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ORIGINAL PAPER

Real exchange-rate uncertainty and US foreign direct investment: an empirical analysis

Christian W. Schmidt · Udo Broll

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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). Using data on US outward FDI for the period 1984–2004 we examine two competing measures of exchange-rate volatility. While the standard measure yields a discouraging effect on FDI outflows in all industries the alternative risk specification reveals a clear distinction between manufacturing and non-manufacturing industries, with the latter showing a positive correlation with increased exchange risk. A real appreciation of host-country currency was associated with higher FDI flows, while expectations about an appreciation showed a negative result.

Keywords Foreign direct investment · Real exchange-rate risk · Volatility

JEL F21 · F23

1 Introduction

Multinational enterprises (MNEs) and foreign direct investment (FDI) are important elements of global commerce and factor mobility. The growth of FDI has exceeded

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the growth of exports and has become the driving force for economic development in many countries. On the one hand, FDI allows 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.[1]

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 Cushman (1985, 1988), Broll and Wong (2006), Goldberg and Kolstad (1995), and Aizenman and Marion (2004), for instance, explain a positive link between increased exchange-rate uncertainty and the size of FDI.

Under the assumption of imperfect capital markets, Froot and Stein (1991) connect the exchange-rate level 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), furthermore, 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. The author derives mainly a positive effect of real host-country currency depreciation on FDI that is along the lines of Froot and Stein (1991) and Blonigen (1997). 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 mainly confirm these varying predictions. A positive impact of exchange-rate uncertainty on FDI is 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 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) corroborate their theoretical predictions of a positive correlation between host-country currency depreciation and FDI in their empirical analyses of FDI data, which is also in line with other empirical studies, e.g., Klein and Rosengren (1994) and Ito (2000). Campa (1993), to the contrary, reports a negative effect. However, a number of studies, including

[1] Though, attracting FDI does not assure economic development in itself. Nunnenkamp (2004) adverts to the weak institutional and structural conditions often found in developing countries, which constrain the possible growth-enhancing and poverty-reducing effects that incoming FDI may posses.

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 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 US outward FDI. Due to the vast variety of possible specifications of exchange-rate uncertainty particular attention is given to the application of two measures of exchange-rate risk. In accordance to Cushman (1988), the 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 part of real exchange-rate volatility that is not explained by the failures of the law of one price (Kiyota and Urata 2004).

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]

The structure of the paper is as follows. Section 2 introduces the analytical methodology used for the empirical investigation, including the benchmark model and the alternative measure of uncertainty, followed by a description of the underlying data. Regression results of both risk specifications are presented in Sect. 3. Section 4 incorporates some extensions to the model while focusing on the alternative measure of real exchange-rate risk before the paper concludes with Sect. 5.

2 Research design

2.1 Benchmark model

The analysis is based on an annual FDI time-series cross-section data set covering outward FDI flows from the US to six selected partner countries. The data set contains disaggregated data of nine industries over a period of 22 years from 1983 to 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 data set 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. FDI flows are measured as percentage of the receiving country's GDP which follows a common specification already used by Klein and Rosengren

[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.

(1994), Stevens (1998), Pain and van Welsum (2003) and Kiyota and Urata (2004) for example.

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

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

where the left-hand side gives the dependent variable, which is industry-specific FDI outflow from the US 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, $E(\theta_{it})$, the standard deviation of the real exchange rate, $\text{Sd}(\theta_{it})$, 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 $\ln R_{it}$, $\ln E(\theta_{it})$ and $\text{Sd}(\theta_{it})$, respectively. The dependent variable is not transformed to natural logarithmic form because of negative values present in the underlying data.

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, $\text{Sd}(\theta_{it})$, is measured by the 3-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 on monthly basis, this paper uses interpolated quarterly PPI data from the IMF to derive missing monthly observations. Due to the rolling 3-year window in the determination of the standard deviation, exchange-rate data for the period 1981–2004 were used.

