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

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Abstract

We consider the problem of a risk-neutral firm contemplating FDI to delocalize production under a stochastic exchange rate, and show the existence of a U-shaped relation between FDI and exchange rate volatility: the effect of exchange rate uncertainty on investment abroad appears to be negative for low values of uncertainty, whereas it is positive for high levels. This stands in stark contrast to the existing results in the real option literature. The difference in results stems from the fact that we consider the expected investment level using all possible net present values of the delocalization projects. Existing literature only focus on the option value or the probability of investing for a single project that is initially unprofitable.

When the delocalization yields a positive pay-off, the probability of investing is reduced with more volatility because the firm targets a higher pay-off. The firm is willing to wait longer for a more favorable exchange rate, which lowers expected investment. By contrast, if investing abroad initially yields a negative pay-off, the firm will not delocalize. However, higher volatility increases the chance that the investment becomes eventually profitable and thus enhances expected investment. When aggregating all possible cases, the relation between exchange rate volatility and expected FDI becomes U-shaped. Using a large dataset of 27 OECD countries over the period 1982-2002, we find strong empirical support for our prediction.

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 of the UNCTAD (2005) shows that countries are responding to increased global competition for foreign direct investment (FDI) by becoming clearly more proactive in their investment promotion efforts. In addition, 80% of the 325 largest multinationals (covering 92% of total FDI flows) view exchange rate volatility as a major threat to FDI flows. By linking these two facts, it is tempting to conclude on a policy implication towards a stabilization of the exchange rate. However, we need to investigate whether exchange rate fluctuations really play a negative role in influencing the attractiveness of a region to FDI. This question precisely constitutes the research agenda of the paper. Using a panel of OECD countries over the period 1982-2002, we show that the relation between exchange rate volatility and FDI is negative when the volatility is low, whereas it is positive when the volatility is high. At the theoretical level, we provide evidence and a rationale for this U-shaped relation and thus offer new insights on the investment-uncertainty relation.

Using a contingent claim approach, we analyze the value of a risk-neutral 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, we estimate the endogenous trigger level that maximizes the firm’s value. At the time the exchange rate hits this barrier, the option to delocalize production is optimally exercised and the firm invests abroad. We then consider the likelihood to exercise the option in a period of time and derive the expected foreign direct investment. More precisely, the expectation to invest is computed with the probability of reaching the endogenous exchange rate trigger value for an infinite range of possible investments. Because FDI involves sunk costs in the foreign country, the best response of a multinational could be to wait for a more favorable exchange rate before investing abroad. Therefore, irreversibility of investment expenditures and the option of waiting for new information render the investment decisions of the firm sensitive to exchange rate uncertainty.

We find that the influence of exchange rate volatility on FDI is non-monotonic because there are two opposing effects resulting from an increase in volatility on the probability of investing within a time period. Depending on the moneyness of the option project, representing the additional firm value attributed to a potential delocalization of production, we show that the effect is of either sign. For in-the-money option projects (yielding a positive profit if the firm invests instantaneously), the probability to invest is unity under certainty. The pay-off cannot increase in the future since there are no fluctuations in the exchange rate and we prefer a dollar today to a dollar tomorrow. However, the probability to invest within the period decreases with more uncertainty. With shocks to the exchange rate being larger, there are more chances to observe an exchange rate level such that investing is not profitable any more. Note that, since the exchange rate optimal barrier is endogenous and depends on the level of volatility, we may not invest instantaneously if it initially becomes optimal to wait for a more favorable exchange rate. Hence, with more uncertainty, the influence on realized investment turns out to be negative. In contrast, for out-of-the-money options (whose projects offer a zero profit in case of investing), the probability to invest is null under certainty since there is no incentives to have a zero pay-off. However, the probability to invest is
raised with volatility. With more fluctuations, the firm has more chances to obtain a positive pay-off in the future. Then, the probability to invest increases, since the volatility creates more flexibility, and the effect on investment is positive. As the resulting effect depends on the moneyness of the option projects, the aggregation of an infinite range of different options projects turns out to present a U-shaped relation between volatility and investment.

One puzzle that our results pose is why this U-shaped relation has not been documented in earlier studies. Several explanations can be put forward. First, conventional wisdom has it that the more volatile the currency is expected to be for a country, the less likely are foreign firms to invest in this economy. Through foreign direct investment, a multinational has operations that generate cash flows in foreign currencies and hence fluctuations in the exchange rate could have important effects on the profits of the firm. This uncertainty would depress foreign direct investment spending if the firm is risk-averse, as in Aizenman (1992) and Goldberg and Kolstad (1995). Therefore, if the only source of uncertainty lies in the exchange rate, supposing a risk-averse behavior engenders a negative relation. This conclusion cannot fit the positive relation observed in the data because the possibility to invest at any time in the future is ignored. Moreover, if all foreign exchange risk has a unique price\(^1\), the firm cannot earn any risk-sharing benefits from financial hedging. When evaluating future cash-flows, exchange rate volatility thus becomes irrelevant in the investment decision of the firm. Therefore, it is more appropriate to analyze a risk-neutral firm in a real options framework.

Second, we are also first to report this pattern\(^2\) in the real option literature. The difference in results stems form the fact that we derive a model in an expected investment perspective, thus avoiding previous shortcomings. A common deficiency of real options models is to assume that exchange rate volatility is necessarily detrimental, without appreciating the increased flexibility offered by the volatility in promoting international financial flows: 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), is to suggest a negative relation between exchange rate volatility and FDI flows (for instance, Campa (1993) or Botteron et al. (2003)). Although greater volatility is likely to enhance the flexibility of the firm’s investment decisions, the current literature is unable to propose a positive relation between exchange rate volatility and FDI. Existing studies have difficulties in providing a convincing rationale regarding the investment-uncertainty relation because their methodology rest on quite restrictive assumptions that we propose to relax: first, they either focus on the uncertainty effect on the option value to invest or on the trigger level of exchange rate, rather than the investment itself. Second, they limit their conclusions to the current period, offering only part of the overall picture. Indeed, waiting is more worthwhile precisely because it is more valuable to invest in the future. We suggest that, in a real option framework, we should not limit the analysis to the investment decision of the current

\(^1\)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. Therefore, shareholders are able to perfectly replicate the firm’s positions in the foreign exchange market and are thus indifferent to exchange rate fluctuations when valuing the firm.

\(^2\)Lund (2005) and Sarkar (2000, 2003) has also documented the 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.
period and provide evidence that exchange rate volatility can actually foster future investment through greater flexibility. The theoretical contribution of this paper is to show that, in order to gauge the overall effect of uncertainty on investment, it is more appropriate to estimate the expected investment within a time period rather than merely looking at the option value. Hence, our study contributes to the literature in its method of theoretically quantifying the uncertainty effect on foreign direct investment.

Yet, given the heterogeneity of the existing theoretical approaches (and their related results), one may appeal to empirical analysis to find out which prediction the data would support. Unfortunately, the empirical literature has not found a consistent relation\(^3\), which calls for a fresh look at the empirical side. 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, 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 heterogeneity in both the econometric techniques and the (small) sets of countries may provide a potential explanation for many studies’ difficulties in finding a consistent link. In this paper, we try to offer a comprehensive empirical analysis and provide results that are consistent with the theoretical findings.

Specifically, the nature of our rich panel data set, covering 27 OECD countries (or 702 observations per year) over the 1982-2002 period, permits scrutiny of the statistical features of the relation between exchange rate volatility and FDI. Using a variety of estimations, the results exhibit an influence of exchange rate volatility on outward FDI in industrialized countries that is in line with the disparity of the theoretical model. A close inspection of the data supports the non-linear U-shaped relation between exchange rate volatility and FDI: the effect is depressive for low levels of volatility, whereas it is stimulative for higher levels. By highlighting this non-linearity, our analysis reveals that the effect appears to be more complicated than the prevalent approach offered by the empirical literature. If countries presenting on average large exchange rate volatility dominate a sample, the effect will turn out to be positive and the opposite holds for a sample mainly constituted of countries with a low volatility. Hence, the paper can explain the disagreements on the sign of the estimate and the behavior of the effect corroborates the theoretical predictions.

