Foreign Direct Investment and Exchange Rate Volatility: a Non-Linear Story

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Abstract

This paper sheds light on the influence of exchange rate volatility on foreign direct investment (FDI), both at the theoretical and the empirical level. The novelty of the empirical analysis, which is based on a panel of 27 OECD countries over the period 1982-2002, is to provide evidence of a U-shaped relation between observed FDI flows and exchange rate volatility: the effect is negative for low levels of uncertainty and positive for higher levels. I also construct a real-options theory of a multinational, which contemplates FDI to relocate production abroad under a stochastic exchange rate. The model provides a theoretical rationale for this finding and offers new insights in the investment-uncertainty relation. Both the predictions and the theoretical approach stand in stark contrast to the real-options literature, which implies a negative relation. Previous studies analyze the option value of investing in a single project and limit their predictions to the current investment level. In contrast, I derive the expected foreign direct investment of an economy over a given time period. To estimate this value, I assume that all exporting firms are proposed a different offshoring project, ranging from loss-making to very profitable. For each firm, I compute the probability of investing abroad over the desired time period. Eventually, I investigate the influence of exchange rate volatility on the expected investment level. The paper therefore extends the real-options literature and proposes a new framework to analyze the dynamics of aggregate investment.

JEL Keywords & Codes:
International Investment (F21), Multinational Firms (F23), Foreign Exchange (F31), Uncertainty (D81), Real Option (G13)

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1 Introduction

A recent survey (UNCTAD, 2005) shows that countries are responding to increased global competition for foreign direct investment (FDI) by becoming more proactive in their investment promotion efforts. It is also found (UNCTAD, 2005) that, for 80% of the 325 largest multinationals (covering 92% of total FDI flows), exchange rate volatility is viewed as a major threat to FDI flows. Linking these two facts, it is tempting to advocate a policy of stabilization of the exchange rate as a means to attract foreign multinationals. The research agenda of this paper is then to investigate whether exchange rate fluctuations have a negative influence on FDI flows.

This article sheds new light on the relation between FDI and exchange rate uncertainty, both at the theoretical and the empirical level. The novelty of the empirical analysis, which is based on the entire panel of OECD countries over the period 1982-2002, is to provide evidence that there exists a U-shaped relation between observed FDI flows and exchange rate volatility: the effect being negative for low levels of uncertainty and positive for higher levels. I also construct a real-options theory of a firm, which contemplates a relocation of production abroad. The theory provides a theoretical rationale for this U-shaped relation and offers new insights in the investment-uncertainty relation. The results stand in stark contrast to the real-options literature, which concludes on a negative relation. The paper suggests that merely investigating the influence of uncertainty on the option value of investing, without measuring the probability of undertaking the investment in the future, is missing part of the empirical picture.

Many empirical studies have difficulties finding a consistent link between exchange rate volatility and FDI flows\(^1\). The heterogeneity in the econometric techniques and the (small) sets of countries considered in the literature are potential explanations for the discrepancies in the results\(^2\). However, opposing or inconclusive results concerning the sign of the effect of exchange rate variability on FDI can also be the manifestation of a non-linearity in the data that has been so far ignored. In this paper, I offer a comprehensive empirical analysis exploiting a rich panel data set, covering 27 OECD countries (which yields 702 observations per year) over the 1982-2002 period. The nature of the data set permits a thorough scrutiny of the statistical features of the relation between exchange rate volatility and FDI. Using a variety of estimation techniques, I exhibit an influence of exchange rate volatility on FDI flows in industrialized countries that is clearly non-monotonic and U-shaped. Considering either FDI flows or outward FDI, the effect is to depress flows for low levels of volatility, whereas it stimulates them for higher levels. Thus, the analysis reveals that the effect appears to be more complicated than has been envisaged by the empirical literature. If countries presenting on average high exchange rate volatility dominate a sample, the effect will turn out to be positive and

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\(^1\)Cushman (1985, 1988) shows that exchange rate volatility may have positive effects on FDI, using bilateral FDI flows from the United States to the United Kingdom, France, Germany, Canada and Japan for 1963-1978. In another study, Goldberg and Kolstad (1995), using quarterly data of bilateral FDI flows from the United States to the U.K., Canada and Japan for 1978-1991, perform a time series analysis on individual country data. They also identify a positive relationship for some of the series. Chakrabarti and Scholnick (2002) however obtain much less conclusive results. In their paper, they consider FDI flows from the U.S. to 20 OECD countries and obtain an insignificant effect of exchange rate volatility on FDI.

\(^2\)This study also allows us to forward our knowledge on this puzzle by addressing some of the deficiencies in prior empirical works: exchange rate volatility is often estimated over a year only, which seems a bit short for long-term investment like FDI; the sample set of countries is typically small, and the information provided by a panel analysis is rarely considered.
the opposite will hold for a sample mainly constituted of countries with low volatility. Hence, the paper can explain the disagreements on the sign of the estimate. So far, extant theoretical literature has not identified a non-linear relation that is consistent with the data.

This paper proposes a fresh theoretical look. Using a contingent-claims approach, I model the market value of a firm facing a trade-off between exporting capital and exporting goods in a foreign country. As the unique source of uncertainty is the exchange rate, I estimate the endogenous trigger level of the exchange rate that maximizes the firm’s value. At the time the exchange rate hits this barrier, the option to relocate production is optimally exercised and the firm invests abroad. Irreversibility of investment expenditures and the option of waiting for a more favorable exchange rate render the investment decisions of the firm sensitive to exchange rate uncertainty. I proceed, however, to consider the likelihood of exercising the option within a period of time and I calculate the expected value of the foreign direct investment. This value is computed from the probability of reaching the endogenous exchange rate trigger value over an infinite range of possible investments.

The result of this paper is to uncover a non-monotonic influence of exchange rate volatility on FDI. Previous authors have shown that volatility causes the firm to require higher project profitability before investing. But I show that volatility also increases the probability of investing within a given time period. When these two effects are multiplied with each other, the result is non-monotonic. To see this, consider the two extreme situations that can cause a project to be either highly profitable or loss making. When a project yields a positive pay-off (the option being in-the-money), the firm under zero volatility would surely invest. There is no incentive to wait, as the pay-off could not increase in the future. With a rise in risk, the probability of investing within a given period decreases, because it is more likely that the firm will find it optimal to wait for a more favorable exchange rate. Hence, with more uncertainty, the influence on realized investment is negative. However, when the option to invest is out-of-the-money, the probability of investing abroad is null under certainty since there is no incentive to have a negative pay-off. But the probability of investing increases with volatility: with larger shocks, the firm is more likely to obtain a positive pay-off in the future and the probability of investing increases. As volatility creates more flexibility, the effect on investment is positive. Finally, the aggregation of all cases turns out to present a U-shaped relation between volatility and investment.

One puzzle that the obtained results raise is why this U-shaped relation has not been found in earlier theoretical studies. Several explanations can be put forward. To start with, conventional wisdom has it that the more volatile the currency, the less likely are firms to invest in the foreign economy. Through foreign direct investment, a multinational has operations that generate cash flows in the foreign currency and hence fluctuations in the exchange rate could have important effects on the profits of the firm. This uncertainty, it is argued, will likely depress foreign direct investment spending if the option to delay investment is ignored (e.g. Aizenman, 1992) and if the firm is risk-averse (e.g. Goldberg and Kolstad, 1995). If the only source of uncertainty lies in the exchange rate, an assumption of risk-averse behavior, indeed, yields a negative relation. This approach cannot explain the positive relation observed in the data in the presence of high uncertainty. More importantly, if a firm can hedge exchange risk, exchange rate volatility becomes irrelevant in the investment decision of the firm. It seems more appropriate, therefore, to analyze the firm’s
decisions as maximizing market value, without imposing any form of risk-aversion. Furthermore, the real-options framework will also account for the possibility of delaying investment.

This paper is the first to report the U-shaped pattern in the real-options literature\(^3\). Existing studies have difficulties in providing a convincing rationale regarding the investment-uncertainty relation. Their methodology rests on quite restrictive assumptions that I relax in this paper: first, they tend to focus on the effect of uncertainty on the option value of investing, rather than the investment amount itself. Second, they consider that exchange rate volatility is necessarily detrimental, without appreciating the role of flexibility generated by the volatility in enhancing future foreign investment: more volatility leads to a greater option value that is interpreted as depressing investment since waiting becomes more valuable. The conclusion of the literature, based on Dixit and Pyndick (1994), suggests a negative relation between exchange rate volatility and FDI flows (e.g. Campa, 1993 and Botteron et al., 2003). The reason is that they limit their conclusions to one date in time. However, waiting is more valuable precisely because the firm would be better off investing in the future.

As a result, the theoretical contribution of this paper is to show that, in order to gauge the overall effect of uncertainty on investment, it is more relevant to estimate the expected value of investment within a given time period. Not only this study provides evidence of a new empirical relation between exchange rate volatility and observed FDI flows but it also contributes to the real-options literature in its method of theoretically quantifying the uncertainty effect on foreign direct investment.

The rest of the paper is organized as follows. Section 2 describes the estimation strategy and data analysis, Section 3 outlines a real-options model underlying the relation between exchange rate uncertainty and FDI. Section 4 is devoted to econometric results and concerns. I finally state the conclusions in Section 5.

2 Empirical analysis

In this section, I empirically explore the effect of exchange rate volatility on foreign direct investment (FDI) for industrialized countries. The analysis sheds new light on the relation between exchange rate volatility and FDI, based on a panel of 27 OECD countries over the period 1982-2002. I provide evidence that there exists a U-shaped relation\(^4\), the effect being negative for low levels of uncertainty and positive for higher levels. The contribution of this analysis is to offer new insights in the empirical investment-uncertainty relation and to suggest that conclusions based on a single linear relation are unlikely to provide the full empirical picture.

\(^3\)Lund (2005) and Sarkar (2000, 2003) also document a non-linearity in the investment-uncertainty relationship. However, they obtain an inverted U-shape relationship, do not specifically study the effect of exchange rate volatility on FDI, and only consider an out-of-the-money option project. Their findings are then not consistent with the observed empirical relation between exchange rate volatility and FDI flows.

\(^4\)The result is robust to a variety of econometric tests that I present in Section 4.
2.1 Description of the data

To perform the empirical analysis, I have compiled a substantial data set that covers 27 OECD countries over the period 1982-2002. This potentially corresponds to 14,742 observations in the bilateral panel format, although only 7,186 observations can be used due to missing data (see Table 1 for the descriptive statistics and Table 2 for the correlations). The panel is unbalanced, with the number of observations per pair of countries ranging from a minimum of 1 to a maximum of 21 (and an average of 11). The nature of the data set, containing bilateral measures of FDI flows, outward FDI, and exchange rate volatility, permits scrutiny of the statistical features over the sample period. An important aspect of this panel data set is to benefit from both substantial within and between variations of country data. A visual interpretation is offered by Figure 1, plotting FDI flows, outward FDI, and exchange rate volatility between US and its 15 largest trading partners.

Regarding the sources, data for this study are taken from the International Direct Investment Statistics Yearbook 2003 (OECD) for FDI series, International Financial Statistics 2006 (IMF) for bilateral exchange rates, the Penn World Table 6.2 for GDPs, the OECD International Trade Indicators 2006 for the degree of openness, and from World Development Indicators 2003 for the remaining control variables.

2.2 Econometric specification

Building on recent augmented gravity-type specifications considered in international economics and finance (e.g. Portes and Rey, 2005, di Giovanni, 2005), the estimated model is

\[ f_{di i,j,t} = \gamma_1 + \gamma_2 \sigma_{ij,t} + \gamma_3 \sigma_{ji,t} + \beta' X + \omega_{ij} + \tau_t + \gamma_4 t + \nu_{ij,t} \]  

where \( f_{di} \) stands for the log value of FDI flows from country \( i \) to \( j \) at time \( t \). This setting separately considers FDI flows from country \( i \) to \( j \) and from country \( j \) to \( i \), which offers more precision than analyzing net flows. To strengthen the investigation, I also consider the series of outward FDI, which denotes the market value of total FDI being in the host country \( j \) and originating from country \( i \). The measure of bilateral exchange rate volatility at time \( t \) is captured by \( \sigma_S \). This measure is computed as the standard error of the first difference of the log of the monthly nominal exchange rate in the five years preceding the current year. The log of the exchange rate \( S \) is defined as the value of the source country’s currency in terms of the host country’s currency. Most of the attention will be paid to the sign and the significance level of the coefficient \( \gamma_2 \), providing the (semi-)elasticity of the exchange rate volatility to FDI.

Given existing correlations between macroeconomic series, I include a set of control factors \( X' = \left( y_{i,t}, y_{j,t}, \sigma_{y_{i,t}}, \sigma_{y_{j,t}}, \sigma_{ij,t}, \sigma_{ji,t}, D_{ij}, B_{ij}, L_{ij}, FTA_{ij,t}, EMU_{ij,t} \right) \) to ensure that \( \gamma_2 \) only captures the exchange rate volatility effect on FDI. The (log of) GDP \( y \) of the host country \( j \) and the source country \( i \) at time \( t \) account for the sizes of the markets. To avoid including all uncertainty effects in \( \gamma_2 \), I consider the volatility of both the source and host country’s GDP \( \sigma_y \),

5Australia, Austria, Belgium-Luxembourg (GDP weighted), Canada, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Iceland, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, South Korea, Switzerland, Turkey, and the United States.
estimated as the standard error of the first difference of the log of the yearly GDP levels in the five years preceding the current year. The degree of openness \( o \) for country \( j \) and \( i \) (defined as the ratio of exports plus imports to GDP, expressed in current value) provides information on the trade barriers and/or the importance of foreign products in the domestic market. The variable \( D \) gives information on the distance between countries and constitutes the foundation of the gravity equation. I also add dummies, often considered in the trade literature, which are likely to also explain FDI flows: \( B \) accounts for two countries having a common border, \( L \) is a dummy for common language, \( FTA \) is a dummy equal to 1 if both countries subscribe to a Free Trade Agreement\(^6\), and \( EMU \) is a dummy variable that has value 1 if both countries are members of the European Monetary Union\(^7\).