With $\theta_t = R_{t+1}/R_t$ 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 $\hat{R}_t/R_t$ where $\hat{R}_t$ is the linear prediction from the regression

$$R_t = a + bt + u_t, \quad (2)$$

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 (PPP) value for which $\hat{R}_t$ could be a reasonable estimate (Cushman 1988: 328). If R is currently above its long-run trend value, which depicts an undervalued US dollar currency, the real exchange rate is expected to fall, representing an anticipated real appreciation of the US dollar in the next period. In this context the introduction of the euro in 1999 that affects three countries under study is seen as no concern to the application of Eq. 2 on real exchange rates for the effective years in this analysis. Despite the fixed bilateral nominal exchange-rate parities among the members of the European Monetary Union (EMU) country-specific real exchange rates continue to reflect international price ratios. Those ratios differ in their evolution as well as volatility, hence allowing for separate linear predictions of unequal real exchange-rate movements for the corresponding countries.

The estimation of Eq. 2 returned a positive correlation between the linear time trend and R_t for four of six countries, with the real exchange rates of Canada and France showing a negative relation. The mean coefficient (b) of all countries is 0.003, the mean t ratio is 0.605, and the mean adjusted R^2 is 0.067. However, statistical significance of the linear time trend is reported only for the real exchange rates of the UK and Canada. The low mean adjusted R^2 for all countries represents a very weak overall fit of the linear time trend on the real exchange-rate data for the underlying time period. Better estimation quality demonstrated by Cushman (1988) might be due to the differing time period covered in the analysis.

In Eq. 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 US dollar. This comes as a result of improved competitiveness in the export strategy as compared to the FDI strategy due to lower relative costs for domestic production. In case of a real appreciation of US dollar the opposite holds, i.e., shifting production to the foreign market lowers relative production costs. Following theoretical predictions by Cushman (1988) signs for β_2 and β_3 are undetermined.

2.2 Alternative measure of exchange-rate 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 taken in this section, following a study by Kiyota and Urata (2004). As a measure of volatility, we now employ a specification that only captures the part of real exchange-rate volatility not explained by failures of the law of one price. Failures to this principle can partly be explained by factors known to investors, such as distance and national border. It is argued that the part of real exchange-rate volatility accounted for by these factors can not be treated as ‘uncertain’. After excluding the impacts from the failures of the law of one price, we predict a negative effect of the ‘true’ exchange-rate volatility on FDI flows to the host country.

For analyzing the effect of this true exchange-rate volatility on FDI flows regression Eq. 1 from the benchmark model is altered to incorporate the alternative volatility specification. The regression equation, which again is applied separately to each industry, is of the following form

$$\left(\frac{\mathrm{FDI}}{\mathrm{GDP}}\right)_{it} = \beta_0 + \beta_1 \ln R_{it} + \beta_2 \ln E(\theta_{it}) + \beta_3 \mathrm{VOL}_{it} + u_{it}, \tag{3}$$

where the previously used standard deviation of future changes in the real exchange rate 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 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, $\widehat{\mathrm{var}}(R_{it})$,

$$\mathrm{VOL}_{it} = |\mathrm{var}(R_{it}) - \widehat{\mathrm{var}}(R_{it})|. \tag{4}$$

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 2 years not including the current by using monthly data.

Real exchange-rate volatility explained by the failures of the law of one price, $\widehat{\mathrm{var}}(R_{it})$, 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. In the next step we, therefore, determine the explained part of real exchange-rate volatility along the lines of Kiyota and Urata (2004) by estimating a gravity equation of the form

$$\mathrm{var}(R_{it}) = \alpha_0 + \alpha_1 \ln \mathrm{Dist}_i + \alpha_2 \ln(\mathrm{GDP}_t \mathrm{GDP}_{it}) + \mu_{it}, \tag{5}$$

where the subscript i denotes the host country, Dist_i is the distance in kilometers between the capital cities of the US and the respective partner country i and μ_{it} is an error term.[3] The border effect is proxied by including the GDP of the home and the host country, GDP_t and GDP_{it}, respectively. This equation is estimated using a random-effects model, including 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, $\widehat{\mathrm{var}}(R_{it})$, as included in Eq. 4. Figure 1 plots the actual real exchange-rate variance, $\mathrm{var}(R_{it})$, against the predicted variance, $\widehat{\mathrm{var}}(R_{it})$, from Eq. 5 for a visual comparison. Noticeable is a roughly flat line at the bottom of the graph which depicts the variance of the USD/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 US seems to decrease the according risk substantially.