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

\(^3\)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 and confirmed a positive relationship. The opposite finding is however obtained by Chakrabarti and Scholnick (2002) in which they consider FDI flows from the U.S. to 20 OECD countries.
2 A theoretical framework

Building on the Pindyck (1991) foundations, Campa (1993) derives the effect of exchange rate uncertainty on irreversible foreign direct investment using a real option approach. He concludes that "the higher the volatility of the exchange rate, the higher the level the exchange rate has to be [to reach the barrier] 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)." Similarly, it is 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).

As this paper shows, this conclusion is not necessarily correct. Such analysis only focus on the influence that uncertainty has on the distance to the barrier level, at which the option is exercised, ignoring the possible positive effect of uncertainty on the probability of reaching this barrier\(^4\). The contribution of the model is to go one step further and to directly derive the expected investment with respect to the volatility of the exchange rate, considering the probability of investment within a time horizon. Using discretized numerical examples, we first show that focusing on the expected investment level is more insightful than only on the option value or on the probability of hitting the barrier. Second the effect of exchange rate uncertainty on the expected investment level presents a U-shape. The key driver of this result is the varying response of the firm, depending on the net present value of the delocalization project, to the enhanced flexibility offered by the stochastic exchange rate.

2.1 The model

We consider a multinational, whose good produced domestically is sold in a competitive market at home and abroad. As it is taken for granted now, exporting is the preferred first strategy for the firm to internationalize (Gilroy and Lukas, 2006). The firm is thus already selling its good abroad in order to capture part of a foreign market. This model investigates then the choice that the firm has between continuing to export the good or investing in a plant abroad to produce the good locally, while abandoning its current export serving strategy.

We 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 then to maximize firm value and act over an infinite time horizon. In particular, firm value can be written as the sum of 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 delocalizing the production aimed at serving the foreign market.

On one hand, the part of the value of the firm coming from domestic sales only is obtained by

simply discounting the riskless perpetual domestic cash-flows

\[ V_d = (p - c) \int_0^\infty e^{-rt} dt = \frac{p - c}{r} \]  \hspace{1cm} (1)

where \( p \) and \( c \) are respectively the constant 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 the firm receives from selling in the foreign market are subject to exchange rate fluctuations. The exchange rate \( s \) is the unique source of uncertainty in our setting and can (along the delocalization option) be spanned by existing tradable assets. We 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

\[ ds_t = (r - \delta)s_t dt + \sigma s_t dZ_t, \quad s_0 > 0 \]  \hspace{1cm} (2)

where \((Z_t)_{0 \leq t < \infty}\) is a standard Brownian motion defined on the filtered probability space \((\Omega, \mathcal{F}, Q)\). 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 \((Z_t)_{0 \leq t < \infty}\)). Although we derive the model in the general case (with \((r - \delta) \geq 0\)), we shall impose the drift to be null. Indeed, as opposed to modeling stochastic cash-flows, an exchange rate can almost surely not reach the value zero. It is therefore not appropriate to assume a non-zero drift in the exchange rate dynamics as proposed by the literature (for instance, Botteron et al (2003) for a positive drift).\(^5\)

Although the Geometric Brownian Motion process is the most commonly used process \(^6\), it could be deemed to be inappropriate. A mean reversion in the process may be more suitable under equilibrium conditions, particularly since currency exchange rates appear to be mean-reverting (although the literature has difficulty in providing evidence). We believe that our results are not altered when ignoring the mean reversion though, as argued by Hassett and Metcalf (1995). These authors found that there are two opposing effects \(^7\) of mean reversion that tend to offset one another. They conclude that the expected cumulative investment after a period of time with heterogeneous firms is the same for both processes. Hence, in the present framework, the type of process does not seem to be an issue.

With the spanning assumption, we can determine the optimal investment rule that maximizes firm value, and the investment problem reduces then to one of contingent claim valuation. If agents

\(^5\)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.

\(^6\)The main advantage is that it leads to tractable solutions and closed-form expressions that can be easily analyzed.

\(^7\)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 we do here.
are risk neutral, consider \( V_d \) the value of home production sold domestically, \( V_e(s_0) \) to be the value of the firm ruling out any future delocalization of the production, and \( V_i(s_0) \) the value of the firm contemplating abandoning the export strategy at time \( T(s^*) \) to invest abroad the irreversible amount \( I \) such that

\[
V_e(s_0) = V_d + E_Q^{s_0} \left[ \int_0^\infty e^{-rt} (p_f s_t - c) dt \right]
\]

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

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 \( E_Q^{s_0} \) 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 per unit of time of the good related to the foreign market, which are denoted in the foreign currency.

Solving Equations (3) and (4) and taking the difference yields (see appendix)

\[
\Delta V(s_0) = V_i(s_0) - V_e(s_0) = \left( \frac{c}{r} - \frac{c_f}{\delta} s^* - Is^* \right)(s^*_0)^{-\beta}
\]

with

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

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

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

The term \( \Delta V(s_0) \) represents the option value of contemplating future foreign direct investment by taking advantage of the fluctuations in the relative exchange rate. A good property of this setting is the non-dependency on the revenues \( p_f \), which makes our results hold for any correlation between the exchange rate and domestic profits. The decision to delocalize the production is made when 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 the 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). We should then expect a positive relation between the option value \( \Delta V(s_0) \) and the exchange rate volatility \( \sigma \).

\footnote{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.}
2.1.1 The option value

In order to investigate the choice of the firm between investing abroad today and waiting for a more favorable exchange rate, the literature analyzes the value of such an option. The option of waiting for new information on the exchange rate is valued by (Equation 5 and 8)

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

\[
= \frac{1}{1 - \beta} \left(\frac{c}{s_0r}\frac{c}{\delta} + I\right)\left(\frac{c}{s_0r}\frac{c}{\delta} + I\beta - 1\right)^{-\beta}
\]

As Dixit and Pindyck (1994) point out, uncertainty increases the value of the option, thus lowering the incentives of investing today. We confirm this result in our setting. Indeed, the derivation of the option value \(\Delta V(s_0)\) with respect to the volatility of the exchange rate \(\sigma^2\) leads to

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

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

with \(\frac{\partial s^*}{\partial \sigma^2} < 0\) and \(\frac{\partial \beta}{\partial \sigma^2} > 0\)

The first positive term incorporates the effect of exchange rate uncertainty on the endogenous threshold level \(s^*\): the higher is the volatility, the lower is the barrier \(s^* < s_0\), thus increasing the incentive of waiting. Nevertheless, the overall effect is not as clear because the uncertainty also influences the stochastic discount factor \(\left(\frac{s^*}{s_0}\right)^{-\beta}\) by lowering the barrier \(s^*\) (Figure 1, lower panel) and by increasing \(\beta\). Although the second term is negative, while the third term is positive, it turns out that more uncertainty does increase the option value of waiting (Figure 1, upper panel). Hence, using contingent claim valuation of the real option investment problem, we show that increased uncertainty may possibly be detrimental for investment as proposed by the literature. Nevertheless, we believe that one cannot draw any conclusions on the investment level merely by looking at the effect on the option value, since only investment at time zero would be considered.

2.1.2 Probability of observing an investment

Consistent with the real option literature, we have shown that a higher level of uncertainty increases the option value to wait before investing, thus predicting a linear negative effect on investment. However, higher volatility also induces larger shocks, thus influencing the likelihood to hit the barrier \(s^*\) in the future. Therefore, in order to gauge the overall effect of uncertainty on investment, we rather need to investigate the probability of investment within a specified time period.

Let’s first determine the probability that a certain investment \(I\) takes place, which corresponds to estimating the likelihood that the critical barrier \(s^*\) will be reached within some time period \(T^9\).