In addition, \( \omega_{ij} \) (not necessarily equal to \( \omega_{ji} \)) characterizes pair-wise specific effects, \( \tau_t \) controls for time specific effects, and \( t \) is a time trend. Examination of Figure 2 highlights an over time negative trend for exchange rate volatility and a positive trend for the FDI series. The variable \( t \) is then included in the estimation to avoid the estimate \( \gamma_2 \) to incorporate spurious explanatory information due to the existence of such trends. Finally, \( \nu_{ij,t} \) is the error term. Reported regressions are estimated with a Fixed Effects model and the heteroskedasticity is controlled using the Huber-White robust estimator of the variance.

### 2.3 Results of the benchmark model

I consider first the simple linear relation between exchange rate volatility and FDI flows, as presented in Analysis 4a of Table 4. The OLS Fixed Effects results show that the effect of exchange rate volatility on FDI flows is not significantly different from zero in OECD countries over the 1982-2002 period. Turning to the control variables, all the coefficients are statistically significant at the 95% confidence level. A focus on the economic interpretation of the statistics suggests that the effects are, ceteris paribus, very important. In particular, a 1% increase in FDI flows is associated with a 0.18% drop of the exchange rate level. The estimation thus suggests that the more favorable the exchange rate, the higher the level of observed FDI flows. If the volatility of the source or the host country’s GDP rises by 1%, FDI flows are respectively depressed by 0.13% and fostered by 0.09%. Furthermore, investment reacts positively to the openness of the source country and negatively to the openness of the recipient country. Finally, being part of either a Free Trade Area or a Monetary Union increases FDI flows between 30 and 40%\(^8\).

#### 2.3.1 Related empirical literature

The empirical literature only considers a linear relation between exchange rate volatility and FDI, in the same spirit as Analysis 4a. At this stage, it is thus interesting to determine whether the linear relation estimated above has any commonalities or discrepancies with earlier research. To compare

\(^6\)This includes the European Free Trade Association (EFTA), the Central European Free Trade Agreement (CEFTA), the Australia-NZL Closer Economic Relations, the European Economic Area (EEA) and the North American Free Trade Agreement (NAFTA).

\(^7\)11 countries were part of the EMU when it was formed in 1999 - Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain - while Greece has been a member since 2001.

\(^8\)The effect is equal to \( \exp(\text{coefficient}) - 1 \).
my results with those of previous studies, I have chosen three widely cited articles: Cushman (1985, 1988), Goldberg and Kolstad (1995), and Chakrabarti and Scholnick (2002).

Cushman (1985, 1988) initially launched the debate on FDI and exchange rate volatility and suggests a positive relation. Through an analysis of FDI percentage changes instead of FDI levels or flows, the author is likely to avoid any non-stationary concerns regarding his results (the presence of unit root has not been explicitly verified though). Although innovative at the time it was published, the empirics, as of today, raise a few issues. First of all, the exchange rate volatility is estimated as the standard deviation of observed quarterly values within the year. But a procedure that uses only 4 data points to assess exchange rate uncertainty is certainly not precise enough. Moreover, FDI decisions are generally taken the year preceding (or even before) the time of investment. It is thus unlikely that firms could observe the exchange rates the year the investment occurs and take this information into consideration. Furthermore, the suggested exchange rate volatility is overestimated if there exists an underlying trend. This result stems from the fact that the author computes the standard deviation of the levels, instead of the log of the exchange rates. In addition, the author focuses on pooled regression estimations only. We may then question the significance of his findings, which generally suggest a positive effect of (very short term) exchange rate uncertainty on FDI. Although Cushman (1985, 1988) is naturally cited in most empirical studies, his predictions are certainly not comparable with the ones of more recent research.

The second most cited article in the literature is Goldberg and Kolstad (1995). The authors also obtain a positive relation when analyzing quarterly bilateral flows between the U.S., Canada, Japan, and the United Kingdom for the period 1978-1991. The paper has been written in a very different setting though. First, the authors analyze each series individually. Second, instead of testing FDI per se, they are interested in the movements in FDI relative to domestic investment. They divide FDI outflows by a measure of investment activity in the source country, which is an elegant way of dealing with the potential non-stationarity of FDI flows. Regarding the measure of uncertainty, the exchange rate volatility is constructed as the standard deviation over twelve quarters of data, prior to and inclusive of the period of investment. As in Cushman (1985, 1988), their measure of exchange rate volatility raises issues; the computation uses the (unobservable) exchange rates of the contemporaneous year and is subject to a potential overestimation of volatility. Interestingly, the authors prefer to remove the potential shifts over time in the expected exchange rate and thus normalize the volatility by the mean level of the exchange rate within the interval. As for the results, they also obtain a positive relation, in four out of the six time series presented. However, the authors analyze different dependent and explanatory variables, compared to either Cushman (1985, 1988) or this paper.

The third study, carried out by Chakrabarti and Scholnick (2002), considers FDI flows from the U.S. to 20 OECD countries over 1982-1995 period. The authors highlight a statistically insignificant relation, either with a Fixed or a Random Effects model. In contrast to earlier studies, the authors analyze a panel data set and estimate exchange rate uncertainty as the standard deviation of monthly exchange rate devaluations during the precedent year. However, as in Cushman (1985, 1988), there is an issue of misspecifying the measure of exchange rate uncertainty; since FDI is viewed as a long-term investment, multinationals are likely to account for exchange rate volatility over a longer
period than a year. Finally, all these studies differ in many important aspects and it would not be reasonable to compare their empirical predictions. However, the heterogeneity of their estimation techniques and the issue raised by the assessment of exchange rate uncertainty instead appeal to a fresh comprehensive empirical analysis. In this regard, I depart now from the literature and shed light on new empirical relations.

2.4 Non-linear relation

The analysis so far does not allow us to identify a significant effect of exchange rate volatility on FDI flows. This result is fully consistent with the predictions of Chakrabarti and Scholnick (2002) and partially with those of Cushman (1985, 1988) and Goldberg and Kolstad (1995). However, an average insignificant estimate can also be the manifestation of a non-linearity that resides in the relation between exchange rate volatility and FDI. In this case, the positive and the negative effects are likely to offset each other. Scrutiny of the data provides evidence that the relation between exchange rate volatility and FDI is indeed non-monotonic and U-shaped. This finding highlights a non-linearity in the data that can be easily masked by a single linear estimation.

As a first piece of evidence, I include the square of the exchange rate volatility as an explanatory variable. The estimation captures a sign change in the relation between exchange rate volatility and FDI flows (Analysis 4b, Table 4). The result is that FDI as a function of $\sigma_S$ presents a quasi-convex shape. I then follow the standard empirical approach of splitting the data set into subsamples, running regressions for each of them, and comparing the coefficients. With a threshold level of the exchange rate volatility set at 3%\(^9\), Analysis 4c and 4d also exhibit a non-linear pattern. Then, exchange rate volatility fosters FDI flows for high levels of uncertainty and depresses them for low levels. The same estimations are carried out using outward FDI instead of FDI flows. As suggested by Table 5, a change of the dependent variable yields identical results though. Hence, I claim that

$$\frac{\partial f_{di}}{\partial E[\sigma_S]} > 0 \text{ if high } E[\sigma_S] \qquad \frac{\partial f_{di}}{\partial E[\sigma_S]} < 0 \text{ if low } E[\sigma_S]$$

(2)

where both estimates are highly statistically significant with heteroskedasticity consistent standard errors\(^{10}\). To investigate the non-linearity with more precision, I also consider rolling-windows over the exchange rate volatility. Figure 3 is clearly illustrative of a U-shape in the relation between foreign direct investment and exchange rate volatility. A thorough empirical investigation of the robustness of the relation is presented in Section 4. The analysis shows that the results do not suffer from potential endogeneity and non-stationarity issues and are robust to various econometric specifications (e.g. Random versus Fixed effects model, exchange rate volatility measured over 24 months versus 60 months, lagged variables versus static model, variables sequentially dropped). Moreover, the non-linearity remains statistically significant and unaltered when the standard errors are corrected for both spatial and temporal dependence, using Driscoll and Kraay’s (1998) covariance

\(^9\)The threshold seems to be near 3%. The results remain very similar if the median (2.74%) is instead considered.

\(^{10}\)As suggested by Figure 2, the average exchange rate volatility has decreased over the 1982-2002 period. However, the low current levels of exchange rate volatility do not imply that the relation becomes predominantly negative. Figure 8 shows that half of the observations consistently remains above the 3% threshold (and respectively half stays below). Hence, the non-linearity in the relation does not capture an effect over time.
This empirical outcome generates strong predictions for policy makers; the estimated model provides predictions on the sign of the effect of exchange rate stabilization on FDI flows. The analysis also suggests that one should be aware of this non-linearity when investigating a set of countries; if the countries under consideration present heterogenous levels of exchange rate volatility, there is a risk of offsetting individual effects on FDI. A common policy, as a means to attract FDI, would then be accurate only if all countries present a similar level of exchange rate volatility. Finally, the heterogeneity of empirical results suggested by the existing (and future) literature naturally arises from the difference in the sets of countries.

The following section offers a theoretical rationale for the U-shaped relation between exchange rate volatility and FDI flows. More precisely, the section provides the literature with a new approach of analyzing the investment-uncertainty relation. I also illustrate why previous real-options models were unsuccessful in predicting this non-monotonicity.

3 Theoretical analysis

From its very definition, FDI differs from other cross-border flows by its irreversibility feature. Hence, a real-options approach arises as a particularly appropriate framework to investigate the theoretical relation between exchange rate volatility and FDI flows. But the extant real-options literature is so far unable to offer a prediction that is consistent with the data. In this section, I explore the limitations of the literature and construct a real-options theory of a firm, which contemplates offshoring production. In contrast to previous studies, the model offers a rationale for the empirical U-shaped relation.

3.1 Standard real-options theory

Building on the Pindyck (1991) foundations, Campa (1993) is first to derive the effect of exchange rate uncertainty on FDI using a real-options model. He concludes that "the higher the volatility of the exchange rate, the higher the level the exchange rate has to be in order for the firm to decide to exercise its option to enter the market. The model gives clear predictions on the effects of exchange rate uncertainty on foreign direct investment. The higher the uncertainty, the more valuable the option to enter will be and the fewer events of entry we will observe (pp.616)." It is also assumed that such a “project is a set of call options on future production, and the greater the volatility, the greater the values of these options. [...]. Hence, greater uncertainty reduces investment.” (Dixit and Pindyck, 1994, pp.192). However, the conclusion drawn by these authors is only partially correct. As highlighted in Section 2, the analysis of the data has identified a U-shaped relation, which contrasts with the monotonic negative relation that they suggest. The discrepancy arises because these authors restrict their analysis to the effect of uncertainty on either the option value or the distance to the exchange rate trigger level, at which the offshoring option is exercised. They

11Foreign direct investment is characterized as long-term investment, whose aim is to exert a significant control on the management of the acquired firm.
ignore, therefore, the potential positive effect of volatility on the likelihood of relocating production abroad\textsuperscript{12}, which corresponds to the probability of exercising the option.

The model that I propose overcomes previous limitations and offers a fresh look at the uncertainty-investment relation. An important point of departure compared to earlier works is that I proceed to consider the probability of investing abroad within a period of time and I calculate the expected value of foreign investment. Using discretized numerical examples, I first show that focusing on the expected value of investment is more insightful than analyzing the option value or the probability of investing abroad. Second, the effect of exchange rate uncertainty on investment presents the non-linearity identified in the data. The firm, depending on the profitability of the relocation project, reacts differently to the flexibility generated by a volatile exchange rate. The model thus extends the real-options theory.

3.2 Model

In this section, I develop a real-options theory of a multinational. The model formalizes the trade-off of a firm between exporting a good and exporting capital in a foreign country. The second choice assumes investing in a plant abroad to produce the good locally, while abandoning the current export serving strategy\textsuperscript{13}. Initially, the firm domestically produces a good, which is sold in competitive markets at home and abroad. It is generally assumed that exporting is the preferred first strategy for the firm to internationalize (Gilroy and Lukas, 2006). However, this strategy may not remain optimal if exchange rate uncertainty changes. The analysis investigates the reaction of the firm and evaluates the probability that the firm relocates production abroad in the future. I eventually derive the relation between the expected value of foreign investment and exchange rate volatility.

3.2.1 Assumptions and valuation of the firm

I assume the firm to be unlevered, thus ruling out the existence of agency problems between stockholders and bondholders. The goal of the firm’s managers is to maximize firm value and act over an infinite time horizon. The firm value can be written as the sum of two parts: the value of a perpetual entitlement to the current profits coming from home and exporting sales, and the value of the option to abandon the exporting strategy by relocating the production aimed at serving the foreign market.

On one hand, the value of the firm generated by domestic sales is not subject to the exchange rate. It is obtained by simply discounting the riskless perpetual domestic cash-flows

\[
V_d = (p - c) \int_0^\infty e^{-rt} dt = \frac{p - c}{r}
\]  

\textsuperscript{12}Sarkar (2000, 2003) also proposes to analyze the probability of investing under uncertainty. Using a single profitable project, he identifies a non-linear relation, which has an inverted U-shape. Altomonte and Pennings (2006) rather investigate the hazard rate of investment and also emphasize an ambiguous effect.