2.3 Description of the data

The analytical investigation of the effects of the exchange rate and the exchange-rate uncertainty on FDI flows is conducted on the basis of a data set obtained from

[3] Gravity data is taken from Haveman (2006).

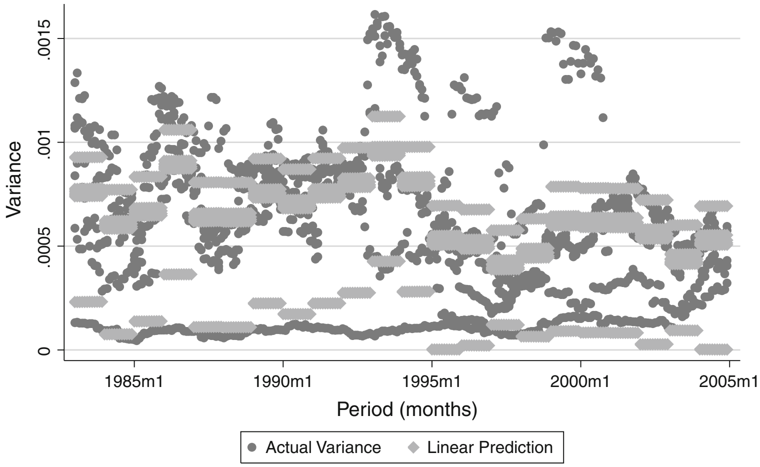

Fig. 1 Actual against predicted variance (Eq. 5)

the Bureau of Economic Analysis (BEA 2007) of the US Department of Commerce for the years 1982–2004. It contains data on international transactions between US 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 (IMF 2004). Due to restrictions on both exchange rate as well as other country-specific data for the time period under study the coverage could not be expanded beyond six major US FDI recipients, namely Japan, Germany, the UK, Canada, France, and Italy, which nevertheless accounted for about 41% of total US FDI outflows during the sample period.

The long-run trends in US outward FDI flows, expressed as percentage of host country GDP, are presented in Table 1. It can be seen that overall FDI outflows' share in GDP increased strongly from 0.25% in the 1980s to 0.8% 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 increase is identified among the nonmanufacturing 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 fivefold 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. Due to data restrictions it was not possible to obtain industry related price indices for the construction of industry-specific real exchange rates. As reasonable alternative the PPI for each country is

Table 1 Trends in FDI outflows (% of GDP, average over countries)

	1982–1989	1990–1997	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

Source: Author's calculations, BEA (2007), IMF *Country Tables* (2004)

Table 2 Trends of the real exchange rates (US 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

Source: Author's calculations, EconStats (2007), IMF *Country Tables* (2004)

used. The nominal exchange rates were then multiplied by the ratio of host country PPI to home country PPI. The development of the respective real exchange rates of the six partner countries in this sample is presented in Table 2. Figures show that most currencies appreciated against the US 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 US dollar than at the beginning of the sample period as well as the beginning of the current decade. Only to the end of the sample period the US dollar revalued again against all currencies, but Japan yen. Real exchange rates for the three countries that introduced the euro as a common currency continue to be determined by both differing movements as well as volatilities of their country-specific international price ratios. In this regard, the introduction of euro is not further addressed at this point.

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. Discussion of the estimation results presented in Sect. 3 of this paper will shed light on this controversial issue.

Table 3 Summary Statistics

	Obs.	Mean	Standard deviation	Minimum	Maximum
$(FDI/GDP)_i$	1,188	0.10640	0.30970	−0.34300	3.45000
$\ln R_i$	132	−2.41294	2.81310	−7.75213	0.55001
$1nE(\theta_i)$	132	0.00951	0.13911	−0.28394	0.32092
$Sd(\theta_i)$	132	0.08439	0.03754	0.02053	0.19667
VOL_i	132	0.00017	0.00013	0.00002	0.00070
$(K/GDP)_{i,\ t-1}$	1,188	0.00804	0.02192	−0.00661	0.20669
$1n(ULC/ULC_i)$	132	0.12808	0.21992	−0.35084	0.78693
$\ln(i/i_i)$	132	0.02578	0.39907	−0.90922	1.33316

Source: Author's calculations

Table 3 presents summary statistics for the variables used in the different regressions conducted in this paper. Complete information on industry-specific correlations of variables are detained at this point but can be provided by the authors upon request.

