries* and *Finance, Insurance and Real Estate* for which again an AR(1) process in the error terms is found.

11 Gravity data is taken from Haveman (2006).

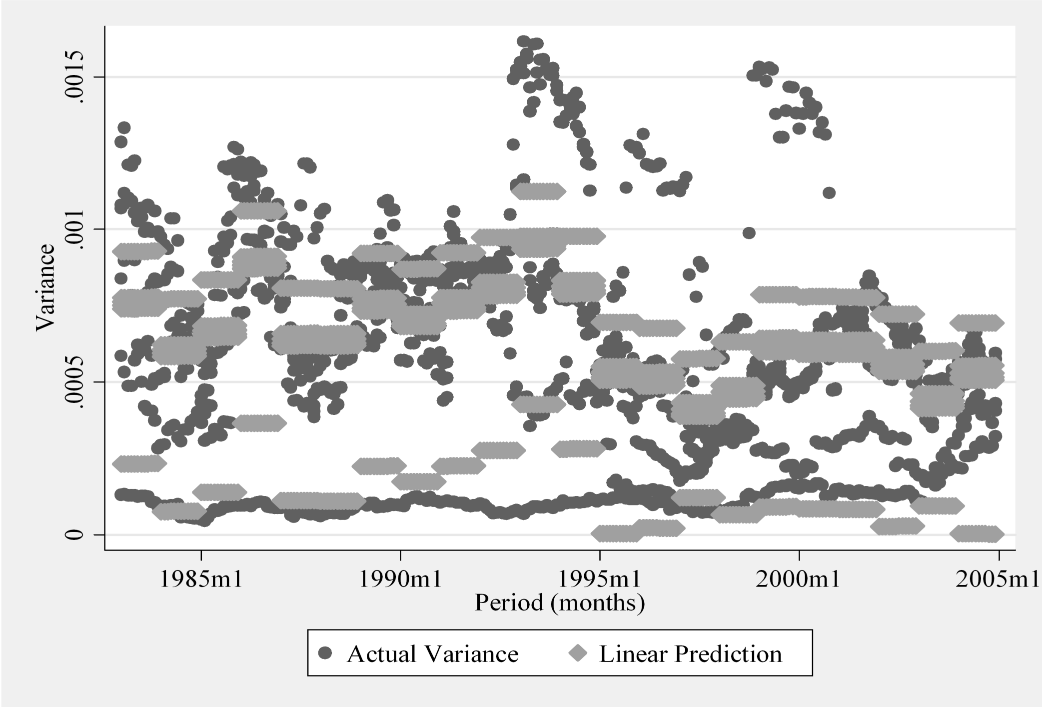

FIGURE 3.1: Actual against Predicted Variance (Eq. 6)

Table 3.2 presents estimation results for the alternative volatility specification from equation (4). Regarding the sign obtained for the level of the current real exchange rate, *R*, results are identical to those from the benchmark model. Even more, the positive effect of the real exchange rate on FDI flows is now found to be statistically significant also in the *Food* industry. But rendering the result for *Electric Machinery* insignificant.

No change is observed for the negative impact of an expected future depreciation of the real exchange rate, E(θ), on FDI flows. The coefficient on E(θ) in the *Chemicals* industry is again statistically significant at the five per cent confidence level. However, the coefficient of the expected future change in *R* in all other industries remains without explanatory power.

Exchange risk measured by the unexplained part of real exchange rate volatility, *VOL*, provides a very different and mixed outcome for the estimated coefficients. Compared to the benchmark specification of real exchange risk, the alternative measure is statistically significant only in six of nine industries, though at least at the five per cent confidence level. While all significant coefficients on Sd(θ) in the benchmark regression in Table 3.1 exhibited a negative sign the picture changes remarkably with the inclusion of *VOL*. A significant negative relationship of *VOL* and FDI flows is found in *Manufacturing Total*, *Chemicals* and

TABLE 3.2

Regression Results: Alternative Volatility, Dependent Variable U.S. Outward FDI: (*FDI/GDP*)$_i$