\(^9\)Although we restrict our interest in the time window \([0, T]\), the firm still contemplates investing at any time.
When current time is zero, this is given by (see appendix for the derivation)

\[ P(\sup_{0 \leq t \leq T} s_t \leq s^* | s_0 > s^*) = \phi\left(\frac{\ln\left(\frac{s^*}{s_0}\right) - \alpha T}{\sigma \sqrt{T}}\right) + \left(\frac{s^*}{s_0}\right)^{2}\phi\left(\frac{\ln\left(\frac{s^*}{s_0}\right) + \alpha T}{\sigma \sqrt{T}}\right) \] (14)

\[ P(\sup_{0 \leq t \leq T} s_t \leq s^* | s_0 \leq s^*) = 1 \] (15)

where \( \phi(.) \) is the cumulative density of a standard normal distribution. Using a similar methodology, Sarkar (2000) points out a non-linear effect suggesting an inverted U-shaped relation between uncertainty and investment, depending on the value of the volatility considered. However, he assumes a single value of investment and limits himself to a real option being out-of-the-money. In our setting, the probability of reaching the barrier rises monotonically with the volatility for (high) levels of investment such that the option is out-of-the-money (Figure 2, right panels), whereas an adverse effect is observed for (low) investment levels inducing the option to be in-the-money (Figure 2, left panels). Note that this effect is insensitive to the length of the period \( T \) considered.

### 2.1.3 Expected foreign direct investment

The sign of the relation, using the probability of exercising the option, is highly dependent on the value of the investment, and particularly on the moneyness of the option. We hence believe that it is more relevant to focus on the expected investment level to capture the behavior of aggregate foreign direct investment. As Lund (2005) points out as a recommendation for further research, "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". Moreover, focusing on the probability only is imprecise because we are likely to observe a high probability of occurrence for low levels of investment and a low probability for rather large investment levels. Therefore, it is difficult to speculate on the overall final effect of the realized level of investment by merely looking at the probability of investing.

To overcome this issue, assume that there exist \( I^* \) heterogeneous firms in the economy contemplating today a potential delocalization strategy at any time in the future. Each firm observes its exogenous (unique firm-specific) cost of the project, drawn from a uniform distribution over the interval \([0, I^*]\). 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. Firms facing different investment levels can be due to firm heterogeneity in the productivity, the market size, or in the type of industry the firm operates. The exogeneity of \( I^* \) is standard in the literature (see for instance Boyle and Guthrie, 2003).

\[ E(I) = \int_{0}^{I^*} IP(\sup_{0 \leq t \leq T} s_t \leq s^* | s_0 \leq s^*)dI = \int_{0}^{I^*} \left[ \phi\left(\frac{\ln\left(\frac{s^*}{s_0}\right) - \alpha T}{\sigma \sqrt{T}}\right) + \left(\frac{s^*}{s_0}\right)^{2}\phi\left(\frac{\ln\left(\frac{s^*}{s_0}\right) + \alpha T}{\sigma \sqrt{T}}\right) \right] dI \] (16)

\( t \in [0, \infty). \)
From a macroeconomic perspective, this approach allows us to much more precisely investigate the relation between exchange rate uncertainty and aggregate investment. Although standard analysis (following Dixit and Pindyck, 1994) claim the existence of a negative investment-uncertainty relation, and the more recent literature based on the probability of exercising an out-of-the-money option (following Sarkar, 2000, 2003) proposes an inverted U-shaped relation, we provide evidence of a new and more general pattern. We show that, as Figure 3 reveals, the expected foreign direct investment level is non-linearly affected by the exchange rate uncertainty: the relation follows a clear U-shape pattern, where the influence is negative for low levels of volatility and positive for higher levels, as already suggested when analyzing the probability of investment. The non-linearity holds for various levels of investment $I^*$ and time horizons $T$. It is interesting to notice however that the switching point depends on the time window we look at, as the longer the horizon is, the lower is the required uncertainty level to observe a sign change. Strikingly, the U-shape pattern is still observed for a wide range of home cost mark-ups reflecting the difference between the costs of exporting and producing locally (assumed to be between 10% to 40% more expensive to export, Figure 3, lower panel). The obtained U-shaped relation seems thus to be very stable and not specific to certain parameters values.

2.1.4 An explanation for the U-shape

Not only is the pattern appealing, but there is a rationale for the non-linearity. The analysis of the probability to exercise the option with an endogenous barrier highlights two opposing effects resulting from an increase in uncertainty: first, by maximizing the option value, the firm is induced to set a more distant optimal barrier $s^*$ with greater volatility through the effect that volatility has on the stochastic discount factor $(\frac{s^*}{s_0})^{-\beta}$. The result for the firm is to target higher profits since $(\xi - \frac{\sigma^*}{\sigma} - Is^*)$ is enhanced when $s^*$ decreases. On the other hand, more volatility also raises the size of the shocks on $s_t$ that will permit to hit this precise barrier $s^*$.

Regarding in-the-money option projects (projects for which the initial net present value is positive), the probability to invest is unity under certainty and can only decrease with uncertainty. With greater volatility, the barrier significantly decreases (the option is likely to become out-of-the-money), thus negatively affecting the probability of hitting the exchange rate trigger $s^*$. On the other hand, for out-of-the-money options, the probability to invest is null under certainty (since the net present value of the project is negative) but rises with volatility because of the presence of shocks being of larger sizes. The probability to reach the barrier then increases despite the fact that $s^*$ is also lowered. The reason is that, the larger is the investment level (and thus the more out-of-the-money is the option), the less dramatic 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

$$\frac{\partial s^*}{\partial \sigma} = \frac{c}{r[\frac{1}{\sigma} + I]} \frac{\partial(\frac{\beta}{\sigma-1})}{\partial \sigma} < 0 \ & \ \text{and} \ & \ \frac{\partial s^*}{\partial I} > 0 \ \ \ \ \ \ \ (17)$$

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

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For high \( I \) levels, the probability of investing thus increases with uncertainty, through additional opportunities to become in-the-money in the future.

In both cases, more volatility affects the realized investment level through enhanced flexibility offered by the fluctuations of the exchange rate. These movements offer the opportunity to either target higher profits in the future or to potentially benefit from the profits of an investment project that would not have been undertaken otherwise. The volatility of the exchange rate is then value-enhancing for the firm, although the realized investment level could be fostered or depressed depending on the moneyness of the option project. When aggregating the entire range of possible \( I \), to obtain the expected investment level, the resulted pattern then presents a U-shape.

We thus provide evidence that considering the option value, presenting a monotonic relation with volatility, is not appropriate. Neither is the probability of investing since the sign of the uncertainty effect depends on the assumed level of investment. The model therefore gives additional insights, with an application in exchange rate volatility and FDI, in our understanding of this complex relation. The following section empirically verifies this finding for industrialized countries over more than 20 years of data.

### 3 Empirical strategy

In this section, we investigate the empirical relation between exchange rate volatility and FDI. More specifically, we test the U-shape pattern suggested by the theory. As in the model, we consider aggregated FDI and not firm level data to capture the exchange rate volatility effect on total FDI. Such data is likely to provide better insights regarding policy implications. Moreover, the exchange rate behavior is not industry or firm dependent. It is thus unlikely that firm level data would provide additional information. The use of aggregated FDI also allows us to consider a broad set of different countries, thus avoiding a focus on a specific country involving a particular currency. Therefore, our analysis considers the main 27 OECD countries over the 1982-2002 period. Building on recent augmented gravity-type specifications used in international economics and finance (see for instance Portes and Rey (2005) or di Giovanni (2005)), the model that we estimate is of the following form:

\[
fdi_{ij,t} = \gamma_1 + \gamma_2 \sigma_{eij,t} + \beta' X + \omega_{ij} + \tau_t + \gamma_3 t + \nu_{ij,t}
\]  

(18)

where \( fdi_{ij,t} \) is the log value of the outward FDI from country \( i \) to \( j \) at time \( t \) and \( \sigma_{eij,t} \) is a measure of expected bilateral exchange rate volatility at time \( t \), 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. Hence, most of the attention will be paid on the sign and the significance level of the coefficient \( \gamma_2 \), which provides the (semi-)elasticity of the exchange rate volatility to the outward FDI.