2.4 Econometric issues

Based on the data at hand, a simple test for serial correlation in the idiosyncratic errors of a linear panel-data model, as discussed by Wooldridge (2001), was performed for all industries for the benchmark model in Sect. 2.1 as well as the alternative model specification discussed in Sect. 2.2. In both cases the null hypothesis of no first-order autocorrelation could generally not be 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. This will be controlled for by allowing a panel-specific autoregressive process with one lag (AR1) for the error terms in the regression.

To examine the existence of a potential heteroscedastic error structure in the panel data in the form of a nonconstant conditional variance of the error terms across different groups of the sample at one point in time, a likelihood-ratio test is conducted. Following closely the procedure proposed by Wiggins and Poi (2001) the existence of heteroscedasticity between panels in the data set at hand is revealed. In the underlying sample, countries seem to exhibit different sensitivities to changes in fundamental factors, therefore introducing cross-sectional heteroscedasticity of the error terms in the model.

As a further issue, the error terms of different cross-sections are assumed to be contemporaneously correlated due to a common element. It appears 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 above 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, we use the feasible generalized least squares (FGLS) estimation method to allow for these error term characteristics.

3 Estimation results

Elasticities at the sample mean computed from the estimated coefficients in Eqs. 1 and 3 are presented in Tables 4 and 5. 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.

The benchmark model specification of exchange-rate risk, Sd(θ), measured as standard deviation of annual real exchange-rate changes over the preceding 3 years including the current, exhibits a statistically significant negative relationship with US FDI outflows in eight industries, including All Industries. In general, declining uncertainty about the future movements of the real exchange rate on average corresponded with increasing US 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).

Exchange risk measured by the unexplained part of real exchange-rate volatility, VOL, is statistically significant in six of nine industries, though at least at the 5%

Table 4 Elasticities: benchmark model, dependent variable US 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(θ_i)	−0.186**	−0.524***	−0.470*	−0.387*
Log-LH	−6.638	78.738	307.581	245.803
AIC	21.276	−149.476	−607.162	−483.606
Wald chi^2	31.080***	65.410***	5.160	13.680***

	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***	0.287***
$E(\theta_i)$	−0.286	1.307	−0.519	1.570	0.407
Sd(θ_i)	−0.483*	−1.012***	−0.242	−3.745***	0.048
Log-LH	319.247	292.664	244.914	339.238	107.786
AIC	−630.494	−577.327	−481.829	−670.477	−207.573
Wald chi^2	15.040***	16.660***	28.650***	42.100***	34.150***

Number of observations: 132

*,**,*** denote statistical significance at the 10, 5, and 1% level, respectively

Source: Author's calculations

Table 5 Elasticities: alternative volatility, dependent variable US 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**
Log-LH	−4.395	88.710	310.561	250.220
AIC	16.790	−169.419	−613.122	−492.439
Wald chi^2	17.290***	136.800***	7.590*	19.220***

	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***	0.274***
$E(\theta_i)$	−0.308	0.928	−0.156	2.382	0.404
VOL_i	−0.261***	−0.086	0.072	0.767**	0.212**
Log-LH	328.462	287.610	250.808	336.659	99.567
AIC	−648.925	−567.220	−493.617	−665.318	−191.134
Wald chi^2	15.040***	3.730	34.870***	17.950***	17.590***

Number of observations: 132

*,**,*** denote statistical significance at the 10, 5, and 1% level, respectively

Source: Author's calculations

confidence level. Unlike the benchmark results a significant negative relationship between VOL and FDI flows is found only in Manufacturing Total, Chemicals and Primary and Fabricated Metals. Contrary to this, the alternative 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 US FDI outflows in these three latter 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.

A remarkable feature in this context is the dichotomy of a negative effect in manufacturing sectors, corresponding to the benchmark results, and a positive effect in nonmanufacturing sectors in the alternative model.