\textsuperscript{13}Offshoring production is considered to be irreversible within the model. Considering the possibility to relocate back home in the future unnecessarily complicates the model as it yields the same theoretical U-shaped relation between FDI and exchange rate volatility. This result arises because of the symmetry of the model: both countries are identical and the exchange rate volatility remains the same, from both the home and foreign country perspective.
where \( p \) and \( c \) are respectively the constant selling price and the cost per unit of time of the good. The default-free term structure is flat with an instantaneous risk-free rate \( r \) in the domestic country (and respectively \( \delta \) in the foreign country), at which investors may lend and borrow freely.

On the other hand, the cash-flows received from exports are subject to exchange rate fluctuations. The traded exchange rate \( s \), defined in terms of domestic currency per unit of foreign exchange, is the unique source of uncertainty within the model. I assume that existing tradable assets can span the offshoring option and that markets are complete. The decision of the firm is then derived under risk-neutrality as shareholders are able to perfectly replicate the firm’s positions in the foreign exchange market\(^{14} \). They are thus indifferent to exchange rate fluctuations when valuing the firm. I can then rely on a single equivalent Martingale measure \( Q \) under which, in the home country, the risk-neutral exchange rate \( (s_t)_{t \geq 0} \) is ruled by the diffusion process

\[
ds_t = (r - \delta)s_t dt + \sigma s_t dZ_t, \quad s_0 > 0
\]

where \((Z_t)_{0 \leq t < \infty}\) is a standard Brownian motion defined on the filtered probability space \((\Omega, \mathcal{F}, \mathbb{Q})\). The constant drift \((r - \delta) \geq 0\) is equal to the difference between the two countries nominal risk-free rates, assuming that the exchange rate is based on the uncovered interest rate parity (with permanent shocks around it given by \((Z_t)_{0 \leq t < \infty}\)). The model is derived in the general case with \((r - \delta) \geq 0\). However, I shall impose the drift to be null. As opposed to modeling stochastic cash-flows, the exchange rate can almost surely not reach the value zero. It is therefore not reasonable to assume a non-zero drift in the exchange rate dynamics, although it is often considered in the literature (e.g. Botteron et al, 2003, for a positive drift\(^{15} \)).

The Geometric Brownian Motion is the most commonly used process for this type of analysis\(^{16} \). However, previous authors have suggested that a mean reversion in the process may be more suitable under equilibrium conditions, particularly since currency exchange rates appear to be mean-reverting. But so far the empirical exchange rate literature has difficulty in providing evidence of a mean reversion over a short horizon. Furthermore, Hasse and Metcalf (1995) argue that results are likely to be unaffected when ignoring this mean reversion. These authors identify two opposing effects\(^{17} \) of mean reversion that tend to offset one another. As a result, the expected cumulative investment after a period of time with heterogeneous firms is the same for both processes. Hence, I voluntarily swap a (more general) mean-reverting process in favor of an intuitive closed-form solution.

I can now determine the optimal investment rule that maximizes firm value, given that the spanning assumption holds. The investment problem reduces then to one of contingent claims valuation. Consider \( V_d \) to be the market value of home production that is sold domestically and

---

\(^{14}\)This is implied from an internationally integrated capital markets model in which all cash flows contingent upon the exchange rate can be priced with a dynamic replicating portfolio of riskless bonds denominated in each of the two currencies.

\(^{15}\)Obviously, assuming a positive trend in the $/£ exchange rate is similar to having a negative trend in the £/$ exchange rate. The £/$ rate will then eventually approach zero.

\(^{16}\)The main advantage is that it leads to tractable solutions and closed-form expressions that can be easily analyzed.

\(^{17}\)On one hand, mean reversion reduces the level of uncertainty, thus bringing closer the critical barrier level needed for investment. On the other hand, lower uncertainty also reduces the likelihood of reaching the investment trigger because it is less probable that the exchange rate will reach extreme high or low values. Sarkar (2003) found a third "risk discounted effect" which is nevertheless not applicable if one assumes risk-neutral shareholders, as I do here.
V_e(s_0) to be the market value of the firm ruling out any future relocation of production. The market value of the firm contemplating abandoning the export strategy at time T(s^*), to invest abroad the irreversible amount I, is denoted by V_i(s_0). We thus have

\[ V_e(s_0) = V_d + E_Q^s \left[ \int_0^\infty e^{-rt}(p_f s_t - c)dt \right] \]  
\[ V_i(s_0) = V_d + E_Q^s \left[ \int_0^{T(s^*)} e^{-rt}p_f s_t dt - \int_0^{T(s^*)} e^{-rt}c_f s_t dt - \int_{T(s^*)}^{\infty} e^{-rt}c_f s_t dt - Is T(s^*)e^{-rT(s^*)} \right] \]

where \( T(s^*) = \inf\{t \geq 0 \mid s \leq s^*\} \) denotes the first passage of time of \((s_t)_{t \geq 0}\) at \( s^* \) and \( E_Q^s \) is the expectation operator associated with the measure \( Q \) conditional on \( s \) starting at the level \( s_0 \). In addition, \( p_f \) and \( c_f \) are respectively the constant price and cost of the good produced and sold in the foreign market, denoted in foreign currency.

Solving Equations (5) and (6) and taking the difference yields (see appendix)

\[ \Delta V(s_0) = V_i(s_0) - V_e(s_0) = \left( \frac{c}{r} - \frac{c_f s^*}{\delta} - Is^* \right) \left( \frac{s^*}{s_0} \right)^{-\beta} \]  
\[ \beta = -\frac{\alpha}{\sigma^2} - \sqrt{\left( \frac{\alpha}{\sigma^2} \right)^2 + \frac{2r}{\sigma^2}} < 0 \]  
\[ \alpha = r - \delta - \frac{\sigma^2}{2} \]  
\[ s^* = \frac{c}{r \left[ \frac{c_f}{\delta} + I \right]^{\beta}} \]

The term \( \Delta V(s_0) \) represents the option value of contemplating future offshoring by taking advantage of a volatile exchange rate. Within the model, the firm is not concerned by the correlation between the exchange rate and domestic profits. In Equation (10), the optimal exchange rate is indeed independent on the revenues \( p_f \). According to the optimality condition, the firm invests abroad as soon as the exchange rate hits an endogenously specified barrier \( s^* < s_0 \). The barrier \( s^* \) indicates the exchange rate level that maximizes the value of a function whose supremum is the value of a perpetual American call option. There is then an obvious analogy with a financial "down-and-in" barrier option, which gives the right to exchange an asset (discounted value of cash-flows with exporting strategy) for another one (discounted value of cash-flows with foreign production). A positive relation between the option value \( \Delta V(s_0) \) and the exchange rate volatility \( \sigma \) is then expected.

\( ^{18} \)This natural restriction is imposed since the firm would invest directly at the exchange rate level \( s_0 \), should it be profitable to invest instantaneously.
3.2.2 Option value of future investment

Most of the current literature tends to focus on the option value of waiting for a more favorable exchange rate. The goal is to predict whether the firm would invest abroad today or rather wait for new information on the exchange rate. Accounting for Equations (5) and (8), the value of this option is

\[
\Delta V(s_0) = \left( \frac{c}{r} - \frac{c_f s^*}{\delta} - Is^* \right) \left( \frac{s^*}{s_0} \right)^{-\beta} 
\]

\[
= \frac{1}{1-\beta} \left( \frac{c_f}{\delta} + I \right) \left( \frac{c}{s_0} \left[ \frac{c_f}{\delta} + I \right] \right)^{-\beta} 
\]

Dixit and Pindyck (1994) point out that uncertainty increases the value of the option of waiting and thus lowers the incentives of investing today. I confirm this result within the model. The derivation of the option value \( \Delta V(s_0) \) with respect to the volatility of the exchange rate \( \sigma^2 \) leads to

\[
\frac{\partial \Delta V(s_0)}{\partial \sigma^2} = -\left( \frac{s^*}{s_0} \right)^{-\beta} \left( \frac{c_f}{\delta} + I \right) \frac{\partial s^*}{\partial \sigma^2} - \left( \frac{s^*}{s_0} \right)^{-\beta-1} \left( \frac{c}{r} - \frac{c_f s^*}{\delta} - Is^* \right) \frac{\beta}{s_0} \frac{\partial s^*}{\partial \sigma^2} 
\]

\[
- \left( \frac{s^*}{s_0} \right)^{-\beta} \ln \left( \frac{s^*}{s_0} \right) \left( \frac{c}{r} - \frac{c_f s^*}{\delta} - Is^* \right) \frac{\partial \beta}{\partial \sigma^2} 
\]

\[
with \ \frac{\partial s^*}{\partial \sigma^2} < 0 \ \& \ \frac{\partial \beta}{\partial \sigma^2} > 0 
\]

The first positive term incorporates the effect of exchange rate uncertainty on the endogenous trigger value \( s^* \): the higher the volatility, the lower the barrier \( s^* < s_0 \). However, uncertainty also influences the stochastic discount factor \( \left( \frac{s^*}{s_0} \right)^{-\beta} \) by lowering the barrier \( s^* \) (Figure 4, lower panel) and by increasing \( \beta \). Although the second term is negative (the third term is positive), uncertainty raises the option value of waiting (Figure 4, upper panel). As suggested by Dixit and Pindyck (1994) and Campa (1993), uncertainty is thus detrimental for investment by increasing the incentive of waiting for a more favorable exchange rate.

The analysis offered by this literature is nevertheless not very convincing. First, the authors investigate the effect of uncertainty on the option value of investing, rather than the investment amount itself. It is surely optimistic to predict a level of investment by merely estimating the option value of the project. Second, they consider that exchange rate volatility necessarily depresses investment, without accounting for the increased flexibility provided by the volatility in fostering future flows. Waiting is indeed more valuable with uncertainty precisely because the firm would be better off investing in the future. By limiting the conclusion to one date in time, they provide only part of the overall picture. I relax these assumptions for the rest of the analysis and proceed to evaluate first the probability of investing and then the realized investment level over a given time period.
3.2.3 Probability of investing

Consistent with the literature, the analysis shows that uncertainty increases the option value of waiting. Some authors would then predict a linear negative effect on investment. However, higher volatility also induces larger shocks on the exchange rate, thus influencing the likelihood of hitting the barrier $s^*$ in the future. To gauge the effect of uncertainty on investment, I then proceed to consider the probability of investing within a period of time.$^{19}$

The probability that investment $I$ takes place corresponds to the likelihood that the trigger value $s$ is reached within a time period $T^{20}$. If the analysis starts at $t = 0$, the risk-neutral probability of investing is defined as (see appendix)

$$
P\left( \sup_{0 \leq t \leq T} s_t \leq s^* \mid s_0 > s^* \right) = \phi \left( \frac{\ln(s^*_0) - \alpha T}{\sigma \sqrt{T}} \right) + \left( \frac{s}{s_0} \right)^{\frac{\sigma^2}{2}} \phi \left( \frac{\ln(s^*_0) + \alpha T}{\sigma \sqrt{T}} \right) \quad (15)$$

$$
P\left( \sup_{0 \leq t \leq T} s_t \leq s^* \mid s_0 \leq s^* \right) = 1 \quad (16)$$

where $\phi(.)$ is the cumulative density of a standard normal distribution. The first term of Equation (15) denotes the probability that $s_T \leq s^*$ at the horizon $T$, whereas the second term is the probability that $s_t \leq s^*$ between $t = 0$ and time $T$, but returns to a value above $s^*$ at $T$. The physical probability is obtained by Equation (15), where $\alpha' = r - \delta - \frac{\sigma^2}{2} - \phi\sigma$ replaces $\alpha = r - \delta - \frac{\sigma^2}{2}$ to incorporate the market price of risk $\phi^{21}$.

To analyze the effect of exchange rate volatility on the probability of investing, I contrast two cases: the first case incorporates projects yielding the relocation strategy to be initially profitable, whereas the second one is for projects that are initially loss making. Within the model, the level of investment $I_0$, measured in domestic currency, determines the initial profitability of the project. Upon instantaneous relocation, the firm saves $c - c_I s_0$ per unit of output, but must bear the investment $I_0$. Hence, if the required investment is too high, the relocation of production is initially not profitable and the option is out-of-the-money. In contrast, for low values of $I_0$, the relocation is initially profitable and the offshoring pay-off $\xi - c_I s_0$ is positive. In this situation, the option of investing is then in-the-money.

The results show that the sign of the effect of exchange rate volatility on the probability of investing abroad depends on the moneyness of the option (Figure 5). If investing abroad today induces a negative pay-off (the option being out-the-money), the probability of relocating production rises with volatility (Figure 5, right panels). However, the opposite effect is observed when the option of investing is in-the-money (Figure 5, left panels). The results are however insensitive to the length $T$ of the period under consideration.

$^{19}$Sarkar (2000) was first to explore the probability of investing under uncertainty in a real-options approach. Assuming a unique profitable project, he identifies an inverted U-shaped relation between the volatility of the cash-flows and investment. However, because he does investigate the investment-uncertainty relation in an international setting, the exchange rate has no role to play in his model. He also only analyzes an option that is initially in-the-money. In contrast, I do not impose restrictions on the initial profitability of the investment. Therefore, both studies are probably too different to allow for a comparison of the predictions.