	All Industries	*Manufacturing Total*	*Food*	*Chemicals*	
lnR_i	0,089 ***	0,029 ***	0,002 **	0,003 ***	
	[0,026]	[0,003]	[0,001]	[0,001]	
lnE(θ_i)	0,049	-0,003	0,001	-0,033 **	
	[0,139]	[0,062]	[0,009]	[0,016]	
VOL_i	168,091 **	-133,288 ***	-2,040	-28,228 **	
	[71,156]	[48,054]	[6,556]	[13,001]	
Contant	0,651 ***	0,273 ***	0,014 ***	0,040 ***	
	[0,166]	[0,016]	[0,004]	[0,005]	
Log-Likelihood	-4,395	88,710	310,561	250,220	
AIC	16,790	-169,419	-613,122	-492,439	
Wald chi²(3)	17,290 ***	136,800 ***	7,590 *	19,220 ***	
	Primary and Fabricated Metals	*Electric Machinery*	*Wholesale Trade*	*Depository Institutions*	*Finance, Insurance and Real Estate*
lnR_i	0,001 ***	0,001	0,005 ***	0,002 ***	0,024 ***
	[0,000]	[0,001]	[0,001]	[0,001]	[0,005]
lnE(θ_i)	-0,004	0,016	-0,006	0,010	-0,024
	[0,008]	[0,018]	[0,015]	[0,008]	[0,055]
VOL_i	-20,516 ***	-8,673	15,144	18,467 **	259,193 ***
	[7,377]	[10,270]	[12,274]	[7,399]	[74,279]
Contant	0,015 ***	0,015 ***	0,041 ***	0,004 *	0,103 ***
	[0,003]	[0,004]	[0,006]	[0,002]	[0,023]
Log-Likelihood	328,462	287,610	250,808	336,659	86,982
AIC	-648,925	-567,220	-493,617	-665,318	-165,964
Wald chi²(3)	15,040 ***	3,730	34,870 ***	17,950 ***	34,000 ***

Note: Standard errors in brackets. *,**,*** denote statistical significance at the 10, 5, 1 per cent level respectively.
Sources: Author’s calculations

Primary and Fabricated Metals. For these three industries an increase in the unexplained part of real exchange rate volatility was on average associated with lower U.S. FDI outflows during the sample period from 1983–2004 and, thus giving, with regards to the direction of the effect, unchanged results to the benchmark model.

Contrary to this, the different measure of exchange rate volatility yields a positive and statistically significant effect in *All Industries*, *Depository Institutions* and *Finance, Insurance and Real Estate*. Hence, an increase in real exchange rate volatility that is not explained by the failures of the law of one price had on average an encouraging effect on U.S. FDI outflows in these three industries. These results stand in opposition to findings by Kiyota and Urata (2004) who found a consistent negative effect of *VOL* on Japan's FDI outflows across all industries for the years 1990–2000. In the *Food* industry the insignificant coefficient for E(θ) and Sd(θ) in conjunction with the newly significant coefficient for *R* cast doubt on the robustness of those results as well as the benchmark results from the previous section in this industry.

A remarkable feature in this context is the dichotomy of the observed results for the effect of the unexplained part of real exchange rate volatility, as an alternative measure of exchange risk, on U.S. FDI outflows. Whereas negative results are reported for all manufacturing industries in the sample, the coefficient is positive for all non-manufacturing sectors.

The overall goodness-of-fit as indicated by the Akaike Information Criterion (AIC) and the Log-likelihood is better for the alternative model specification than for the benchmark model for six of the nine industries. This leads to the conclusion that Kiyota and Urata's (2004) unexplained part of real exchange rate volatility as a measure of 'true' uncertainty seems slightly superior to the more commonly used standard deviation from the benchmark model.

4 Model Comparison

Results from the benchmark and alternative model specification in Table 3.1 and 3.2 present slope coefficients for ln*R*, lnE(θ), Sd(θ) and *VOL* respectively, which do not allow to elicit the actual sensitivities of the observed effects but rather show the corresponding unit change in FDI outflows as proportion of host-country GDP, $(FDI/GDP)_{it}$, for a given change by one unit in the logarithm of the real exchange rate, ln*R*, the logarithm of the expected change of the real exchange rate, lnE(θ), real exchange rate risk, Sd(θ), and the unexplained part of real exchange rate uncertainty, *VOL*. For a better understanding of above results in the next step elasticities are obtained from those slope coefficients.