Given the existing correlations between macroeconomic series, we include the set of control factor

\[
X' = \left( \pi_{j,t} \ o_{i,t} \ o_{j,t} \ y_{i,t} \ y_{j,t} \ \sigma_{yj,t} \ D_{ij} \ B_{ij} \ L_{ij} \ FTA_{ij,t} \ EMU_{ij,t} \right)
\]

to ensure that \( \gamma_2 \) only captures the exchange rate volatility effect on outward FDI. The inflation rate \( \pi \) observed in
country \( j \) at time \( t \) is likely to affect a delocalization decision through an impact on the costs of production. The (log of) GDP \( y \) of the host country \( j \) and the source country \( i \) at time \( t \) capture the size of both markets. The degree of openness \( o \) for country \( j \) and \( i \) (defined as the ratio of export plus import to GDP expressed in current value) provide information on the trade barriers and/or the importance of foreign products in the domestic market. To avoid capturing all uncertainty effects in \( \gamma_2 \), we consider the volatility of the host country’s GDP \( \sigma_y \), 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. More volatility in the foreign market is likely to deter FDI because of the irreversibility of the investment. Finally, \( D \) is the distance between the two countries, which constitutes the foundation of the gravity equation. We also add dummies affecting both goods trade and FDI: \( B \) 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\(^{11}\), and \( EMU \) is a dummy variable that has the value 1 if both countries are members of the European Monetary Union\(^{12}\). In addition, \( \omega_{ij} \) (not necessarily equal to \( \omega_{ji} \) in our setting) captures a pair-wise specific effects, \( \tau_t \) controls for time specific effects, \( t \) is a time trend, and \( \nu_{ij,t} \) is the error term. Finally, reported regressions are estimated with a Fixed Effects model and the heteroskedasticity is controlled using the Huber-White robust estimator of the variance.

3.1 Description of the data

To perform the empirical analysis, we have compiled a substantial data set that covers 27 OECD countries\(^{13}\) over the period 1982-2002. This potentially corresponds to 14,742 observations in the bilateral panel format, although 6,087 observations only 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 our panel data set, containing bilateral measures of outward FDI and exchange rate volatility, permits scrutiny of the features of these data over the sample period. To provide a visual interpretation of both within and between variations of country data, Figure 6 plots 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 outward FDI, *International Financial Statistics 2006* (IMF) for bilateral exchange rates and inflation 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.

\(^{11}\)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).

\(^{12}\)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.

\(^{13}\)Australia, 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.
3.2 The estimation results

Regarding the most important specifications, Table 3 reports coefficient estimates for specifications using either OLS or GLS regressions. The same table also analyzes the non-linearity suggested by the theory, while Table 4 provides a robustness check using the distance between the source and the host countries as a proxy for exchange rate volatility. We eventually take into consideration the potential endogeneity of the exchange rate volatility in Table 5 and offer different specifications, depending on the lag levels in the instrument matrix and the number of steps included in the estimation.

3.2.1 The results of the benchmark model

Let us start by considering the estimate of the expected exchange rate volatility of Analysis B in Table 3. With OLS Fixed Effects, the results show that the effect of exchange rate uncertainty is not significantly different from zero in OECD countries over the 1982-2002 period. Turning to the control variables, all the coefficients are positive and statistically significant at the 99% confidence level. Moreover, if we focus on the economic interpretation of the statistics, we observe that the positive effects are, ceteris paribus, very significant. In particular, a 1% increase in outward FDI is associated with 1.3% of the sending country’s GDP and 0.7% of the host country’s GDP. If the volatility and the inflation rate of the host country are raised by 1%, outward FDI are respectively fostered by 4.4% and 0.2%. Furthermore, investment reacts positively to the openness of both the sending and the recipient country. Finally, being part of either a Free Trade Area or a Monetary Union increase FDI between 10 and 15%.

3.2.2 A non-linearity in the exchange rate volatility

Although, on average, the influence of exchange rate volatility on FDI is not significantly different from zero, it does not mean that the same effect should equally apply for the whole sample. The theoretical model has stressed that, in presence of high uncertainty, the higher the level of exchange rate volatility, the more multinationals are willing to invest abroad, whereas the adverse effect occurs with uncertainty. Scrutiny of the data provides evidence that the relation is indeed non-monotonic and the non-linearity resides in the exchange rate volatility. Let’s start with a sample split, where the threshold level is the median value of the exchange rate volatility (2.67%). As Table 3 (Analysis C and D) exhibits, outward FDI are greatly fostered for high levels of uncertainty. Therefore, the multinational will more certainly exercise the option and invest rather than export, when the exchange rate volatility rises. On the other hand, the reverse occurs for levels of exchange rate volatility below the median value. Hence,

\[
\frac{\partial f_{di_s}}{\partial E_s[\sigma_e]} > 0 \text{ if high } E_s[\sigma_e] \quad \& \quad \frac{\partial f_{di_s}}{\partial E_s[\sigma_e]} < 0 \text{ if low } E_s[\sigma_e]
\]

where both estimates are highly statistically significant, either with heteroskedasticity consistent or Driscoll and Kraay (1998) standard errors. With rolling-windows over the exchange rate volatility in
Figure 8, we more precisely emphasize the non-linearity, following the predictions of the theoretical model. We thus obtain a clear U-shape in the foreign direct investment-exchange rate volatility relation. Therefore, it is the uncertainty level of the option of investing that dictates the different responses of the firm towards exchange rate volatility when contemplating a delocalization strategy in a uncertain environment. Furthermore, a striking feature of the analysis is that we are able to explain the non-linear pattern in the data without imposing any form of risk-aversion in our theoretical model.

This result is important for policy makers because it provides the sign of the effect of an exchange rate stabilization. It also shows that aggregating countries with different exchange rate volatilities mask the variation in these effects across uncertainty levels, and finally allows to explain the heterogeneity of the existing literature, which never considers a similar set of countries.

3.2.3 A distance effect

Since most of the data points lie around the median value, we may face an issue while creating sample splits using the exchange rate volatility level. Indeed, to obtain the estimated coefficients, we have to observe changes in the volatility, but these changes could also be high enough to move the observations across sample splits. Hence, we first lose relevant observations and consider heterogeneous windows over time. To verify the non-linearity hypothesis, we reconsider the analysis using the distance between countries as a proxy for the exchange rate volatility threshold.

Exchange rate volatility is indeed increasing with distance between countries (see the correlation of 0.47 in Table 2) and we can offer a simple straightforward rationale. As Broda and Romalis (p.2, 2003) elegantly put it, "since distance cannot be affected by volatility, this strong relation 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 a lower real exchange rate volatility than more distant countries. The implicit reason is that a shock that changes price of a country's good will affect the price of the consumption basket of a neighboring country more than that of a more distant country. Engel and Rogers (1990) also confirm the validity of that hypothesis by showing that the volatility of the prices of similar goods in different locations is positively related to the distance because of the geographical separation of the markets in determining the degree of the failures of law of one price.

To verify the existence of the non-linear relation between exchange rate volatility and outward FDI, consider first an interaction term to capture the linear change of the estimate according to the distance (see Table 4, Analysis E). As we can see, for proximate countries, the effect is significantly negative, while it is significantly positive for distant countries. Dividing the dataset into two sub-samples of equal sizes, with 2500 km being the distance threshold, we can draw similar conclusions, as highlighted by Analysis G & H. A more precise result can be obtained when estimating the same

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14 As widely shown in the literature, nominal and real exchange rate volatilities present very close behaviors over time.
regression with a breakdown of the distance into five subsamples of equal sizes. Once again, the results are similar, as seen in Analysis F. Therefore, using distance as a proxy for the exchange rate volatility thresholds, as suggested by Table 4, we provide evidence on the reliability and consistency of the obtained non-linear effect on outward FDI.