$^{20}$Although I restrict the interest to the time window $[0, T]$, the firm contemplates investing at any time $t \in [0, \infty]$. 

$^{21}$I do not provide details on the price of risk $\phi$ because it is small for exchange rates. Hence, results are not sensitive to the value of $\phi$. 

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3.2.4 Expected foreign direct investment

The moneyness of the option of future investment determines the sign of the relation between the probability of investing and the exchange rate volatility. But there is no reason to restrict the analysis to projects that are initially either profitable or loss making. Both types of project can exist at the same time and are then not mutually exclusive. We need to therefore come up with a single measure, which captures the overall effect of exchange rate volatility on foreign investment.

In this perspective, Lund (2005) suggests to analyze expected investment instead of the probability of investing. He points out, as a recommendation for further research, that "the simpler probability measure is more interesting if one is only considering the decision on a single investment project. The expected investment with a distinction of projects is more interesting for macroeconomic predictions about the effect of uncertainty on investment in a sector or a nation". I then follow this approach and proceed to estimate the expected value of foreign direct investment $E(I)$. This value is computed from the probability of investing abroad over all possible investments $I$. I then cover a range of projects, which are from highly loss making to highly profitable.

More formally, I assume an economy that consists of $I^* \in [0, \infty]^{22}$ identical firms contemplating future offshoring. Each firm is proposed a particular investment project abroad. To undertake the relocation strategy, the firm must bear an exogenous\(^{23}\) (and firm-specific) investment level, which is measured in foreign currency and drawn from a uniform distribution over the interval $[0, I^*]$. In this economy, the expected value of foreign direct investment observed within a period of time $T$ corresponds to

$$E(I) = \int_0^{I^*} IP \left( \sup_{0 \leq t \leq T} s_t \leq s^* \mid s_0 \right) dI$$

$$= \int_0^{I^*} I \left[ \phi \left( \frac{\ln(s^*) - \alpha'T}{\sigma \sqrt{T}} \right) + \left( \frac{s^*}{s_0} \right)^{\frac{\alpha}{2}} \phi \left( \frac{\ln(s^*) + \alpha'T}{\sigma \sqrt{T}} \right) \right] dI$$

(17) (18)

This approach investigates the relation between exchange rate uncertainty and aggregate investment in a macroeconomic perspective. This framework suggests a U-shaped relation between exchange rate volatility and FDI flows (Figure 6), which is consistent with the data. The non-linearity holds for any upper boundary $I^*$, time horizon $T$, and whether expected investment is evaluated in home or foreign currency. Nevertheless, the inflection point depends on the time window under consideration: the longer the period of time $T$, the lower the uncertainty level, at which a sign change is identified. The U-shape pattern is also observed for a wide range of home cost mark-ups, which reflect the cost difference between exporting and producing the good abroad. In the analysis of Figure 7 (lower panel), I assume that the cost difference between exporting the good

\(^{22}\)The maximum exogenous level $I^*$ does not need to be explicitly determined. Above a certain point, the probability that the firm invests is close to zero, and so is the value of the expected investment. Hence, assuming $I^* = \infty$ yields identical results.

\(^{23}\)The exogeneity of $I$ is standard in the literature. For instance, Boyle and Guthrie (2003) or Miao and Wang (2007) assume a constant and exogenous cost of investment in their analysis. Within this model, the cost is stochastic in the home currency and constant in the foreign currency.
and producing it locally ranges from 10% to 40%. The U-shaped relation is thus stable and not subject to specific parameters values.

3.2.5 Rationale for the U-shape

When the exchange rate barrier is endogenously determined, greater uncertainty yields two opposing effects on the probability of investing: on one hand, the firm is willing to increase her pay-off by waiting for a more favorable exchange rate, which decreases the probability of investing. More formally, the value-maximizing firm is induced to set a more distant optimal barrier $s^*$ with greater volatility (this effect is due to the role that volatility plays in the stochastic discount factor $(\frac{s}{s_0})^{-\beta}$).

As a result, the firm targets higher profits as $\left(\frac{c}{s} - \frac{cs^*}{s} - Is^*\right)$ rises when $s^*$ decreases. On the other hand, more volatility also raises the size of the shocks on $s_t$ that permit to hit the barrier $s^*$, which raises the probability of investing. The relation between exchange rate volatility and expected investment accounts for these two effects. Depending on the moneyness of the option to invest, either effect will be dominant and will determine the sign of the relation.

When the relocation project yields a positive pay-off (the option is in-the-money), the firm under zero volatility would surely invest. There is no incentive to wait, as the pay-off could not increase in the future. With a rise in risk, the probability of investing within a given period decreases, because it is more likely that the firm will find it optimal to wait for a more favorable exchange rate. Hence, with more uncertainty, the influence on realized investment is negative. However, when the option to invest is out-of-the-money, the probability of investing abroad is null under certainty since there is no incentive to have a negative pay-off. But the probability of investing increases with volatility: with larger shocks, the firm is more likely to obtain a positive pay-off in the future and the probability of investing increases.

The aggregation of all cases presents a U-shaped relation between exchange rate volatility and FDI. As a result, this pattern captures the effect of exchange rate volatility on the probability of investing, for both profitable and loss making projects. The influence on expected investment is dominated by the negative effect on the probability of investing (for in-the-money options) when volatility is low, whereas it is dominated by the positive effect on the probability of investing (for out-of-the-money options) when volatility is high. Hence, the existence of various offshoring projects, each of them having a different profitability, is the key driver for the non-linearity.

For any project, the volatility of the exchange rate creates flexibility for the firm. The exchange rate movements offer the opportunity to either target higher future profits or to benefit from a relocation that would not have been profitable. Volatility is then value-enhancing for the firm, through a greater option value, although realized investment can be either fostered or depressed.

24The probability of hitting the barrier $s^*$ increases despite the fact that the distance to this barrier is also higher. The technical reason is that the larger the investment $I$ (inducing a deeper out-of-the-money option), the relatively smaller the influence of the volatility on the barrier $s^*$ is. Indeed, the magnitude of the effect $\frac{\partial s^*}{\partial \sigma}$ negatively depends on $I$ in

$$\frac{\partial s^*}{\partial \sigma} = \frac{c}{r} \left[ \frac{\sigma}{\sigma} + I \right] \frac{\partial \left( \frac{\sigma}{\sigma - 1} \right)}{\partial \sigma} < 0 \text{ & thus } \frac{\partial 2s^*}{\partial I} > 0$$

whereas, of course, the influence of the volatility on the exchange rate path is independent on $I$. 

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Therefore, the option value is not a good measure to assess the investment-uncertainty relation. In addition, an analysis based on the probability of investing only provides a partial explanation. The effect of uncertainty on the probability measure depends on the assumed level of investment, which itself determines the initial profitability of the project. As a result, the expected value of investment offers much more insights in the understanding of the complex relation between exchange rate volatility and FDI: the level of uncertainty dictates the relation between exchange rate volatility and aggregate foreign investment. This framework can then explain the empirical non-linear U-shaped relation that is observed for industrialized countries.

4 Econometric issues and robustness checks

To ascertain the robustness of the empirical predictions, I proceed here to a thorough econometric analysis. Table 4 first provides a robustness check using the distance between the source and the host countries as a proxy for exchange rate volatility. Then, Table 5 reconsiders the estimations presented in Table 4 using outward FDI as the dependent variable. I also reproduce Table 4’s estimations using standard errors consistent to both cross-sectional and temporal dependence and present the results in Table 6. In Table 7, I sequentially add the control variables to test the sensitivity of the model and report the GLS coefficient estimates. I eventually consider both a dynamic OLS and GMM estimation procedures, in Table 8, to account for the potential endogeneity of the exchange rate volatility.

4.1 Distance as a proxy of the exchange rate volatility threshold

To provide evidence that FDI as a function of exchange rate volatility presents a quasi-convex shape, recall that the data set has been split into subsamples (Section 2.4). I have then run regressions for each of them and compared the coefficients. With a threshold level of the exchange rate volatility set at 3%, the results have exhibited a non-linear pattern. However, analysing these subsamples may be problematic because most of the data points lie around the threshold value. To obtain the estimated coefficients for each subsample, the observations on volatility must be varying over time. However, in case of relatively important changes, observations move across samples. Hence, the analysis is based on fewer observations as only changes within the subsamples are relevant. Second, the split creates heterogenous windows over time. To deal with these issues, I reconsider the analysis using the distance between countries as a proxy for the exchange rate volatility threshold. This change allows to verify the non-linearity hypothesis without losing any observations.

Distance between countries and exchange rate volatility are closely linked in the data. As Broda and Romalis (p.2, 2003) put it, "since distance cannot be affected by volatility, this strong relation [the correlation for OECD countries over the 1982-2002 period is 0.47, see Table 2] suggests that greater distance between countries significantly increases bilateral exchange rate volatility through the effect of distance on the intensity of commercial relations such as trade". They show that proximate countries have more similar consumption baskets and thus lower real exchange rate volatility\(^{25}\).

\(^{25}\)As widely shown in the literature, nominal and real exchange rate volatilities present very close behaviors over
than more distant countries. Shocks changing the price of a country’s good affect the price of the
consumption basket of a neighboring country more than that of a more distant country. Engel and
Rogers (1990) confirm the validity of that hypothesis. They show that the volatility of the prices
of similar goods in different locations is positively related to the distance. They argue that the
geographical separation of the markets determines the degree of the failures of the law of one price.
As a result, distance is an adequate proxy for the exchange rate volatility threshold.

I now verify the existence of the non-linear relation between exchange rate volatility and FDI
flows, when the threshold is determined by the distance between countries. First, I consider an
interaction term between exchange rate volatility and distance to capture the linear change of the
estimate (Table 4, Analysis 4e). For proximate countries, the effect is significantly negative, whereas
it is significantly positive for distant countries. Second, I use spline regressions to precisely detect the
nonlinearities in the data. I divide exchange rate volatility into five subsamples and estimate FDI as
a piecewise linear and continuous function of exchange rate volatility. The non-monotonic relation
still holds and results are similar with either FDI flows (Analysis 4f, Table 4) or outward FDI
(Analysis 5f, Table 5) as the explained variable. The analysis provides evidence on the consistency
of the non-linear relation between exchange rate volatility and FDI.

4.2 Non-stationarity

A recurrent potential problem of macro and financial panel studies is the non-stationarity of the panels.
To ensure the validity of the results, I conduct panel-based unit root tests. Pooling cross-section
time series data generates more powerful unit root tests\(^{26}\) than the single series tests suggested by
Dickey and Fuller (1981) and Phillips and Perron (1988). In finite samples (especially with small
time and large cross-section dimensions), tests on single series are known to have limited power
against alternative hypotheses with highly persistent deviations from equilibrium. I first conduct
the three-step procedure test proposed by Levin, Lin and Chu (2002). All individuals in the panel
are assumed to have identical first-order partial correlation. However, the other parameters in the
error process are permitted to vary freely across individuals. The hypothesis, in which the series
\(\{y_{ijt}\}\) has an individual-specific mean, is as follows:

\[
\Delta y_{ij,t} = \delta_{ij} y_{ij,t-1} + \sum_{l=1}^{p_i} \theta_{ijl} \Delta y_{ij,t-l} + \alpha_{ij} + \varepsilon_{ijt} \quad (20)
\]

where \(y_{ij,t}\) is a variable under consideration (either FDI flows, the log of FDI flows, the log of
Outward FDI, exchange rate volatility, or the log of the GDPs), and \(p_i\) is a lag. The panel test
procedure evaluates the null hypothesis that \(H_0 : \delta_{ij} = 0 \text{ and } \alpha_{ij} = 0 \forall ij\) against the alternative
\(H_1 : \delta_{ij} < 0 \forall ij \text{ and } \alpha_{ij} \in \mathbb{R}\). I also consider the test proposed by Im, Pesaran and Shin (2003).
Like the Levin-Lin-Chu test, this test allows for residual serial correlation and heterogeneity of both the dynamics and error variances across groups. However, the formulation of the alternative

\(^{26}\)Yet panel-based unit root tests require a balanced panel, a condition that is impossible to fulfill with such a broad
data set. I therefore consider only pair of countries for which we have series without gaps. Stationarity tests on FDI
flows are thus based on 143 pairs of countries, considering at most 2857 observations.
hypothesis of the Im-Pesaran-Shin test permits $\delta_{ij}$ to differ across groups, and is thus more general. It is possible for some (but not all) of the individual series to have unit roots under the alternative hypothesis $H_1: \delta_{ij} < 0$ for $ij = 1, 2, ..., N_1$, $\delta_{ij} = 0$ for $ij = N_1 + 1, N_1 + 2, ..., N$ and $\alpha_{ij} \in \mathbb{R}$. The IPS $t$-bar test statistic is constructed by averaging the augmented Dickey-Fuller (ADF) $t$-statistic as

$$
\bar{t} = \frac{1}{N} \sum_{k=1}^{N} t_{p_{ij}}
$$

where $t_{p_{ij}}$ is the ADF $t$-statistic for pair of countries $ij$. The test results indicate that FDI flows, the log of FDI flows, the log of Outward FDI and the exchange rate volatility reject the null hypothesis that the series contain unit roots$^{27}$ (Table 3). They are so characterized as stationary and therefore exhibit mean reversion in that they fluctuate around a constant long run mean with finite variance. Were the series non-stationary, the results would suffer from serious problem of forecasting because of the time-dependent variance. These findings are consistent with those of Kiyota and Urata (2004) in their analysis of Japan’s FDI between 1990 and 2000 and with those of Andersen et al. (2001) regarding the stationarity of the conditional variance of the nominal exchange rates. On the other hand, the Im-Pesaran-shin test cannot reject the nonstationarity of the log GDP series. I have therefore removed the GDP series from the estimated model and ignored this variable in Tables 4 and onwards (except in Table 7).