The corresponding elasticities ε_1 and ε_2 for the level of the real exchange rate, *R*, and the expected change of the real exchange rate, E(θ), in both model specifications are calculated from the estimated beta coefficients, β_1 and β_2, as follows

$$\varepsilon_1=\beta_1\cdot\frac{1}{(\overline{FDI/GDP})}=\frac{d(\overline{FDI/GDP})}{d(\overline{R})}\cdot\frac{\overline{R}}{\overline{FDI/GDP}}, \tag{7}$$

$$\varepsilon_2=\beta_2\cdot\frac{1}{(\overline{FDI/GDP})}=\frac{d(\overline{FDI/GDP})}{d(\overline{E(\theta)})}\cdot\frac{\overline{E(\theta)}}{\overline{FDI/GDP}}, \tag{8}$$

where bars indicate the sample mean of the particular variable. With regard to the two competing measures of real exchange rate risk, Sd(θ) and *VOL*, elasticities are derived slightly differently in the following way

$$\varepsilon_{3a}=\beta_{3a}\cdot\frac{\overline{Sd(\theta)}}{(\overline{FDI/GDP})}=\frac{d(\overline{FDI/GDP})}{d(\overline{Sd(\theta)})}\cdot\frac{\overline{Sd(\theta)}}{\overline{FDI/GDP}}, \tag{9}$$

$$\varepsilon_{3b}=\beta_{3b}\cdot\frac{\overline{VOL}}{(\overline{FDI/GDP})}=\frac{d(\overline{FDI/GDP})}{d(\overline{VOL})}\cdot\frac{\overline{VOL}}{\overline{FDI/GDP}}, \tag{10}$$

with subscripts a and b denoting the benchmark model and the alternative volatility specification, respectively.

The so derived sensitivities, measured at the sample mean, are summarized for both models in Table 4.1 and show the proportionate change in U.S. outward FDI flows relative to a one per cent change in *R*, E(θ), Sd(θ), and *VOL*.

However, quantitative interpretations of the sensitivity of FDI flows with respect to exchange rate uncertainty should be undertaken carefully. In fact, only the relative size of the effect in reference to other industries can provide a qualitative reading in giving an ordering of diverse states. In this, it indicates whether FDI outflows in one industry are more or less sensitive to exchange risk compared to other industries.

While the sensitivity of FDI outflows with respect to the level of the real exchange rate, *R*, is higher in the alternative volatility specification across the board, with the single exception of *All Industries*. Relative differences in magnitude between industries are roughly the same. In both models a fairly high sensitivity is reported for *Depository Institutions*. More precisely, a ten per cent real deprecia-

TABLE 4.1
Elasticities: Benchmark Model, Dependent Variable U.S. Outward FDI: $(FDI/GDP)_i$

	All Industries	*Manufacturing Total*	*Food*	*Chemicals*
R_i	0,177 ***	0,103 ***	0,049	0,057 **
$E(\theta_i)$	0,031	-0,176	-0,571	-1,326 **
$Sd(\theta_i)$	-0,186 **	-0,524 ***	-0,470 *	-0,387 *

	Primary and Fabricated Metals	*Electric Machinery*	*Wholesale Trade*	*Depository Institutions*	*Finance, Insurance and Real Estate*
R_i	0,101 ***	-0,002	0,114 ***	0,310 ***	0,163 ***
$E(\theta_i)$	-0,286	1,307	-0,519	1,570	-0,355
$Sd(\theta_i)$	-0,483 *	-1,012 ***	-0,242	-3,745 ***	-0,229 **

Elasticities: Alternative Volatility, Dependent Variable U.S. Outward FDI: $(FDI/GDP)_i$

	All Industries	*Manufacturing Total*	*Food*	*Chemicals*
R_i	0,174 ***	0,156 ***	0,102 **	0,081 ***
$E(\theta_i)$	0,095	-0,016	0,080	-0,963 **
VOL_i	0,057 **	-0,121 ***	-0,022	-0,143 **

	Primary and Fabricated Metals	*Electric Machinery*	*Wholesale Trade*	*Depository Institutions*	*Finance, Insurance and Real Estate*
R_i	0,102 ***	0,050	0,142 ***	0,502 ***	0,177 ***
$E(\theta_i)$	-0,308	0,928	-0,156	2,382	-0,179
VOL_i	-0,261 ***	-0,086	0,072	0,767 **	0,335 ***

Note: *,**,*** denote statistical significance at the 10, 5, 1 per cent level respectively.
Sources: Author's calculations

tion of the U.S. dollar was on average accompanied by a 3.1 and 5 per cent increase in U.S. FDI outflows for the respective model during the research period. However, when looking at the separate industries one can see large variations in the sensitivity of FDI flows with regard to *R*. In the benchmark model the sensitivity of FDI outflows to a ten per cent rise in *R* ranges from 0.6 to 1 per cent within manufacturing industries, whereas this changes to 0.8 to 1.6 per cent in the alternative model. *All Industries*, as aggregated size of total FDI outflows in the U.S. economy, shows with 1.8 respectively 1.7 per cent, an almost identical reaction of FDI in both models to a ten per cent increase in the level of the real exchange rate.