Interesting to note is the relatively high sensitivity of US FDI outflows in Depository Institutions with respect to increased exchange risk in both models, showing a multiple of the other industries' sensitivities. Another characteristic in the comparison of the two model specifications is that for most of the industries in this study the reported sensitivities of FDI outflows with regard to real exchange-rate risk turn out to be lower when applying 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.

A real depreciation of the US dollar during the research period, indicated by a rise in R, was on average associated with an increase in US outward FDI flows in the majority of industries in both models,[4] which is at odds with theoretical predictions of Cushman (1988) and Froot and Stein (1991) as well as several empirical findings,[5] but in line with, for example, Campa (1993) and Görg and Wakelin (2002).

The expected future change in the real exchange rate, $E(\theta)$, shows very weak results for an effect on FDI outflows. In the two models 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 $E(\theta)$] of the US dollar was on average accompanied by decreased US FDI outflows of MNEs operating in the Chemicals sector. Apparently, this expectations variable generally seems inapplicable to explain locational decisions of MNEs as theoretically predicted by Cushman (1988).

As adumbrated above 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. In addition, the overall goodness-of-fit as indicated by the Akaike Information Criterion (AIC) and the log-likelihood is in general better for the alternative model specification than for the benchmark model. This leads to the conclusion that the unexplained part of real exchange-rate volatility as a measure of 'true' uncertainty seems superior to the more commonly used standard deviation from the benchmark model. Further research is required to assert those coherences in reference to different country sets and time frames.

4 Further extensions

Having discussed the two competing measures of real exchange-rate uncertainty in the preceding section the analysis is now augmented with additional explanatory variables traditional to FDI analyses, though, directed only to the unexplained part of real exchange-rate uncertainty as risk measure. Previous studies by Froot and Stein (1991), Klein and Rosengren (1994), Ito (2000), Sazanami et al. (2003), Kiyota and Urata (2004) and others have discovered that capital stock already existent in the host country as well as relative labor costs are important factors in determining new FDI. Agglomeration might be important for FDI decisions because of its status as indicator for established markets and positive investment climate. Since FDI incurs substantial sunk costs, a considerable existing stock of FDI in a country is regarded as sign of security for potential investors and could encourage new FDI. An investor may find further benefits in a market with larger FDI stock as compared to other markets, such as knowledge spillovers from other firms and

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

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

network effects. As argued by Kiyota and Urata (2004), at the industry level FDI stock can partly capture the agglomeration effect. To incorporate this possible effect accumulated FDI flows from the previous period are included as proportion of host-country GDP $(K/\mathrm{GDP})_{i,t-1}$, into the regression. $K_{i,t-1}$ is defined as the cumulated sum of industry-specific real US FDI outflows to the particular partner country i from 1982 to $t-1$.

As another explanatory variable the ratio of the home-country unit labor cost index to the host-country unit labor cost index $(\mathrm{ULC}/\mathrm{ULC}_i)_t$, is included in the regression equation to control for relative labor costs. This measure is preferred over wage rates because it does not only quantify labor cost distinctions but also productivity differences between two partner countries in that unit labor cost gives the actual labor cost necessary to produce one unit of output. Data on national-level unit labor costs are taken from the US Bureau of Labor Statistics (BLS 2007) and transformed to ratios. Multinational companies are presumed to favor regions with higher productivity and lower labor cost over others when locating new FDI.

Motivated by Görg and Wakelin (2002), a third variable is added to control for financing costs in the home country. This is proxied by the inclusion of the relative real interest rate $(i/i_i)_t$, between the US and its particular partner country. Especially MNEs that depend largely on external financing for their business may be discouraged by higher real interest rates. Annual nominal interest rate information are obtained from IMF *Country Tables* (IMF 2004) and transformed to real values by the GDP deflator with base year 2000 to correct for changes in the purchasing power of money.