### 4.3 Error term structure and cross-sectional dependence

In the 1982-2002 period, we have experienced an ever-increasing economic and financial integration of countries, which implies substantial interdependencies between (pairs of) countries. This cross-sectional dependence may arise due to the presence of common shocks and unobserved components that become part of the disturbance term. If these common factors are unobserved (and uncorrelated with the included regressors), the standard Fixed (or Random) Effects estimators are consistent, although not efficient, and the estimated standard errors are biased.

Hence, because testing for cross-sectional dependence is important in estimating panel data models, I consider and describe the Pesaran’s (2004) test. Recall first that the structure of the model was defined as

$$
fd_{ij,t} = \gamma_1 + \gamma_2 s_{ij,t} + \gamma_3 S_{ij,t} + \beta' X + \omega_{ij} + \tau_t + \gamma_3 t + \nu_{ij,t}
$$

Under the null hypothesis of the Pesaran’s test of cross-sectional dependence, $\nu_{ij,t}$ is assumed to be i.i.d. over years and across cross-sectional units such that $H_0: \rho_{ij,kl} = \rho_{kl,ij} = \text{cor}(\nu_{ij,t}, \nu_{kl,t}) = 0$ for $ij \neq kl$. Under the alternative $H_1$, $\rho_{ij,kl} = \rho_{kl,ij} \neq 0$ for some $ij \neq kl$, where $\rho_{ij,kl}$ is the product-moment correlation coefficient of the disturbances. The Pesaran’s (2004) test statistic is then given

$^{27}$However, I cannot reject the nonstationarity of Outward FDI. Although transforming a series in log does not influence the results for a single time series, it does for panel estimations using cross-section averages.
by

\[ T_{\text{Pesaran}} = \sqrt{\frac{2T}{N(N-1)}} \left( \sum_{ij=1}^{N-1} \sum_{kl=ij+1}^N \hat{\rho}_{ij,kl} \right) \]  

(23)

This test statistic has exactly mean at zero for fixed values of \( N \) and \( T \). The usual LM test, developed by Breusch and Pagan (1980), is not as desirable in panels with international data because it requires a time dimension that is larger than the cross-sectional dimension. In the present case \((T = 21, N = 593)\), their test statistic would exhibit substantial size distortions\(^{28}\). As Table 3 illustrates, the Pesaran’s test strongly rejects the null hypothesis of no dependence between pairs of countries at least at the 1% level of significance. In the same table, I corroborate this result using the approach of Frees (1995), which is a non-parametric test based on the sum of squared Spearman’s rank correlation coefficients.

These tests highlight a significant cross-sectional dependence in the model. In addition, there exists a temporal dependence in the data set arising from the construction of the exchange rate volatility measure (using rolling-windows). However, the empirical results of the paper remain robust. In Table 6, I reproduce the estimations of Table 4 with a correction of the standard errors to allow for possible serial correlation and cross-sectional dependence in the panel data by applying Driscoll and Kraay’s (1998) nonparametric covariance matrix. This approach produces heteroskedasticity consistent standard errors that are robust to very general forms of spatial and temporal dependence. Qualitative results from this alternative procedure are largely the same as those of the benchmark model, which is based on OLS Fixed Effects estimations with heteroskedasticity consistent standard errors. There is then a substantial spatial and temporal dependence that needs to be accounted for in the data. Nevertheless, the non-linear relation remains significant with the corrected Driscoll and Kraay’s standard errors.

### 4.4 Other models

A substantiated criticism of the model lies with the number of data observations used in its estimation. Although there are 14,742 potential data points in the dataset, only 7,186 are used in the analysis. This highlights an underlying problem of the empirical work – that of missing data. Hence, it seems important to check that the results do not only hold for a unique econometric specification. In Table 7, I sequentially add the control variables in the estimation and find that the coefficients of the exchange rate volatility (and its square) remain unchanged. Although the GDPs of both the source and the host country are deemed to belong to the gravity-type model, I have removed these nonstationary series from the model. However, I include them in Table 7 and show that ignoring these explanatory variables does not alter the predicted non-linearity in the data.

The results presented so far have been estimated with Fixed Effects. In this framework, such structure is likely to be more insightful than a Random Effects model. The analysis seeks to capture the change of FDI between two countries in the case of varying exchange rate volatility. This is purely a within effect. The Random Effects, being by construction a weighted average between

\(^{28}\)The LM test, given by \( T_{\text{B-P}} = T \sum_{ij=1}^{N-1} \sum_{kl=ij+1}^N \hat{\rho}_{ij,kl}^2 \), is not correctly centered for finite \( T \) and the bias is likely to get worse with large \( N \).
within and between effects, includes information that is less relevant for policy makers. However, the results are robust to a change of specification: a comparison of Analysis 7e with 7f in Table 7 suggests that there is very little difference in the results between a Random and a Fixed Effects model. In addition, when performing a Hausman test on the difference between the two models, I cannot reject the null hypothesis suggesting that there is no systematic difference. Although the Fixed effects estimation is more reasonable in this paper, both estimation procedures conclude on a non-linearity in the data.

Furthermore, various other models have been estimated, although not presented for space consideration but available on request: I investigate whether the exchange rate volatility’s marginal effect on FDI is constant over time or time-varying, I estimate the exchange rate volatility over 24 months instead of 60 months, I consider the variables lagged by one period, and finally set the ratio of outward FDI to GDP to be the explained variable. All yield similar results and thus emphasize the robustness of the findings.

4.5 Endogeneity

At this stage, it is relevant to investigate the potential endogeneity issue. For instance, it is plausible that governments try to attenuate the exchange rate risk that multinationals encounter (through lower exchange rate volatility) in order to attract future expected foreign investment. In that setting, multinationals would exert pressure on a government to lower the exchange rate volatility against a promise to invest in this country later on. If this were the case, FDI would probably have a negative effect on exchange rate volatility. Endogeneity could also arise from the possibility that FDI affect the exchange rate, and thus its volatility, in equilibrium. For instance, Russ (2006) argues that because exchange rates and FDI are jointly determined by underlying macroeconomic factors, regressing FDI on exchange rate volatility may be subject to bias. Unfortunately, it is problematic to verify the validity of this assumption given the lack of relevant data. Nevertheless, I try to solve this issue in three ways: with a dynamic GMM structure, with appropriate sample splits, and with simple but straightforward arguments.

First of all, it is generally claimed that we can econometrically verify the existence of an endogeneity bias with the GMM dynamic panel data estimator, which is developed in Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1997). I test here the validity of this hypothesis. I proceed to compare the GMM estimates with those of a OLS Fixed Effects model that includes a lag of the dependent variable. The dynamic OLS model can be viewed as

\[ fdi_{ij,t} - fdi_{ij,t-1} = \gamma_1 + (\alpha - 1) fdi_{ij,t-1} + \Phi X_{ij,t} + \gamma_2 \sigma_{Sij,t} + \gamma_3 S_{ij,t} + \omega_{ij} + \tau_t + \nu_{ij,t} \tag{24} \]

Regarding the system GMM estimator, I combine the equation in differences - instrumented with lagged levels of regressors - with the equation in levels, instrumented with lagged differences of the regressors. The model then includes internal instruments to deal with the correlation between the

\[29\] This means that the Fixed Effects are significantly uncorrelated with each of the explanatory variables considered in the model.

\[30\] This approach is an improvement of the difference GMM estimator proposed by Arellano and Bond (1991), which
lagged endogenous variable and the time-invariant component of the disturbance. This approach is claimed to address the issue of joint endogeneity of the explanatory variables in a dynamic setting and of potential biases coming from pair-wise specific effects. In the estimation, I assume the level and the volatility of the exchange rates and FDI to be potentially endogenous. I also compute robust two-step standard errors - asymptotically robust to both heteroskedasticity and serial correlation - by following the methodology proposed by Windmeijer (2004), which corrects the downward bias in small sample\textsuperscript{31}.

As long as the model is overidentified, validity of the assumptions underlying the system estimator can be tested through Hansen or Sargan tests of orthogonality between the instruments and the residuals, and through tests of (first and second order) residual correlations. The results in Table 8 show that the validity of the instruments can be rejected when the square of the exchange rate is included (Analysis 8a). However, with sample splits (Analysis 8b and 8c), the validity of the instruments cannot be rejected and I can safely reject any second order serial correlation, which constitutes a necessary condition for the consistency of the estimation. In any case, the data present the non-linear relation between exchange rate volatility and FDI flows. Although not presented for space consideration, while re-estimating the regression with various lag levels in the instrument matrix, using 2SLS as the one-step estimator instead of the two-step procedure, and finally including openness of both countries in the set of endogenous variables, the estimations yield similar results.

Nevertheless, on the whole (see Analysis 8a, 8b, and 8c), the parameters corroborate with the intuition that internal instruments are weak. Indeed, results are very similar to those of a OLS Fixed Effects model with a lagged dependent variable (Analysis 8d, 8e, and 8f). Either a system GMM estimation is not an appropriate procedure to solve the endogeneity issue or the bias is so small that it is not detected. Furthermore, the gain from adding a dynamic in the structure is not subsequent. Hence, relying on the simple Fixed Effects model estimated in Table 4 seems reasonable to capture the exchange rate volatility effect on FDI.

As a result, either the reverse causality issue cannot be solved econometrically or it is inexistent. To shed light on this issue, I tackle the problem from another perspective. I consider the evolution of FDI in two equal subsamples: one including pairs of countries that are close to each other (the distance between countries is less than the median) and one with distant countries (distant by more than the median). In the two subsamples (Figure 8), FDI flows behave similarly, both in terms of size and pace over time. Exchange rate volatility is large and stable over time for distant countries, whereas it is low and decreasing over the 1982-2002 period for proximate countries (Figure 8). If FDI flows were to depress exchange rate volatility for proximate countries, the same effect would also be observed for distant countries. This is clearly not the case. Hence, FDI flows cannot be the source of the average decrease in volatility, which rules out a reverse causality effect from FDI. As a robustness check, Figure 8 presents the same analysis for outward FDI. The conclusion remains

\textsuperscript{31}This approach is theoretically superior to relying on the commonly used one-step estimates and standard errors since only the two-step estimator is asymptotically efficient. However, results are very similar when I consider the one-step estimation. See Bond (2002) for a description of the methodology.
Eventually, a third line of argument can be put forward to support the main findings of the paper. If there exists an endogeneity bias, as suggested by the theoretical model of Russ (2005), it will equally apply to both subsamples. All the estimates are then shifted (up or down). However, the non-linearity between exchange rate volatility and FDI remains: the estimate $\gamma_2$ stays larger with high exchange rate volatility than with low volatility. The endogeneity bias is eventually not relevant for the suggested U-shape pattern.

5 Conclusions

This paper sheds light on the relation between FDI and exchange rate uncertainty, both at the theoretical and the empirical level. The novelty of the empirical analysis is to provide evidence that there exists a U-shaped relation between FDI and exchange rate volatility over the 1982-2002 period. Exchange rate volatility fosters FDI flows for high levels of volatility, while it depresses them for low levels. The manifestation of a non-linearity in the data provides an explanation as to why earlier empirical studies had difficulties in finding a consistent link between exchange rate volatility and FDI flows. So far, the literature only obtained opposing or inconclusive results. The empirical results suggested in this paper are robust to a variety of estimations and tests. However, regressing FDI on exchange rate volatility may still be subject to bias. For instance, exchange rates and FDI are likely to be jointly determined by underlying macroeconomic factors. There is also a risk of capturing a reverse causality in the estimates. In this paper, I suggest that the econometric techniques claimed to deal with common endogeneity issues are not particularly insightful. I instead consider appropriate sample splits, which suggest that the bias is certainly very small. Nevertheless, the presence of a bias would merely shift the estimates, without affecting the non-linear relation between exchange rate volatility and FDI.