As presented in Table 3.1 and 3.2, expectations about the future change of the real exchange rate, $E(\theta)$, statistically determine FDI flows only in the *Chemicals* industry. The according sensitivity seems very high, showing a 13.3 respectively 9.6 per cent increase in U.S. FDI outflows for a given expected real appreciation of the U.S. dollar by ten per cent.

When looking at the sensitivity relating to real exchange rate risk we see a mixed picture. As indicated in Section 3.2 results of the two model specifications now differ significantly in terms of the direction as well as the general magnitude of the effect. Using the standard deviation, Sd(θ), as a measure of exchange rate risk gives a negative reaction of U.S. FDI outflows of 1.9 per cent for a ten per cent increase in real exchange rate uncertainty for *All Industries*. In contrast, the inclusion of the unexplained part of volatility, *VOL*, as done in the alternative model specification, returns a positive sensitivity of 0.6 per cent – again for the case of *All Industries*. In the benchmark model the sensitivities of FDI outflows with respect to a ten per cent increase in real exchange rate uncertainty, Sd(θ), ranges for most industries from -1.9 per cent in *All Industries* to -5.2 per cent in *Manufacturing Total*. A higher sensitivity of -10.1 per cent is found for companies in the *Electric Machinery* industry as a sub-sector of *Manufacturing Total*. However, compared to those industries, the sensitivity in *Depository Institutions* is reported extremely high for the research period, showing a 37.5 per cent gain in U.S. FDI outflows for a ten per cent increase in the standard deviation of future changes in the real exchange rate. U.S. FDI outflows in *Depository Institutions* appear to be much more sensitive to real exchange rate uncertainty than in all other industries.

This is consistent with results from the alternative model specification, where *Depository Institutions*' sensitivity to exchange risk is again comparatively large showing a 7.7 per cent increase in FDI outflows for a given ten per cent rise in the unexplained part of real exchange rate volatility. Though, this qualifies a much lower magnitude as compared to the standard deviation of the benchmark risk specification. For the majority of industries in this study the reported sensitivities of FDI outflows with regard to real exchange rate risk turn out to be lower using the alternative risk specification. *Finance, Insurance and Real Estate* is the only industry that exhibits a higher sensitivity for real exchange rate uncertainty in comparison to the benchmark results.

As adumbrated in Section 3.2 the introduced alternative measure of real exchange rate uncertainty, *VOL*, produces not only a clustered outcome among identified industries but also less sensitive reactions of FDI outflows to real exchange rate risk *vis-à-vis* the benchmark specification. Further research is required to assert those coherences in reference to different country sets and time frames.

5 Concluding Remarks

This paper introduces an analytical framework that analyzes the impact of real exchange rate risk, the real exchange rate level and its expected future change on outward FDI flows in nine industries from the USA to six partner countries for the period 1983–2004. Two different measures of exchange rate uncertainty are applied for these purposes.

Using first a benchmark definition of real exchange rate risk, measured by the standard deviation of annual percentage changes, the empirical analysis shows a statistically significant negative effect on U.S. outward FDI flows for the majority of industries. These findings are in line with empirical studies of Bénassy-Quéré *et al.* (2001) and Urata and Kawai (2000).

Applying an alternative measure of real exchange rate risk, defined as the unexplained part of real exchange rate volatility, results in a clustered outcome among industries. While manufacturing industries exhibit a negative effect of real exchange risk on U.S. FDI outflows, the relationship is now positive for non-manufacturing sectors. Moreover, calculated sensitivities are generally lower when using the alternative exchange risk specification. This seems to indicates a better applicability of the unexplained part of real exchange rate volatility, as adopted from Kiyota and Urata (2004), when studying locational decisions of MNE.

In contrast to theoretical predictions of a negative effect of real home-country currency depreciation on outward FDI the analysis shows a persistent positive sign across industries for the underlying research period. Statistical significance is reported for all industries, except *Electric Machinery* in both models, and *Food* in just the benchmark model. This is a clear difference to earlier empirical findings by Klein and Rosengren (1994) and Ito (2000) among others. The controversial result may be due to the particular period covered, which in this analysis differs from previous studies in that a more recent time-frame is used. The specific pattern of the positive relationship between home-country currency depreciation and FDI outflows can be explained by the increased FDI flows worldwide applying to most countries, including the USA. This development, at the same time, coincided with a real depreciation of the U.S. dollar against major currencies, leading to these particular interesting findings.

An expected future depreciation of the real exchange rate was found to have a statistically significant effect only in the *Chemicals* industry where it was associated with diminishing FDI activities of MNE.

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