3.3 A comparison with the empirical literature

Cushman (1985, 1988) launched the debate on FDI and exchange rate volatility, suggesting a positive relation. Through an analysis of FDI percent 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. Given that such a procedure uses only 4 data points, it is not an accurate way of assessing the exchange rate uncertainty. Moreover, FDI decisions are generally taken the year preceding (or before) the time of investment and it is thus unlikely that firms could observe the exchange rates, and thus use the relevant information, the year the investment occurs. Furthermore, the standard deviation of the levels, instead of the log of the exchange rates, overestimates the exchange rate volatility if there exists an underlying trend within the year. We may then question the interpretation of the two significant estimates out of the four regressions presented in the paper for the effect of the (very short term) exchange rate uncertainty on FDI flows. In addition, the author focuses on a pooled regression instead of using a panel (Fixed Effects) estimation and omits most of the control variables. The results are then not really comparable with more recent studies.

The second most cited paper in the literature is the study of Goldberg and Kolstad (1995). They also obtain a positive relation when analyzing quarterly bilateral flows between the U.S., Canada, Japan, and the United Kingdom for the 1978 to 1991 period. Nevertheless, it has been written in very different setting. First, they analyze each series individually. Second, instead of testing FDI between those countries, the authors are interested in the movements in FDI relative to domestic investment. They divide the FDI outflows by a measure of investment activity in the source country to probably deal with the potential non-stationarity of FDI flows. Regarding the exchange rate volatility, it is constructed as the standard deviation over twelve quarters of data, prior to and inclusive of the period of investment. Once again, the issues regarding the use of levels and the current year in the exchange rate, appearing in Cushman (1985, 1988), apply here too. Because they prefer to remove the potential shifts over time in the expected exchange rate, they normalize the volatility by the mean level of the exchange rate within the interval. Although they also obtain a positive relation, in the four out of the six time series, both the dependent and the explanatory variables are different and, as in Cushman (1985, 1988), they miss including some important control factors.

On the other hand, Chakrabarti and Scholnick (2002), considering FDI flows from the U.S. to 20 OECD countries over 1982-1995 period, estimate exchange rate uncertainty as the standard devia-
tion of monthly exchange rate devaluations during the precedent year. They obtain a statistically
insignificant estimate, even though most of the control variables suggested by the literature have
been ignored and the non-stationarity issue not tackled. Although they take into consideration
both Fixed and Random Effects, there is an issue of misspecification of the perceived exchange rate
uncertainty. As FDI is viewed as long-term investment, one should estimate the uncertainty factor
over more than one year. Hence, it would not be appropriate to compare our finding to theirs since
we assume long run exchange rate volatility. Although, the sign of the effect obtained in our analysis
is similar (null or positive) to these studies, we believe that both our procedure and dataset are
likely to be more comprehensive, inducing more accurate estimates. Yet the key finding of this paper
is not an analysis of the average effect but to highlight the presence of a non-monotonic relation
between exchange rate volatility and FDI.

3.4 Econometric issues

3.4.1 Non-stationarity

A recursive potential problem concerning macro and financial panel study is the non-stationarity
of the panels. To ensure the validity of our results, we decide to conduct panel-based unit root
tests, rather than single series tests suggested by Dickey and Fuller (1981) and Phillips and Perron
(1988). Pooling cross-section time series data generate more powerful unit root tests\footnote{Yet panel-based unit root tests require a balanced panel, a condition that is impossible to fulfill with such a broad
dataset. We therefore create an artificial panel only constituted with pair of countries for which we have long time
series without gaps. Results are thus based on 110 pairs of countries, considering 1650 observations.} because, 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. We first conduct the three-step procedure test proposed by Levin, Lin and Chu
(2002) assuming that all individuals in the panel have identical first-order partial correlation, but all
other parameters in the error process are permitted to vary freely across individuals. Our maintain
hypothesis, in which the series \( \{y_{ijt}\} \) has an individual-specific mean, is as follows:

\[
\Delta y_{ij,t} = \delta_{ij} y_{ij,t-1} + \sum_{l=1}^{p_k} \theta_{ijkl} \Delta y_{ij,t-l} + \alpha_{0ij} + \varepsilon_{ijt}
\]  

(20)

where \( y_{ij,t} \) is a variable under consideration, and \( p_{ij} \) is a lag. The panel test procedure evaluates
the null hypothesis that \( H_0 : \delta_{ij} = 0 \) and \( \alpha_{1ij} = 0 \) \( \forall ij \) against the alternative \( H_1 : \delta_{ij} < 0 \) \( \forall ij \)
and \( \alpha_{1ij} \in \mathbb{R} \). Similarly, we also consider the test proposed by Im, Pesaran and Shin (2003) that
allows, like the Levin-Lin-Chu test, for residual serial correlation and heterogeneity of the dynamics
and error variances across groups. However, the formulation of the alternative hypothesis of the
Im-Pesaran-Shin test permits \( \delta_{ij} \) to differ across groups, and is thus more general. It is thus possible
for some (but not all) of the individual series to have unit roots under the alternative hypothesis
\( H_1 : \delta_{ij} < 0 \) for \( ij = 1, 2, \ldots, N_1, \delta_{ij} = 0 \) for \( ij = N_1 + 1, N_1 + 2, \ldots, N \) and \( \alpha_{1ij} \in \mathbb{R} \). The IPS \( t\)-bar
test statistic is constructed by averaging the augmented Dickey-Fuller (ADF) $t$-statistic as

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

where $t$ is the ADF $t$-statistic for pair of countries $ij$. The test results indicate, in Table 1, that the log of Outward FDI and the exchange rate volatility reject the null hypothesis that the series contain unit roots\(^\text{16}\). 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. Our 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.

### 3.4.2 Time effects

As the unit root tests suggest, the series are found to be stationary. Examination of the evolution over time of the aggregated exchange rate volatility and outward FDI in Figure 7 shows two opposite secular patterns: a (relatively) negative trend for the former variable and a positive trend for the latter one. We will however consider the log of outward FDI, which presents a much less obvious trend than the outward FDI series, as suggested by Figure 7 (upper and middle panels). Nevertheless, we wish to avoid the observed estimate incorporating spurious explanatory information due to the existence of a potential trend. We hence take into account, in all regressions, both a time trend and yearly time effects to help overcome this concern. When the model is estimated with time dummies only, results remain very similar though.

### 3.4.3 Error term structure

The results have been estimated with Fixed Effects, while a Random Effects model would have also been possible. We believe that the Fixed Effects structure is more appropriate in our framework. Indeed, we are trying to capture the change of FDI between two countries in the case of a varying exchange rate volatility. This is purely a within effect. The Random Effects, being by construction a weighted average between within and between effects, includes information that is much less useful for policy makers. However, a comparison of specifications A vs B in Table 3 suggests that there is little difference in the results between a Random and a Fixed Effects model. When performing a Hausman test on the difference between these two models, we cannot reject the null hypothesis suggesting that there is no systematic difference\(^\text{17}\).

\(^{16}\)However, we 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. A look at Figure 7 confirms the intuition.

\(^{17}\)This means that the Fixed Effects are significantly uncorrelated with each of the explanatory variables considered in the model.
To ascertain the robustness of our findings we also allow for possible serial correlation and cross-sectional dependence in the panel data by applying Driscoll and Kraay’s (1998) nonparametric covariance matrix, which produces heteroskedasticity consistent standard errors that are robust to very general forms of spatial and temporal dependence. However, as the reader can see, qualitative results from this alternative procedure are largely the same as those of the benchmark model. Except for the most important results, where both standard errors are suggested, the analysis is then only based on an OLS Fixed Effects estimation with heteroskedasticity consistent standard errors.