With the addition of these new explanatory variables the augmented regression equation becomes

$$\begin{aligned}\left(\frac{\mathrm{FDI}}{\mathrm{GDP}}\right)_{it} = {} & \beta_1 \ln R_{it} + \beta_2 \ln E(\theta_{it}) + \beta_3 \mathrm{VOL}(\theta_{it}) + \beta_4 \mathrm{Trend}_{it} \\ & + \beta_5 \left(\frac{K}{\mathrm{GDP}}\right)_{i\,t-1} + \beta_6 \ln\left(\frac{\mathrm{ULC}}{\mathrm{ULC}_i}\right)_t + \beta_7 \ln\left(\frac{i}{i_i}\right)_t + u_{it},\end{aligned} \tag{6}$$

where a time trend, Trend_{it}, cumulated stock of real US FDI outflows relative to GDP in the host-country of the previous period $(K/\mathrm{GDP})_{i,t-1}$, unit labor cost ratio $(\mathrm{ULC}/\mathrm{ULC}_i)_t$, and real interest rate ratio $(i/i_i)_t$, are included. With the inclusion of a trend variable we control for possible trends in US outward FDI as indicated in Table 1 and follow more closely the specification used by Kiyota and Urata (2004) who reported significant trends in Japan's FDI.

Coefficients β_5 and β_6 are expected to show positive signs as a larger existing stock of FDI in the destination region and higher relative unit labor cost at home promote FDI flows to the host country. A significant negative sign on β_7 would indicate higher dependency of the MNE on domestic financing, and thus discourage FDI in face of higher domestic capital costs.

As discussed earlier in Sect. 2.4 a simple test for first-order autocorrelation was performed for the benchmark specification. Due to the changed specification in the augmented model, the same test was conducted including the additional variables. This time, the test statistic had to be rejected in all but one industry. Wholesale

Trade was found to exhibit no first-order autocorrelation in the underlying data. In opposition to this, all other industries now show serial correlation with at least one lag. For these industries a panel-specific AR(1) process is assumed during the estimation, using FGLS again.

Results of the augmented model regression expressed in elasticities at the sample mean calculated from coefficients in Eq. 6 are presented in Table 6. Results for the level of the real exchange rate, *R*, correspond to those from the benchmark and the alternative model in Tables 4 and 5. Estimates for the expected future change in the real exchange rate, $E(\theta)$, show mixed outcomes. An expected real depreciation of the US dollar in the subsequent period has had a diminishing effect on US FDI outflows in Chemicals and Wholesale Trade industries. Whereas increases in outward FDI in Electric Machinery and Depository Institutions were associated with appreciation expectations for the host-country currency.

In spite of controlling for additional factors concerning FDI decisions the bipartite results on real exchange-rate volatility, VOL, for manufacturing and

Table 6 Elasticities: augmented model, dependent variable US outward FDI: $(FDI/GDP)_i$

	All Industries	Manufacturing Total	Food	Chemicals
R_i	0.058**	0.064***	0.087	0.047*
$E(\theta_i)$	−0.560	−0.275	−0.763	−1.719***
VOL_i	0.081**	0.003	−0.017	−0.043
$(K/GDP)_{i,\ t-1}$	0.671***	0.577***	0.258	0.534***
ULC/ULC_i	0.481	0.473	1.196*	1.157**
i/i_i	0.050	−0.081	−0.593***	−0.276*
Trend	0.242	0.393**	0.715	0.479**
Log-LH	−2.577	102.312	320.379	265.855
AIC	19.154	−190.623	−626.759	−517.710
Wald chi^2	116.100***	111.910***	29.430**	138.830***

	Primary and Fabricated Metals	Electric Machinery	Wholesale Trade	Depository Institutions	Finance, Insurance and Real Estate
R_i	0.128***	0.007	0.090***	0.995***	0.099**
$E(\theta_i)$	−0.756	2.735**	−1.289***	14.685***	−0.876
VOL_i	−0.224**	−0.131	0.065	0.636*	0.219**
$(K/GDP)_{i,\ t-1}$	−0.006	0.304	0.448***	−0.698**	2.280***
ULC/ULC_i	0.438	−1.465	1.005***	−7.388**	0.779
i/i_i	−0.331*	0.027	−0.363***	−0.168	−0.060
Trend	1.206***	0.878***	0.522***	3.763***	0.300
Log-LH	333.615	298.935	269.306	343.393	109.231
AIC	−653.230	−583.871	−524.611	−672.786	−204.462
Wald chi^2	18.270**	57.650***	145.340***	25.530***	143.350***

Number of observation: 132

*,**,*** denote statistical significance at the 10, 5, and 1% level, respectively

Source: Author's calculations

non-manufacturing sectors remain present, though, less pronounced due to a reduction in the number of reported industries. The absolute sensitivity of FDI outflows to real exchange-rate risk is highest for Depository Institutions as before, which, in conjunction with sensitivities on real exchange-rate level and future expectations, discloses a significant dependence on real exchange-rate characteristics for this industry.