So far, extant theoretical literature has not identified a non-linear relation that is consistent with the data. This paper proposes a fresh theoretical look. I construct a real-options theory of a firm, which contemplates a relocation of production abroad. The firm faces a trade-off between exporting capital and exporting goods in a foreign country. The theory provides a theoretical rationale for this U-shaped relation and offers new insights in the investment-uncertainty relation. The results stand in stark contrast to the real-options literature. Existing studies have difficulties in providing a convincing investment-uncertainty relation as they tend to focus on the effect of uncertainty on the option value of investing, rather than the investment amount itself. They consider that exchange rate volatility is detrimental because more volatility leads to a greater option value of waiting that is interpreted as depressing investment. But waiting is more valuable precisely because the firm would be better off investing in the future. The paper then suggests that merely investigating the influence of uncertainty on the option value of investing, without measuring the probability of undertaking the investment in the future, is missing part of the empirical picture. I then proceed to consider the likelihood of investing abroad within a period of time and I calculate the expected value of the foreign direct investment. Eventually, the analysis exhibits an influence of exchange rate volatility on FDI that is clearly non-monotonic and U-shaped.
References


6 Appendix

Option’s value of relocating production in the future (with optimal stopping time)

The option value of the unlevered firm can be written as

\[
\Delta V(s_0) = V_i(s_0) - V_e(s_0)
\]

Using standard computations with Brownian motion,

\[
\Delta V(s_0) = \left( \frac{c}{r} - I s^* \right) E_Q^{s_0} \left[ e^{-rT(s^*)} \right] - s^* c_f \int_0^{\infty} \int_t^\infty e^{(r-\delta)(t-t')} e^{-r T(s^*)} \mathbb{Q}(T(s^*) \in dt')
\]

where by continuity of the process \( s \), \( s_{T(s^*)} = s^* \). After simplifications,

\[
\Delta V(s_0) = \left( \frac{c}{r} - I s^* \right) E_Q^{s_0} \left[ e^{-rT(s^*)} \right] - s^* c_f \int_0^{\infty} \int_t^\infty e^{(r-\delta)(t-t')} e^{-r T(s^*)} \mathbb{Q}(T(s^*) \in dt')
\]

where I can use the Laplace transform of the stopping time \( T(s^*) \) to rewrite

\[
\int_0^{\infty} e^{-rt'} \mathbb{Q}(T(s^*) \in dt') = E_Q^{s_0} \left[ e^{-rT(s^*)} \right] = \left( \frac{s^*}{s_0} \right)^{-\beta}
\]

with

\[
\beta = -\frac{\alpha}{\sigma^2} - \sqrt{\left( \frac{\alpha}{\sigma^2} \right)^2 + \frac{2r}{\sigma^2}} < 0
\]

\[
\alpha = r - \delta - \frac{\sigma^2}{2}
\]
Then,

\[
\Delta V(s_0) = \left( \frac{c}{r} - \frac{c_f s^*}{\delta} - Is^* \right) E_{Q}^{s_0} e^{-\rho T(s^*)} \tag{34}
\]

\[
= \left( \frac{c}{r} - \frac{c_f s^*}{\delta} - Is^* \right) \left( \frac{s^*}{s_0} \right)^{-\beta} \tag{35}
\]

**Optimal exchange rate barrier** \( s^* \)

To obtain the trigger level of the exchange rate that maximizes the firm’s value, I derive the option value with respect to the threshold level \( s^* \)

\[
\frac{\partial \Delta V(s_0)}{\partial s^*} = -\left( \frac{c_f}{\delta} + I \right) \left( \frac{s^*}{s_0} \right)^{-\beta} - \left( \frac{c}{r} - \frac{c_f s^*}{\delta} - Is^* \right) \frac{\beta}{s_0} \left( \frac{s^*}{s_0} \right)^{-\beta-1} = 0 \tag{36}
\]

\[\iff s^* = \frac{c}{r} \frac{\beta}{\left[ \frac{c_f}{\delta} + I \right] \beta - 1} \tag{37}\]

**Probability of investing**

To estimate the probability of reaching the barrier \( s^* \) within period \( T \), I build on previous results of barrier options. Attaining the trigger value of the exchange rate in a "down-and-in" option allows to define without loss of generality

\[
S_{T \wedge T(s^*)} = \begin{cases} 
S_T & \text{if } T < T(s^*) \\
\min_m s & \text{if } T \geq T(s^*)
\end{cases} \tag{38}
\]

Let \( m^*_T = \min_{h \in [0, T]} S_h \) and \( s_0 > s^* \) then,

\[
P\left( \sup_{0 \leq t \leq T} s_t \leq s^* \mid s_0 > s^* \right) = P\{ S_{T \wedge T(s^*)} \leq s^* \} \tag{40}
\]

\[
= P\{ S_T \leq s^* \} + P\{ S_T \geq s^*, m^*_T \leq s^* \} \tag{41}
\]

\[
= P \left\{ \frac{\alpha T}{\sigma} + Z_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \tag{42}
\]

\[
+ P \left\{ \frac{\alpha T}{\sigma} + Z_T \geq \frac{\ln(s^*) - \ln(s_0)}{\sigma}, m^*_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \tag{43}
\]

The first term is easily computed since \( Z_T \) is normally distributed with mean 0 and standard deviation \( \sqrt{T} \). Hence,

\[
P_1 = P \left\{ Z_T \leq \frac{\ln(s^*) - \ln(s_0) - \alpha T}{\sigma} \right\} = \frac{1}{\sqrt{2\pi T}} \int_{-\infty}^{\frac{\ln(s^*) - \ln(s_0) - \alpha T}{\sigma}} e^{-\frac{w^2}{2}} dw \tag{44}
\]

For the second term, I apply the Girsanov Theorem. I start by defining two probability measures
by the Radon-Nikodým derivatives

\[
\frac{d\hat{P}}{dP} = \exp \left( -\frac{\alpha Z_T - \alpha^2 T}{2\sigma^2} \right), \quad P\text{-a.s.} \tag{45}
\]

\[
\frac{d\hat{P}}{dP} = \exp \left( -\frac{\alpha Z_T - \alpha^2 T}{2\sigma^2} \right), \quad \hat{P}\text{-a.s.} \tag{46}
\]

By the Girsanov Theorem, we know that \( \hat{Z}_T = \frac{\alpha T}{\sigma} + Z_T \) follows a standard Brownian motion under \( \hat{P} \). Since

\[
\frac{dP}{d\hat{P}} = \exp \left( \frac{\alpha Z_T + \alpha^2 T}{2\sigma^2} \right) = \exp \left( \frac{\alpha \hat{Z}_T - \alpha^2 T}{2\sigma^2} \right), \quad \hat{P}\text{-a.s.} \tag{47}
\]

I can rewrite the second term as

\[
I = \exp \left( \frac{\alpha \hat{Z}_T - \alpha^2 T}{2\sigma^2} \right) \left\{ \hat{Z}_T \geq \frac{\ln(s^*) - \ln(s_0)}{\sigma}, m_T^\sigma \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \tag{48}
\]

\[
= \left[ \frac{2 \ln(s^*) - 2 \ln(s_0)}{\sigma} - \frac{2 \ln(s^*) - 2 \ln(s_0)}{\sigma} \right] I \left\{ \hat{Z}_T \leq \frac{2 \ln(s^*) - 2 \ln(s_0)}{\sigma} - \hat{Z}_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \tag{50}
\]

where \( I \) is an indicator function. Due to the symmetry of the Brownian motion, the reflection principle implies that

\[
I \left\{ \hat{Z}_T \geq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} = I \left\{ -\hat{Z}_T \leq -\frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \tag{53}
\]

\[
= I \left\{ \frac{2 \ln(s^*) - 2 \ln(s_0)}{\sigma} - \hat{Z}_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \tag{54}
\]

we have

\[
P_2 = E_{\hat{P}} \left[ e^{\left( \frac{\alpha \hat{Z}_T - \alpha^2 T}{2\sigma^2} \right)} I \left\{ \hat{Z}_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \right] \tag{49}
\]

\[
= e^{\left( \frac{2 \alpha \hat{Z}_T - \alpha^2 T}{2\sigma^2} \right)} E_{\hat{P}} \left[ e^{-\left( \frac{2 \alpha \hat{Z}_T - \alpha^2 T}{2\sigma^2} \right)} I \left\{ \hat{Z}_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \right] \tag{56}
\]

where by the Girsanov Theorem we know that \( \hat{Z}_T = \hat{Z}_T + \frac{\alpha T}{\sigma} \) follows a Brownian motion under \( \hat{P} \).

Then, the second term \( P_2 \) becomes
\[ P_2 = e^{\left(\frac{2a[\ln(s^*) - \ln(s_0)]}{\sigma^2}\right)} E_{\bar{P}} \left[ I \left\{ \bar{Z}_T - \frac{\alpha T}{\sigma} \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \right] \quad (57) \]

\[ = e^{\left(\frac{2a[\ln(s^*) - \ln(s_0)]}{\sigma^2}\right)} \bar{P} \left\{ \bar{Z}_T - \frac{\alpha T}{\sigma} \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \quad (58) \]

\[ = e^{\left(\frac{2a[\ln(s^*) - \ln(s_0)]}{\sigma^2}\right)} \bar{P} \left\{ \bar{Z}_T \leq \frac{\ln(s^*) - \ln(s_0) + \alpha T}{\sigma} \right\} \quad (59) \]

\[ = \left(\frac{s^*}{s_0}\right)^{\frac{2a}{\sigma^2}} \bar{P} \left\{ \bar{Z}_T \leq \frac{\ln(s^*) - \ln(s_0) + \alpha T}{\sigma} \right\} \quad (60) \]

\[ = \left(\frac{s^*}{s_0}\right)^{\frac{2a}{\sigma^2}} \frac{1}{\sqrt{2\pi T}} \int_{-\infty}^{\frac{\ln(s^*) - \ln(s_0) + \alpha T}{\sigma}} e^{-\frac{w^2}{2}} dw \quad (61) \]

Finally,

\[ P \left( \sup_{0 \leq t \leq T} s_t \leq s^* \mid s_0 > s^* \right) = P_1 + P_2 \quad (62) \]

\[ = \frac{1}{\sqrt{2\pi T}} \int_{-\infty}^{\frac{\ln(s^*) - \ln(s_0) - \alpha T}{\sigma}} e^{-\frac{w^2}{2}} dw \quad (63) \]

\[ + \left(\frac{s^*}{s_0}\right)^{\frac{2a}{\sigma^2}} \frac{1}{\sqrt{2\pi T}} \int_{-\infty}^{\frac{\ln(s^*) - \ln(s_0) + \alpha T}{\sigma}} e^{-\frac{w^2}{2}} dw \]
Figure 1: FDI and Bilateral Exchange Rate Volatilities for US and 15 Partners, 1982-2002

The upper panel represents the dynamics of the log of Foreign Direct Investment flows between US and its main 15 OECD trading partners over the 1982-2002 period. Similarly, the middle panel represents the dynamics of log outward FDI. The lower panel illustrates the data on bilateral exchange rate volatility, computed as the standard error of the first difference of the log of the monthly nominal exchange rate in the five years preceding the current year.
Figure 2: Average Exchange Rate Volatility and FDI, 1982-2002

The figure shows the sample average dynamics of FDI flows, outward FDI, and bilateral exchange rate volatility over the 1982-2002 period. The panels suggest a clear positive trend for the two FDI series. On the other hand, exchange rate volatility is, on average, decreasing over time in OECD countries.
Figure 3: U-Shape Empirical Relation Between Exchange Rate Volatility and Outward FDI, 1982-2002

The figure provides evidence of a U-shape in the effect of the exchange rate volatility on Foreign Direct Investment in OECD countries over the 1982-2002 period. In the first panel, rolling-windows keep a constant range equal to 3% of the exchange rate volatility (horizontal axis). We can see that the estimate is significantly negative for low levels of exchange rate uncertainty, whereas it is positive for higher levels. A clearer picture (lower panel) is obtained when the vertical axis denotes the Outward FDI normalized to unity to capture the cumulative effect of a change in exchange rate volatility. When splitting the sample in four and, as the figure suggests, we can observe a U-shaped relation between exchange rate volatility and Outward FDI. The black dotted lines show the two standard deviations bound using heteroskedasticity consistent standard errors, whereas the (light blue) dotted lines use Driscoll and Kraay’s (1998) standard errors consistent to spatial and temporal dependence.
Figure 4: Standard Approach of Investigating the Investment-Uncertainty Relation (with Varying Investment Levels)

The figure investigates the investment-uncertainty relation, based on the standard real option literature (see Dixit and Pindyck, 1994). The upper panel shows that, for any level of investment, greater volatility induces the option value of waiting (before investing) to become more valuable. Similarly, as illustrated by the lower panel, uncertainty raises the distance at which the exchange rate barrier lies. The conclusion of the literature is that investment linearly decreases with uncertainty.

Parameters:
I=[1, 60], sigma=[0, 0.25], Cf=2, C=2.6, So=1, r=0.05, rho=0.05
Figure 5: Effect of Varying Investment and Volatility on the Probability of Investing

The previous figure highlighted the negative relation between the trigger level of the exchange rate and exchange rate uncertainty. As we can observe with the probability of investment, the same parameters lead to a completely different story: for low levels of investment (left panels), the probability of reaching the barrier is decreasing (being close to one initially) with uncertainty, while it is increasing for higher investment levels (right panels). This sheds light on the necessity to consider any possible level of investment - as in the expected investment - rather than assuming a single investment value. Although the pattern is very similar for an analysis over either a short period (upper panels) or a long period (lower panels), the probability of observing an investment is much higher with a larger frame window.

Parameters:
I=[0, 10] for left panels and I=[11, 30] for right panels, sigma=[0, 0.25], C=2.6, Cf=2, So=1, r=0.05, rho=0.05
Figure 6: Uncertainty Effect on Expected Investment

Three different cases are numerically simulated, depending on the length of the time window $T$. The expected investment-uncertainty relation presents a U-shape pattern, whatever the level of investment and the length of the time horizon considered. The time window has nevertheless an effect on the value of the uncertainty at which there is a sign change of the effect.

Parameters:
$I=[0,I^*]$ with $I^*=[20, 50]$, $C=2.6$, $C_f=2$, $S_0=1$, $r=0.05$, $\rho=0.05$
Figure 7: Effect of Varying Parameters on Expected Investment

This figure presents an overview of the exchange rate volatility effect with different time horizons and different gains in terms of the production costs abroad relative to the home country. The upper panel shows that, for different values of the time horizon (2 to 8 years), the non-linear relation holds. Similarly, the same shape of the uncertainty effect is also observed when varying the percentage difference of the home and foreign production costs.