3.4.4 Other models

A substantiated criticism of the model lies with the number of data observations used in its estimation. As noted, there are 14,742 potential data points in our dataset. However, the fact that only 6,087 are used highlights an underlying problem of the empirical work – that of missing data. Hence, it seems important to check that our results do not hold only for a unique econometric specification. Then, several other models have been estimated, although not presented for space consideration but available on request. We investigate whether the exchange rate volatility’s marginal effect on outward FDI is constant over time or time-varying, we consider the variables lagged by one period, include the exchange rate level 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.

3.4.5 Endogeneity

We may also raise the question of the potential endogeneity issue. For instance, it is plausible that governments may try to reduce 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. Endogeneity also comes from the possibility that outward FDI affect the exchange rate, and thus its volatility, in equilibrium. If this were true, FDI would indeed have a negative effect on exchange rate volatility. Unfortunately, it is problematic to verify the validity of such an assumption because of the lack of relevant data.

It is often claimed that it is possible to econometrically verify the existence of such a bias with the use of a GMM dynamic panel data estimator developed in Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1997). We therefore test the validity of such an hypothesis by comparing the GMM estimate to the one resulting from the benchmark OLS Fixed Effects model in which we add a lag of the dependent variable as follows

\[
fd_{it} - fd_{it-1} = \gamma_1 + (\alpha - 1)fd_{it-1} + \Phi X_{it} + \gamma_2 E(\sigma_{it}) + \omega_{it} + \tau_t + \nu_{it} + (22)
\]

For this purpose, we consider here a system GMM estimator that combines the equation in differences - instrumented with lagged levels of regressors - with the equation in levels, instrumented
with lagged differences of the regressors. We 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. Using internal instruments to deal with the correlation between the lagged endogenous variable and the time-invariant component of the disturbance, this approach is claimed to address the issues of joint endogeneity of the explanatory variables in a dynamic setting and of potential biases coming from pair-wise specific effects. In our estimation, we assume the volatility of the exchange rates and the outward FDI to be potentially endogenous.

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 5 show that the validity of the instruments cannot be rejected and that we can safely reject any second order serial correlation, which constitutes a necessary condition for the consistency of the estimation. While re-estimating the regression with one (not presented), two or three lag levels in the instrument matrix, the estimation still yields very similar results, as obtained in Analysis I and Analysis J in Table 5. In addition, the estimation does not seem to be sensitive to the procedure considered, as shown by the comparison of Analysis I, estimated with the predescribed two-step procedure, and Analysis K, using 2SLS as the one-step estimator.

On the whole (see Analysis I, J, and K), the parameters corroborate with our intuition that the internal instruments are weak. Indeed, results are very similar to just considering a lagged dependent variable in a OLS Fixed Effects model, as presented in Analysis L. In addition, lagging one period the FDI is not very useful when the exchange rate volatility is estimated over 5 years. We thus believe that it is not an appropriate procedure in our framework to solve the endogeneity issue. Considering a dynamic structure (with OLS or a system GMM) provides very similar results, thus highlighting the fact that we may simply rely on the more standard Fixed Effects estimation technique previously presented.

Hence, either the reverse causality issue cannot be solved econometrically or it is inexistent. To verify which claim is more likely to be valid we can tackle the problem from another (and more convincing) perspective. Let’s consider the evolution of outward FDI in two equal subsamples, one in which only pair of countries deemed to be close to each other (the distance is less than 2500 km) are included and one with distant countries (distant by more than 2500 km). Obviously, we could have provided the same picture with the exchange rate volatility breakdown, but we are more likely to avoid suffering from the heterogenous samples issue previously described when using distance as a proxy. As we can observe in Figure 9, outward FDI are very much alike, both by their sizes and their pace over time. Therefore, if FDI does influence the exchange rate volatility directly, or indirectly

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18 This approach is an improvement of the difference GMM estimator proposed by Arellano and Bond (1991), which only considers as predetermined instruments the lagged values of the levels of the explanatory variables. The problem arises when the regressors display persistence over time because their lagged levels thus become very poor instruments for their differences.

19 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 in our case when we consider the one-step estimation. See Bond (2002) for a description of the methodology.
through stabilization policies of governments, the effect should be observed in both subsamples. It is not the case though. For distant countries, the exchange rate volatility is large and stable over time, while the volatility is significantly lower and decreasing over time for proximate countries (see Figure 9). We can thus conclude that it is unlikely to find a significant influence of FDI on exchange rate volatility, as highlighted by the control subsample covering the distant countries. The stabilization efforts observed in proximate countries are then probably due to outside forces, such as the magnitude of goods trade, thus ruling out an obvious reverse causality effect from FDI.

If we miss convincing the reader of the absence of a reverse causality, we can put forward a third line of argument to definitely support the main finding of the paper: the existing bias would apply equally to both subsamples since FDI are of the same magnitude. Therefore, for high exchange rate volatility, the influence would stay much larger than that for low volatility, thus confirming that the level of uncertainty matters in the perception of flexibility for a firm willing to invest abroad. The exact same idea can also apply to the endogeneity story proposed by Russ (2006) in her theoretical model of a multinational firm’s response with endogenous exchange rate. She argues that because exchange rates and FDI are jointly determined by underlying macroeconomic factors, regressing outward FDI on exchange rate volatility may be subject to bias. Although it is not the goal of the paper to test her hypothesis empirically, the potential bias is likely to apply to the whole sample, irrespective of the value of the exchange rate volatility. We can thus claim that the endogeneity of the exchange rate volatility could not be as dramatic for the suggested U-shape pattern as the theoretical model of Russ (2005) emphasizes: we still obtain a non-linear effect of exchange rate volatility on outward FDI, as observed in Table 3, that is probably due to a varying response of risk-neutral multinationals to exchange rate uncertainty, as suggested by the real option analysis.

4 Conclusions

This paper sheds new lights on the relation between FDI and exchange rate uncertainty, both at the theoretical and the empirical level. By directly estimating the expected (irreversible) investment level in a real option analysis using contingent claim valuation of a risk-neutral firm, the model generates new predictions compared to the existing literature. In particular, the model predicts a rise of the expected investment level when contemplating the delocalization strategy under high uncertainty, whereas the adverse effect is observed when the uncertainty is rather low. We thus provide evidence of a new U-shape in the investment-uncertainty relation. In contrast, the option value to invest becomes larger for both cases, thus providing evidence that the option value and the distance to the exchange barrier can be totally unrelated to the actual investment level.

The novelty of the empirical analysis is to provide evidence that there also exists a U-shaped relation between outward FDI and exchange rate volatility over the 1982-2002 period, just as suggested by the real options model. We entertain the idea that exchange rate volatility significantly impact outward FDI, which could be considered as either inhibiting for low levels of uncertainty or rather enhancing for higher levels. This non-linear effect perfectly corroborates the various nu-
metrical simulations. The diversity of our findings suggests that research making use of aggregate measures, which assume that a single linear relation exists at the aggregate level, is not likely to be successful. This may provide a potential explanation as to why different empirical studies have difficulties in finding a consistent link between outward FDI and exchange rate volatility.

It is often claimed that most of the studies analyzing FDI and exchange rate volatility are subject to potentially severe endogeneity or reverse causality biases that are generally not empirically accounted for. However, the potential biases would apply to the whole sample, thus keeping the exchange rate volatility effect to be still varying with the exchange rate volatility level. The main finding of the paper regarding the non-linear effect is therefore unaltered even if such an endogeneity bias were to really exist. When using system GMM Dynamic Panel Data estimations, a procedure that is claimed to control for the endogeneity of the exchange rate volatility, as well as appropriate sample comparisons, we empirically highlight the unlikely existence of such a bias.