Among the additional control variables existing stock of FDI in the host country proves to be highly significant in six industries, showing the expected positive sign in all but one cases. A negative effect on new FDI, however, is found for Depository Institutions. Higher productivity, as captured by the unit labor cost ratio, is found to be important for FDI decisions in Food, Chemicals and Wholesale Trade industries. An exception again are Depository Institutions in that they show a strong link between increased unit labor costs at home relative to the host country and reduction of FDI in the host country. The inclusion of the real interest rate ratio yields a significant negative effect on FDI in Food, Chemicals, Primary and Fabricated Metals, and Wholesale Trade industries. MNE in these four industries appear to rely more on external financing, especially domestic, than others. Hence their investment decisions are notedly influenced by changes in real interest rates. Interestingly, according to de Serres et al. (2006: 47) the Chemical, Wholesale Trade and Food industries are listed among the top ten industries most dependent on external finance, thus the result in this analysis would confirm the strong interest rate dependence of these industries as implied by de Serres et al. (2006). In contrast to our findings, a positive effect of relative interest rate on US outward FDI is found by Görg and Wakelin (2002). However, the applied measure of FDI is very different in that it is defined as US outward MNE sales of affiliates in the host country rather than capital transfers.

Corresponding to Kiyota and Urata (2004) a trend variable, Trend, was included in the regression to control for a possible time dependent evolution of US FDI outflows during the sample period. As indicated by the discussion in Sect. 2.3 a significant and positive trend in US outward FDI as percentage of host-country GDP is confirmed for six out of nine industries describing an autonomous expansion of FDI in these industries independent of the variables under study. The specific upsurge in FDI outflows in Depository Institutions from Table 1 is also noticeable reflected in the high sensitivity of the trend variable in Table 6. Yet, the results in this analysis stand in contrast to the consistently negative findings of Kiyota and Urata in their study on Japan’s outward FDI to its partner countries for the period 1990–2000.

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 US to six partner countries for the period 1983–2004. Two different measures of exchange-rate uncertainty are applied for this purpose.

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 US 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 exhibit a clustered characteristic among industries. While manufacturing industries reveal a negative effect of real exchange-rate risk on US FDI outflows, the relationship is positive for nonmanufacturing sectors. Moreover, calculated sensitivities are generally lower when using the alternative exchange risk specification. This seems to indicate a better applicability of the unexplained part of real exchange-rate volatility, as adopted from Kiyota and Urata (2004), when studying locational decisions of multinational firms.

In contrast to theoretical predictions of a negative effect of real home-country currency depreciation on outward FDI results show a persistent positive sign across industries for the underlying research period. Statistical significance is reported for most industries. 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 US. This development, at the same time, coincided with a real depreciation of the US dollar against major currencies, leading to these particular findings.

Expectations on future changes of the real exchange rate are found to have a statistically significant effect in only one industry. In the Chemicals industry an expected future depreciation of the real exchange rate is associated with diminishing FDI activities of MNEs.

The inclusion of additional control variables within an augmented model framework, namely existing stock of FDI, relative unit labor costs and relative real interest rate, improves the overall goodness-of-fit of the estimation and contributes largely to the explanation of US FDI outflows. The cumulated stock of FDI shows the expected positive sign and is statistically significant in six of nine industries. Similarly, higher domestic unit labor costs compared to the host country stimulate FDI outflows in four of the investigated industries.

Assuming mainly domestic financing of funds we expected the relative real interest rate, defined as home-to-host-country real interest rate, to capture financing costs of MNEs engaged in FDI. The anticipated negative effect is found to be statistically significant in four industries, of which three are listed among the sectors most dependent on external financing according to a study by de Serres et al. (2006). Those industries, therefore, seem to be more sensitive to interest rate fluctuations than other industries in this study for which no effect is observed.

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