Parameters:
I=[0, 30], sigma=[0, 0.25], C=2.6, Cf=2, So=1, r=0.05, rho=0.05
Figure 8: FDI Flows, Outward FDI and Exchange Rate Volatility with a Distance Breakdown, 1982-2002

The figure provides an analysis of the evolution of FDI flows, Outward FDI and exchange rate volatility when the dataset is split into two subsamples: either close or distant countries (the threshold level being the median, 2233km). Both the magnitude and the dynamics of the FDI series in the two subsamples are very similar. However, exchange rate volatility varies over time in a completely different manner: volatility is large and relatively stable over time for distant countries, whereas it is low and negatively trended for proximate countries.
In the following tables, I perform an empirical analysis on 27 OECD countries over the period 1982-2002: $\text{Ln FDI Flows}$ and $\text{Ln Outward FDI}$ capture the logarithm value of the FDI flows and outward FDI between the source and the host country, $\text{Exchange Rate Volatility}$ is a measure of expected bilateral exchange rate volatility computed as the standard error of the first difference of the log of the monthly nominal exchange rate in the five years preceding the current year. $\text{Ln GDP}_{\text{Source}}$ corresponds to the GDP of the source country, $\text{Ln GDP}_{\text{Host}}$ corresponds to the GDP of the host country, and $\text{Distance}$ is the distance between the two countries. As for the dummies, $\text{Common Border}$ accounts for two countries having a common border, $\text{Common Language}$ is a dummy for common language, $\text{Both in FTA}$ is a dummy equal to 1 if both countries subscribe to a Free Trade Agreement, and $\text{Both in EMU}$ is a dummy variable that has the value 1 if both countries are members of the European Monetary Union. In the regressions we also control for pair-wise specific fixed or random effects as well as for time specific effects. Data sources data for this study are taken from the International Direct Investment Statistics Yearbook 2003 (OECD) for FDI series, International Financial Statistics 2006 (IMF) for bilateral exchange rates, the Penn World Table 6.2 for GDPs, the OECD International Trade Indicators 2006 for the degree of openness, and from World Development Indicators 2003 for the other control variables.

<table>
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<th>Statistics</th>
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<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>.471</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Both in FTA</td>
<td>7186</td>
<td>.331</td>
<td>.471</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
### Table 2: Correlation Matrix

This table presents the correlation coefficients between the different variables considered in the benchmark analysis. The values reported use the 7186 observations for which we have data on FDI flows.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Ln FDI Flows</th>
<th>Exchange Rate Volatility</th>
<th>Ln GDP</th>
<th>Ln GDP</th>
<th>GDP Volatility</th>
<th>GDP Volatility</th>
<th>Openness</th>
<th>Openness</th>
<th>Distance</th>
<th>Common Language</th>
<th>Common Border</th>
<th>Both in EMU</th>
<th>Both in FTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln FDI Flows</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exchange Rate Volatility</td>
<td>-0.148</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln GDP Source</td>
<td>0.418</td>
<td>0.047</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln GDP Host</td>
<td>0.347</td>
<td>-0.004</td>
<td>-0.094</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP Volatility Source</td>
<td>-0.266</td>
<td>0.190</td>
<td>-0.371</td>
<td>0.069</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP Volatility Host</td>
<td>-0.174</td>
<td>0.320</td>
<td>0.046</td>
<td>-0.418</td>
<td>-0.059</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Openness Source</td>
<td>-0.107</td>
<td>-0.003</td>
<td>-0.444</td>
<td>0.073</td>
<td>0.238</td>
<td>-0.032</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Openness Host</td>
<td>-0.085</td>
<td>0.306</td>
<td>0.052</td>
<td>-0.328</td>
<td>-0.044</td>
<td>0.396</td>
<td>0.003</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>-0.080</td>
<td>0.471</td>
<td>0.157</td>
<td>0.068</td>
<td>-0.014</td>
<td>0.032</td>
<td>-0.128</td>
<td>0.047</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Language</td>
<td>0.205</td>
<td>-0.076</td>
<td>0.011</td>
<td>-0.047</td>
<td>-0.033</td>
<td>-0.092</td>
<td>-0.015</td>
<td>-0.050</td>
<td>0.073</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Border</td>
<td>0.231</td>
<td>-0.239</td>
<td>0.012</td>
<td>0.006</td>
<td>-0.047</td>
<td>-0.089</td>
<td>0.005</td>
<td>-0.014</td>
<td>-0.300</td>
<td>0.225</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both in EMU</td>
<td>0.101</td>
<td>-0.347</td>
<td>-0.004</td>
<td>0.020</td>
<td>-0.057</td>
<td>-0.099</td>
<td>0.100</td>
<td>0.013</td>
<td>-0.161</td>
<td>-0.039</td>
<td>0.077</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Both in FTA</td>
<td>0.122</td>
<td>-0.499</td>
<td>-0.127</td>
<td>-0.049</td>
<td>-0.109</td>
<td>-0.174</td>
<td>0.092</td>
<td>-0.069</td>
<td>-0.546</td>
<td>-0.001</td>
<td>0.256</td>
<td>0.303</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3: Identification Tests

The upper results present two panel-based unit root tests that are particularly relevant for panels of moderate size. The first test is developed by Levin, Lin, and Chu (2002) and allows for residual serial correlation and heterogeneity of both the dynamics and error variances across groups. It assumes that all pairs in the panel have identical first-order partial correlation. The test proposed by Im, Pesaran, and Shin (2003) is similar except that the formulation of the alternative hypothesis permits the first-order partial correlation to differ across groups, and is thus more general. Both procedures evaluate the null hypothesis that each pair of countries in the panel has integrated time series versus the alternative hypothesis that all pairs time series are stationary. The lower part of the table is constituted of the Pesaran (2004) and the Frees (1995) procedures that allow a test for the presence of cross-sectional dependence in panels with a large number of cross-sectional units and a small number of time series observations. In both cases, the null hypothesis of no cross-sectional dependence is tested using the variance-covariance matrix estimated in Analysis 4a, Table 4.

<table>
<thead>
<tr>
<th>Panel-based Unit Root Tests:</th>
<th>Observations</th>
<th>Pairs</th>
<th>P-value</th>
<th>t-bar Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Im, Pesaran, and Shin (2003)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln FDI Flows</td>
<td>2717</td>
<td>143</td>
<td>0.00</td>
<td>-2.42</td>
</tr>
<tr>
<td>FDI Flows</td>
<td>2717</td>
<td>143</td>
<td>0.00</td>
<td>-2.22</td>
</tr>
<tr>
<td>Ln Outward FDI (1986-2002)</td>
<td>1650</td>
<td>110</td>
<td>0.00</td>
<td>-1.86</td>
</tr>
<tr>
<td>Exchange Rate Volatility (%)</td>
<td>13338</td>
<td>702</td>
<td>0.00</td>
<td>-1.96</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>13338</td>
<td>702</td>
<td>0.00</td>
<td>-1.40</td>
</tr>
<tr>
<td><strong>Levin, Lin, and Chu (2002)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln FDI Flows</td>
<td>2857</td>
<td>143</td>
<td>0.00</td>
<td>-26.47</td>
</tr>
<tr>
<td>FDI Flows</td>
<td>2857</td>
<td>143</td>
<td>0.00</td>
<td>-12.67</td>
</tr>
<tr>
<td>Ln Outward FDI (1986-2002)</td>
<td>1758</td>
<td>110</td>
<td>0.00</td>
<td>-8.69</td>
</tr>
<tr>
<td>Exchange Rate Volatility (%)</td>
<td>13459</td>
<td>702</td>
<td>0.00</td>
<td>-16.88</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>13459</td>
<td>702</td>
<td>0.00</td>
<td>-27.80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cross-sectional Independence Tests:</th>
<th>Observations</th>
<th>P-value</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pesaran (2004)</strong></td>
<td>7186</td>
<td>0.00</td>
<td>61.20</td>
</tr>
<tr>
<td>Average Absolute Correlation</td>
<td></td>
<td></td>
<td>0.252</td>
</tr>
<tr>
<td><strong>Frees (1995)</strong></td>
<td>7186</td>
<td>0.00</td>
<td>6.72</td>
</tr>
<tr>
<td>Critical Value for 99% Confidence</td>
<td></td>
<td></td>
<td>0.234</td>
</tr>
</tbody>
</table>
Table 4: Exchange Rate Volatility Effects on FDI: Main Results

*Estimation: Fixed Effects OLS\(^\$\) with Time Dummies and Time Trend, Period 1982-2002*

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>4a</th>
<th>4b</th>
<th>4c</th>
<th>4d</th>
<th>4e</th>
<th>4f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>All Data</td>
<td>All Data</td>
<td>Low ER Vol.</td>
<td>High ER Vol.</td>
<td>All Data</td>
<td>All Data</td>
</tr>
<tr>
<td>Exchange Rate Volatility:</td>
<td>0.014</td>
<td>-0.208***</td>
<td>-0.103***</td>
<td>0.054***</td>
<td>-0.040*</td>
<td>-0.241***</td>
</tr>
<tr>
<td>0 &lt; Distance &lt; 1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 &lt; Distance &lt; 2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000 &lt; Distance &lt; 6000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6000 &lt; Distance &lt; 9000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9000 &lt; Distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interacted with Distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.009***</td>
</tr>
<tr>
<td>(1000 km)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.003)</td>
</tr>
<tr>
<td>(Exchange Rate Volatility(^2))</td>
<td>-0.177***</td>
<td>-0.156***</td>
<td>-0.143**</td>
<td>-0.142***</td>
<td>-0.177***</td>
<td>-0.170***</td>
</tr>
<tr>
<td>Log Exchange Rate Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP Volatility source</td>
<td>-0.131***</td>
<td>-0.116***</td>
<td>-0.160***</td>
<td>-0.084**</td>
<td>-0.129***</td>
<td>-0.115***</td>
</tr>
<tr>
<td>GDP Volatility host</td>
<td>0.091***</td>
<td>0.089***</td>
<td>0.171***</td>
<td>0.005</td>
<td>0.088***</td>
<td>0.088***</td>
</tr>
<tr>
<td>Openness source</td>
<td>0.011***</td>
<td>0.011***</td>
<td>0.111***</td>
<td>0.007**</td>
<td>0.010***</td>
<td>0.009***</td>
</tr>
<tr>
<td>Openness host</td>
<td>-0.005**</td>
<td>-0.003</td>
<td>-0.010**</td>
<td>-0.002</td>
<td>-0.005**</td>
<td>-0.005**</td>
</tr>
<tr>
<td>Both in EMU</td>
<td>0.270**</td>
<td>-0.010</td>
<td>-0.085</td>
<td>dropped</td>
<td>0.198*</td>
<td>0.051</td>
</tr>
<tr>
<td>Both in FTA</td>
<td>0.320***</td>
<td>0.265***</td>
<td>0.197**</td>
<td>0.146</td>
<td>0.299***</td>
<td>0.284***</td>
</tr>
</tbody>
</table>

R\(^2\) Within | 0.372 | 0.376 | 0.423 | 0.224 | 0.373 | 0.376 |
R\(^2\) Between | 0.035 | 0.036 | 0.001 | 0.005 | 0.044 | 0.060 |
R\(^2\) Overall | 0.031 | 0.031 | 0.066 | 0.005 | 0.029 | 0.024 |
Number of observations | 7186 | 7186 | 4231 | 2955 | 7186 | 7186 |

Notes:

Heteroskedasticity-robust standard errors reported in parentheses.

\(\ast\), \(\ast\ast\), \(\ast\ast\ast\) relate to coefficients respectively significant at the 90, 95, 99% confidence level.

\(^\$\) In order to control for both source and recipient country effects, a pair-wise index was created that assigns a unique identifier to each country’s FDI with every other country. In the three country case, this measure will assign six different identifiers: 1) X/Y; 2) Y/X; 3) X/Z; 4) Z/X; 5) Y/Z; and 6) Z/Y.
<table>
<thead>
<tr>
<th>Table 5: Robustness Check with Outward FDI</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Estimation: Fixed Effects OLS with Time Dummies and Time Trend, Period 1982-2002</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Log Outward FDI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5a</td>
</tr>
<tr>
<td>Sample</td>
<td>All Data</td>
</tr>
<tr>
<td>Exchange Rate Volatility:</td>
<td></td>
</tr>
<tr>
<td>0 &lt; Distance &lt; 1000</td>
<td>0.005***</td>
</tr>
<tr>
<td>1000 &lt; Distance &lt; 2000</td>
<td></td>
</tr>
<tr>
<td>2000 &lt; Distance &lt; 6000</td>
<td></td>
</tr>
<tr>
<td>6000 &lt; Distance &lt; 9000</td>
<td></td>
</tr>
<tr>
<td>9000 &lt; Distance</td>
<td>0.043***</td>
</tr>
<tr>
<td>Interacted with Distance (1000 km)</td>
<td></td>
</tr>
<tr>
<td>(Exchange Rate Volatility)^2</td>
<td></td>
</tr>
<tr>
<td>Log Exchange Rate Level</td>
<td>-0.032***</td>
</tr>
<tr>
<td>GDP Volatility Source</td>
<td>-0.041***</td>
</tr>
<tr>
<td>GDP Volatility Host</td>
<td>0.050***</td>
</tr>
<tr>
<td>Openness Source</td>
<td>-0.001</td>
</tr>
<tr>
<td>Openness Host</td>
<td>0.004***</td>
</tr>
<tr>
<td>Both in EMU</td>
<td>0.043*</td>
</tr>
<tr>
<td>Both in FTA</td>
<td>0.117***</td>
</tr>
<tr>
<td>R^2 Within</td>
<td>0.556</td>
</tr>
<tr>
<td>R^2 Between</td>
<td>0.113</td>
</tr>
<tr>
<td>R^2 Overall</td>
<td>0.000</td>
</tr>
<tr>
<td>Number of observations</td>
<td>6087</td>
</tr>
</tbody>
</table>