Among others, a criticism of the paper is that firms - as in the empirical part - may not use exchange rate uncertainty as its sole measure of uncertainty when making investment decisions. Also important is the political stability of a country and the stability of the economy. An improvement for further work might therefore be to include in the real options model fluctuations of demand shocks in the foreign market. Alternatively, the uncertainty of the economy could also be empirically proxied, for example, by the volatility of a foreign country’s stock exchange index. Clearly, we are just beginning to really understand the relation between FDI and exchange rate volatility.
References


5 Appendix

Option's value of delocalizing production at any time in the future

The option value of the unlevered firm can be written as

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

\[ = E_Q^{s_0} \left[ \left( \int_0^{T(s^*)} e^{-rt} dt - \int_0^c e^{-rt} dt \right)c - \int_0^{T(s^*)} e^{-rt} c_f s_t dt - Is_{T(s^*)} e^{-rT(s^*)} \right] \] \quad (23)

Using standard computations with Brownian motion,

\[ \Delta V(s_0) = cE_Q^{s_0} \left[ -\frac{e^{-rt}}{r} \right]_{T(s^*)}^{\infty} \]

\[ -c_f E_Q^{s_0} \left[ \int_{T(s^*)}^0 (s_{T(s^*)}) e^{(r-\delta - \frac{\sigma^2}{2})(t-T(s^*) + \sigma(Z_t - Z_{T(s^*)}))} e^{-rt} dt - Is_{T(s^*)} e^{-rT(s^*)} \right] \] \quad (24)

\[ = (\frac{c}{r} - Is^*) E_Q^{s_0} [e^{-rT(s^*)}] - s^* c_f E_Q^{s_0} \left[ \int_0^{\infty} \int_0^{T(s^*)} e^{(r-\delta - \frac{\sigma^2}{2})(t-t')} e^{-rt} e^{\sigma(Z_t - Z_{t'})} dt Q(T(s^*) \in dt') \right] \] \quad (25)

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

\[ \Delta V(s_0) = (\frac{c}{r} - Is^*) E_Q^{s_0} [e^{-rT(s^*)}] - s^* c_f \left[ \int_0^{\infty} \int_0^{T(s^*)} e^{(r-\delta - \frac{\sigma^2}{2})(t-t')} e^{-rt} dt Q(T(s^*) \in dt') \right] \] \quad (26)

\[ = (\frac{c}{r} - Is^*) E_Q^{s_0} [e^{-rT(s^*)}] - s^* c_f \delta \int_0^{\infty} e^{-rt} \delta Q(T(s^*) \in dt') \] \quad (27)

\[ \text{where we can use the Laplace transform of the stopping time} \ T(s^*) \text{to rewrite} \]

\[ \int_0^{\infty} e^{-rt} \delta Q(T(s^*) \in dt') = E_Q^{s_0} [e^{-rT(s^*)}] = \left( \frac{s^*}{s_0} \right)^{-\beta} \] \quad (28)

with

\[ \beta = -\frac{\alpha}{\sigma^2} - \sqrt{\frac{\alpha}{\sigma^2} + \frac{2r}{\sigma^2}} < 0 \] \quad (29)

\[ \alpha = r - \delta - \frac{\sigma^2}{2} \] \quad (30)
Then,
\[ \Delta V(s_0) = \left( \frac{c}{r} - \frac{c_fs^*}{\delta} - Is^* \right)E_Q[e^{-rT(s^*)}] = \left( \frac{c}{r} - \frac{c_fs^*}{\delta} - Is^* \right)\left( \frac{s^*}{s_0} \right)^{-\beta} \]

(34)

(35)

Optimal exchange rate barrier $s^*$

Let’s derive the option value with respect to the threshold level $s^*$

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

(36)

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

(37)

Probability of investment

To estimate the probability of reaching the barrier $s^*$ within period $T$, we can build on the results derived from the barrier options theory. Attaining the trigger value of the exchange rate in our "down-and-in" option allows us to define without loss of generality

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

(38)

(39)

Let $m_T^* = \min_{h \in [0,T]} S_h$ and $s_0 > s^*$ then,

\[ P\left( \sup_{0 \leq t \leq T} s_t \leq s^* \mid s_0 > s^* \right) = P\{S_{T \wedge (s^*)} \leq s^*\} = P\{S_T \leq s^*\} + P\{S_T \geq s^*, m_T^* \leq s^*\} = P\left\{ \frac{\alpha T}{\sigma} + Z_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \right\} \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma} = P_1 + P_2 \]

(40)

(41)

(42)

(43)

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

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

(44)

For the second term, we need to apply the Girsanov Theorem. Let start by defining two probability measures by the Radon-Nikodym derivatives

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

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

(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

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

(47)

we can rewrite the second term as

\[
P_2 = E_{\hat{P}} \left[ I\left\{ \frac{\alpha T}{\sigma} + Z_T \geq \frac{\ln(s^*) - \ln(s_0)}{\sigma}, m_{\hat{T}} \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma}\right\} \right]
\]

(48)

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

\[
\hat{P}\{ \hat{Z}_T \geq \frac{\ln(s^*) - \ln(s_0)}{\sigma}, m_{\hat{T}} \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma}\} = \hat{P}\{ \hat{Z}_T \leq -\frac{\ln(s^*) - \ln(s_0)}{\sigma}\} = \hat{P}\{ \hat{Z}_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma}\}
\]

Hence, since \( I\{ \hat{Z}_T \geq \frac{\ln(s^*) - \ln(s_0)}{\sigma}\} = I\{ -\hat{Z}_T \leq -\frac{\ln(s^*) - \ln(s_0)}{\sigma}\} = I\{ \frac{2\ln(s^*) - 2\ln(s_0)}{\sigma} - \hat{Z}_T \leq \frac{\ln(s^*) - \ln(s_0)}{\sigma}\} \),

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

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,

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

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

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

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

27
**Figure 1: The Standard Way of Investigating the Investment-Uncertainty Relationship with Varying Investment Levels**

The figure investigates two ways of interpreting the investment-uncertainty relationship, based on the standard real options literature (see Dixit and Pindyck, 1994). The upper panel shows that, for all levels of investment, greater volatility induces the option value of waiting (and invest later) to become more valuable. Similarly, as illustrated by the lower panel, uncertainty also raises the distance at which the exchange rate barrier lies. The conclusion of the literature is that investment linearly decreases with uncertainty.

*Parameters:*

$I=[1, 60], \sigma=[0, 0.25], C_f=2, C=2.6, S_0=1, r=0.05, \rho=0.05$
Figure 2: Effect of Varying Investment and Volatility on the Probability of Investing

The previous figure highlighted the negative relationship 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 include the information of all levels 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 more important when the frame window is larger.

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 3: The Uncertainty Effect on Expected Investment**

We numerically simulate three different cases, depending on the length of the time window T. It can be noticed that the expected investment-uncertainty relationship presents a U-shape pattern. The non-linearity holds 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=[0,1*] with 1*=20, 50, C=2.6, Cf=2, So=1, r=0.05, rho=0.05
Figure 4: 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 still holds. Similarly, the same shape of the uncertainty effect can also be observed when varying the difference of the costs transposed in percentage of the increased costs of producing at home compared to producing in the foreign country. The firm perceives negatively an increase of the exchange rate uncertainty on its investment level for low values of the volatility, whereas for higher levels of uncertainty the influence is positive. The U-shape pattern that conditions the firm's optimal decision seems therefore to play a key role in the understanding of the investment-uncertainty relation.