**Notes:**
- Heteroskedasticity-robust standard errors reported in parentheses.
- *, **, *** relate to coefficients respectively significant at the 90, 95, 99% confidence level.
- In order to control for both source and recipient country effects, a pair-wise index was created that assigns a unique identifier to each country’s FDI with every other country. In the three country case, this measure will assign six different identifiers: 1) X/Y; 2) Y/X; 3) X/Z; 4) Z/X; 5) Y/Z; and 6) Z/Y.
Table 6: Robustness Check with Driscoll and Kraay’s (1998) Covariance Matrix


<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Log FDI Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>6a</td>
</tr>
<tr>
<td><strong>Sample</strong></td>
<td>All Data</td>
</tr>
</tbody>
</table>

| Exchange Rate Volatility: | 0.014 \(0.031\) | -0.208 \(*0.064\) | -0.103 \(*0.059\) | 0.054 \(*0.028\) | -0.040 \(0.037\) |

\(0 < \text{Distance} < 1000\) | -0.241 \(*0.048\) |

\(1000 < \text{Distance} < 2000\) | -0.146 \(*0.043\) |

\(2000 < \text{Distance} < 6000\) | 0.075 \(*0.038\) |

\(6000 < \text{Distance} < 9000\) | 0.011 \(0.036\) |

\(9000 < \text{Distance}\) | 0.048 \(*0.042\) |

Interacted with Distance (1000 km) | 0.009 \(*0.004\) |

\((\text{Exchange Rate Volatility})^2\) | 0.021 \(*0.005\) |

Log Exchange Rate Level | -0.177 \(*0.024\) | -0.156 \(*0.023\) | -0.143 \(*0.084\) | -0.142 \(*0.032\) | -0.177 \(*0.024\) | -0.170 \(*0.023\) |

\(\text{GDP Volatility}_{\text{Source}}\) | -0.131 \(*0.039\) | -0.116 \(*0.049\) | -0.160 \(*0.088\) | -0.084 \(*0.063\) | -0.129 \(*0.041\) | -0.115 \(*0.045\) |

\(\text{GDP Volatility}_{\text{Host}}\) | 0.091 \(*0.031\) | 0.089 \(*0.030\) | 0.171 \(*0.052\) | 0.005 \(*0.031\) | 0.088 \(*0.031\) | 0.088 \(*0.029\) |

Openness_{\text{Source}} | 0.011 \(*0.004\) | 0.011 \(*0.004\) | 0.011 \(*0.006\) | 0.007 \(*0.003\) | 0.010 \(*0.004\) | 0.009 \(*0.004\) |

Openness_{\text{Host}} | -0.005 \(0.005\) | -0.003 \(0.004\) | -0.010 \(*0.006\) | -0.002 \(0.005\) | -0.005 \(0.005\) | -0.005 \(0.005\) |

Both in EMU | 0.270 \(*0.139\) | -0.010 \(0.122\) | -0.085 \(0.101\) | dropped \(0.144\) | 0.198 \(0.109\) | 0.051 \(0.109\) |

Both in FTA | 0.320 \(*0.148\) | 0.265 \(*0.122\) | 0.197 \(*0.111\) | 0.146 \(0.143\) | 0.299 \(*0.148\) | 0.284 \(*0.137\) |

\(R^2\) Within | 0.372 | 0.376 | 0.423 | 0.224 | 0.373 | 0.376 |

\(R^2\) Between | 0.035 | 0.036 | 0.001 | 0.005 | 0.044 | 0.060 |

\(R^2\) Overall | 0.031 | 0.031 | 0.066 | 0.005 | 0.029 | 0.024 |

Number of observations | 7186 | 7186 | 4231 | 2955 | 7186 | 7186 |

Notes:

Standard errors reported in parentheses are robust to heteroskedasticity, but also to cross-sectional and temporal dependence.

\* \**, \*** \* relate to coefficients respectively significant at the 90, 95, 99% confidence level.

\^\ In order to control for both source and recipient country effects, a pair-wise index was created that assigns a unique identifier to each country’s FDI with every other country. In the three country case, this measure will assign six different identifiers: 1) X/Y; 2) Y/X; 3) X/Z; 4) Z/X; 5) Y/Z; and 6) Z/Y.
Table 7: Robustness Check with Removed Control Variables


<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Model 7a</th>
<th>Model 7b</th>
<th>Model 7c</th>
<th>Model 7d</th>
<th>Model 7e</th>
<th>Model 7f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange Rate Volatility</td>
<td>-0.243***</td>
<td>-0.227***</td>
<td>-0.225***</td>
<td>-0.214***</td>
<td>-0.186***</td>
<td>-0.213***</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.034)</td>
<td>(0.034)</td>
<td>(0.034)</td>
<td>(0.037)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>(Exchange Rate Volatility)^2</td>
<td>0.024***</td>
<td>0.023***</td>
<td>0.023***</td>
<td>0.022***</td>
<td>0.020***</td>
<td>0.023***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Log Exchange Rate Level</td>
<td>-0.178***</td>
<td>-0.175***</td>
<td>-0.183***</td>
<td>-0.158***</td>
<td>-0.158***</td>
<td>-0.063***</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.023)</td>
<td>(0.023)</td>
<td>(0.025)</td>
<td>(0.025)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Ln GDP Source</td>
<td>1.595***</td>
<td>1.465***</td>
<td>1.282***</td>
<td>1.287***</td>
<td>2.169***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.324)</td>
<td>(0.331)</td>
<td>(0.331)</td>
<td>(0.331)</td>
<td>(0.105)</td>
<td></td>
</tr>
<tr>
<td>Ln GDP Host</td>
<td>0.389</td>
<td>0.799**</td>
<td>0.936***</td>
<td>0.914***</td>
<td>1.561***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.302)</td>
<td>(0.323)</td>
<td>(0.323)</td>
<td>(0.320)</td>
<td>(0.106)</td>
<td></td>
</tr>
<tr>
<td>GDP Volatility Source</td>
<td>-0.067**</td>
<td>-0.085***</td>
<td>-0.095***</td>
<td>-0.108***</td>
<td>0.014**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.028)</td>
<td>(0.029)</td>
<td>(0.027)</td>
<td>(0.027)</td>
<td></td>
</tr>
<tr>
<td>GDP Volatility Host</td>
<td>0.114***</td>
<td>0.127***</td>
<td>0.120***</td>
<td>0.125***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.029)</td>
<td>(0.029)</td>
<td>(0.029)</td>
<td>(0.027)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Openness Source</td>
<td>0.009***</td>
<td>0.009***</td>
<td>0.004**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Openness Host</td>
<td>-0.005**</td>
<td>-0.005**</td>
<td>-0.004***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance (1000 km)</td>
<td>dropped</td>
<td>0.008***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Language</td>
<td>dropped</td>
<td>1.530**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.189)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Border</td>
<td>dropped</td>
<td>0.750***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.249)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both in EMU</td>
<td>0.041</td>
<td>0.051</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.117)</td>
<td>(0.115)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both in FTA</td>
<td>0.258***</td>
<td>0.309***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.073)</td>
<td>(0.068)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R² Within | 0.370 | 0.372 | 0.375 | 0.377 | 0.378 | 0.374
R² Between | 0.025 | 0.130 | 0.156 | 0.137 | 0.149 | 0.456
R² Overall | 0.041 | 0.211 | 0.236 | 0.244 | 0.251 | 0.435
Number of observations | 7186 | 7186 | 7186 | 7186 | 7186 | 7186

Notes:
Heteroskedasticity-robust standard errors reported in parentheses.
*, **, *** relate to coefficients respectively significant at the 90, 95, 99% confidence level.
A In order to control for both source and recipient country effects, a pair-wise index was created that assigns a unique identifier to each country’s FDI with every other country. In the three country case, this measure will assign six different identifiers: 1) X/Y; 2) Y/X; 3) X/Z; 4) Z/X; 5) Y/Z; and 6) Z/Y.
Table 8: Robustness Check with Dynamic GMM and OLS


<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Log FDI Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>8a</td>
</tr>
<tr>
<td><strong>Lag structure</strong></td>
<td>t-2</td>
</tr>
<tr>
<td><strong>Sample</strong></td>
<td>All data</td>
</tr>
</tbody>
</table>

### Lagged Dependent Variable
- 8a: 0.134*** (0.033) 0.115** (0.054) 0.190*** (0.042) 0.120*** (0.015) 0.171*** (0.026) 0.171*** (0.020)
- 8b: -0.080 (0.142) 0.135** (0.05) -0.240** (0.11) -0.147*** (0.039) 0.058*** (0.022) -0.069 (0.055)
- 8c: 0.015 (0.010) 0.016*** (0.003)
- 8d: -0.042 (0.040) -0.005 (0.095) 0.200 (0.24) -0.131*** (0.027) -0.128*** (0.033) -0.165*** (0.076)
- 8e: -0.787*** (0.273) -0.802*** (0.289) -1.403*** (0.359) -0.086*** (0.031) -0.079* (0.045) -0.138*** (0.046)
- 8f: -0.509*** (0.153) -0.453** (0.212) -0.318*** (0.284) 0.055** (0.028) 0.044 (0.043) 0.137*** (0.042)

### Exchange Rate Volatility
- 8a: -0.080 (0.142) 0.135** (0.05) -0.240** (0.11) -0.147*** (0.039) 0.058*** (0.022) -0.069 (0.055)
- 8b: 0.015 (0.010) 0.016*** (0.003)

### Log Exchange Rate Level
- 8a: -0.080 (0.142) 0.135** (0.05) -0.240** (0.11) -0.147*** (0.039) 0.058*** (0.022) -0.069 (0.055)
- 8b: 0.015 (0.010) 0.016*** (0.003)

### GDP Volatility Source
- 8a: -0.080 (0.142) 0.135** (0.05) -0.240** (0.11) -0.147*** (0.039) 0.058*** (0.022) -0.069 (0.055)
- 8b: 0.015 (0.010) 0.016*** (0.003)

### GDP Volatility Host
- 8a: -0.080 (0.142) 0.135** (0.05) -0.240** (0.11) -0.147*** (0.039) 0.058*** (0.022) -0.069 (0.055)
- 8b: 0.015 (0.010) 0.016*** (0.003)

### Openness Source
- 8a: -0.080 (0.142) 0.135** (0.05) -0.240** (0.11) -0.147*** (0.039) 0.058*** (0.022) -0.069 (0.055)
- 8b: 0.015 (0.010) 0.016*** (0.003)

### Openness Host
- 8a: -0.080 (0.142) 0.135** (0.05) -0.240** (0.11) -0.147*** (0.039) 0.058*** (0.022) -0.069 (0.055)
- 8b: 0.015 (0.010) 0.016*** (0.003)

### Distance (1000 km)
- 8a: -0.080 (0.142) 0.135** (0.05) -0.240** (0.11) -0.147*** (0.039) 0.058*** (0.022) -0.069 (0.055)
- 8b: 0.015 (0.010) 0.016*** (0.003)

### Common Language
- 8a: 0.015 (0.010) 0.016*** (0.003)

### Common Border
- 8a: 0.015 (0.010) 0.016*** (0.003)

### Both in EMU
- 8a: 0.015 (0.010) 0.016*** (0.003)

### Both in FTA
- 8a: 0.015 (0.010) 0.016*** (0.003)

### Specification tests (p-values)
- (a) Hansen Test
  - 8a: 0.001 0.183 0.099 0.099 Within: 0.39 0.39 0.39 Within: 0.39 0.39 0.39 Within: 0.39 0.39 0.39
  - 8b: 0.000 0.000 0.000 Between: 0.13 Between: 0.13 Between: 0.13
  - 8c: 0.330 0.433 0.940 Overall: 0.24 Overall: 0.24 Overall: 0.24
- (b) First-Order Correlation
  - 8a: 0.001 0.183 0.099 0.099 Within: 0.39 0.39 0.39 Within: 0.39 0.39 0.39 Within: 0.39 0.39 0.39
  - 8b: 0.000 0.000 0.000 Between: 0.13 Between: 0.13 Between: 0.13
  - 8c: 0.330 0.433 0.940 Overall: 0.24 Overall: 0.24 Overall: 0.24

### Number of instruments
- 8a: 104 84 84
- 8b: 104 84 84
- 8c: 104 84 84
- 8d: 104 84 84
- 8e: 104 84 84
- 8f: 104 84 84

### Number of observations
- 8a: 6222 2536 3686 6222 2536 3686
- 8b: 6222 2536 3686 6222 2536 3686
- 8c: 6222 2536 3686 6222 2536 3686
- 8d: 6222 2536 3686 6222 2536 3686
- 8e: 6222 2536 3686 6222 2536 3686
- 8f: 6222 2536 3686 6222 2536 3686

### Estimation structure
- 8a: 2-step 2-step 2-step FE FE FE
- 8b: 2-step 2-step 2-step FE FE FE
- 8c: 2-step 2-step 2-step FE FE FE
- 8d: 2-step 2-step 2-step FE FE FE
- 8e: 2-step 2-step 2-step FE FE FE
- 8f: 2-step 2-step 2-step FE FE FE

### Yearly Time Effects
- 8a: Yes Yes Yes Yes Yes Yes
- 8b: Yes Yes Yes Yes Yes Yes
- 8c: Yes Yes Yes Yes Yes Yes
- 8d: Yes Yes Yes Yes Yes Yes
- 8e: Yes Yes Yes Yes Yes Yes
- 8f: Yes Yes Yes Yes Yes Yes

Notes:
- Heteroskedasticity-robust standard errors reported in parentheses.
- *, **, *** relate to coefficients respectively significant at the 90, 95, 99% confidence level.