Parameters:
I=[0, 30], sigma=[0, 0.25], C=2.6, Cf=2, So=1, r=0.05, rho=0.05
**Figure 6: Bilateral Exchange Rate Volatilities and Outward FDI for US with 15 Countries, 1982-2002**

The upper panel represents the dynamic of the bilateral exchange rate volatility, between US (chosen as a representative country) and the main 15 OECD trading partners over the 1982-2002 period, 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. Similarly, the lower panel represents the dynamic of Foreign Direct Investment. The figure suggests that a panel framework seems appropriate for our analysis since there exists some important variation over time, as well as between pair of countries, in the bilateral exchange rate volatilities.
**Figure 7: Average Exchange Rate Volatility and Outward FDI, 1982-2002**

The figure shows the sample average dynamic of (both the raw and the log series of) Foreign Direct Investment and bilateral exchange rate volatility over the 1982-2002 period. The panels suggest a clear positive trend for the former series, representing Outward FDI. However, the trends are not as clear for the two series of interest, namely the log of Outward FDI and the exchange rate volatility. We may presuppose that the log series of FDI will face less concern in terms of stationarity issue.
**Figure 8: U-shape empirical relationship 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, we assume rolling-windows keeping a constant range equal to 3% of the exchange rate volatility (horizontal axis). We can see that the estimate coming from the Fixed Effects regression is significantly negative for low levels of exchange rate uncertainty, whereas it turns out to be positive for higher levels. A clearer picture (lower panel) is obtained when the vertical axis denotes the Outward FDI normalized to unity so that we are able to capture the cumulative effect of a change in exchange rate volatility. We split 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 blue dotted lines use Driscoll and Kraay’s (1998) standard errors consistent to spatial and temporal dependence.
The figure provides an analysis of the evolution of the Outward FDI and exchange rate volatility when the dataset is split into a sample including relatively close countries and another one that includes rather distant countries. The threshold considered is 2500 km, so that we analyze two samples with the same size. Surprisingly, when the source and the host countries are distant to each other, it appears that FDI is larger than for countries being close to each other. The pattern over time is very similar though. However, the exchange rate volatility seems to vary over time in a completely different manner in the two subsamples. Indeed, the volatility is much larger for distant countries and relatively stable over time, whereas there is a significant negative trend for proximate countries. As the control group (of distant countries) suggests, it seems that increasing FDI over time has had no significant influence on the exchange rate volatility. A reverse causality effect is then unlikely to be observed.
In the following tables, we perform an empirical analysis on 27 OECD countries over the period 1982-2002: Ln Outward FDI captures the logarithm value of the outward FDI between the source and the host country, 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. Ln GDP \textit{Source} corresponds to the GDP of the source country, Ln GDP \textit{Host} corresponds to the GDP of the host country, and Distance is the distance between the two countries. As for the dummies, Common Border accounts for two countries having a common border, Common Language is a dummy for common language, Both in FTA is a dummy equal to 1 if both countries subscribe to a Free Trade Agreement, and 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 \textit{International Direct Investment Statistics Yearbook 2003} (OECD) for Outward FDI, \textit{International Financial Statistics 2006} (IMF) for bilateral exchange rates and inflation rates, the \textit{Penn World Table 6.2} for GDPs, the \textit{OECD International Trade Indicators 2006} for the degree of openness, and from \textit{World Development Indicators 2003} for the other control variables.

### Table 1: Table of Statistics

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Observations</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln Outward FDI</td>
<td>6087</td>
<td>2.702</td>
<td>1.225</td>
<td>1</td>
<td>5.481</td>
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<tr>
<td>Exchange Rate Volatility (%)</td>
<td>6087</td>
<td>2.738</td>
<td>1.620</td>
<td>0</td>
<td>12.023</td>
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<tr>
<td>Ln GDP \textit{Source}</td>
<td>6087</td>
<td>11.675</td>
<td>.645</td>
<td>9.737</td>
<td>13.017</td>
</tr>
<tr>
<td>Ln GDP \textit{Host}</td>
<td>6087</td>
<td>11.509</td>
<td>.613</td>
<td>9.444</td>
<td>13.017</td>
</tr>
<tr>
<td>GDP Volatility (%) \textit{Host}</td>
<td>6087</td>
<td>2.453</td>
<td>0.961</td>
<td>0.943</td>
<td>5.499</td>
</tr>
<tr>
<td>Inflation Rate (%) \textit{Host}</td>
<td>6087</td>
<td>6.775</td>
<td>13.90</td>
<td>-0.915</td>
<td>131.82</td>
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<tr>
<td>Openness (%) \textit{Source}</td>
<td>6087</td>
<td>60.07</td>
<td>24.03</td>
<td>16.11</td>
<td>184.12</td>
</tr>
<tr>
<td>Openness (%) \textit{Host}</td>
<td>6087</td>
<td>73.57</td>
<td>43.26</td>
<td>16.11</td>
<td>278.99</td>
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<td>Common Language</td>
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<td>.200</td>
<td>.400</td>
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<tr>
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<td>.072</td>
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<td>Both in EMU</td>
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<td>Both in FTA</td>
<td>6087</td>
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<td>.471</td>
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### Panel-based Unit Root Tests: null hypothesis of nonstationarity

<table>
<thead>
<tr>
<th></th>
<th>Observations</th>
<th>Im-Pesaran-Shin Test</th>
<th>Levin-Lin-Chu Test</th>
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<tbody>
<tr>
<td></td>
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<td>t-bar Statistic</td>
<td>P-value</td>
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<tr>
<td>Ln Outward FDI</td>
<td>1650, 1758</td>
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<td>0.000</td>
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<td>Exchange Rate Volatility (%)</td>
<td>13459, 13338</td>
<td>-1.964</td>
<td>0.000</td>
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<td>Ln GDP</td>
<td>13459, 13338</td>
<td>-1.403</td>
<td>0.999</td>
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Table 2: Correlation Matrix

This table considers the correlation coefficients between the different variables considered in the benchmark analysis. The figures reported are those for the 6087 observations for which we have data on Outward FDI.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Ln Outward FDI</th>
<th>Exchange Rate Volatility</th>
<th>Ln GDP Source</th>
<th>Ln GDP Host</th>
<th>GDP Volatility Host</th>
<th>Inflation Rate Host</th>
<th>Openness Source</th>
<th>Openness Host</th>
<th>Distance</th>
<th>Common Language</th>
<th>Common Border</th>
<th>Both in EMU</th>
<th>Both in FTA</th>
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</tr>
<tr>
<td>Exchange Rate Volatility</td>
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<td>Ln GDP Source</td>
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<tr>
<td>Ln GDP Host</td>
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<td>0.028</td>
<td>-0.127</td>
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<tr>
<td>GDP Volatility Host</td>
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<td>0.272</td>
<td>0.068</td>
<td>-0.357</td>
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<tr>
<td>Inflation Rate Host</td>
<td>-0.128</td>
<td>0.347</td>
<td>0.082</td>
<td>-0.216</td>
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<td>Openness Source</td>
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<td>-0.598</td>
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<td>-0.033</td>
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<tr>
<td>Openness Host</td>
<td>-0.055</td>
<td>0.164</td>
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<tr>
<td>Distance</td>
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<td>Common Language</td>
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<td>-0.040</td>
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<td>-0.125</td>
<td>-0.126</td>
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<td>-0.050</td>
<td>0.051</td>
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<tr>
<td>Common Border</td>
<td>0.255</td>
<td>-0.245</td>
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<td>0.019</td>
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<td>-0.050</td>
<td>0.012</td>
<td>0.044</td>
<td>-0.307</td>
<td>0.237</td>
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<tr>
<td>Both in EMU</td>
<td>0.074</td>
<td>-0.375</td>
<td>-0.030</td>
<td>0.018</td>
<td>-0.044</td>
<td>-0.067</td>
<td>0.063</td>
<td>0.056</td>
<td>-0.167</td>
<td>-0.037</td>
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<tr>
<td>Both in FTA</td>
<td>0.122</td>
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<td>-0.143</td>
<td>-0.067</td>
<td>-0.153</td>
<td>-0.164</td>
<td>0.093</td>
<td>0.032</td>
<td>-0.541</td>
<td>-0.028</td>
<td>0.206</td>
<td>0.315</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3: Exchange Rate Volatility Effects on FDI with Pooled OLS-GLS: a Non-Linear Effect on FDI

*Estimation:* Random and Fixed Effects with Time Dummies and Time Trend

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Ln Outward FDI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>A</td>
</tr>
<tr>
<td>Exch. Rate Volatility Breakdown</td>
<td>&lt; Median</td>
</tr>
<tr>
<td>Exchange Rate Volatility</td>
<td>0.004 (0.004)</td>
</tr>
<tr>
<td>Ln GDP Source</td>
<td>1.334* (0.043)</td>
</tr>
<tr>
<td>Ln GDP Host</td>
<td>0.773* (0.045)</td>
</tr>
<tr>
<td>GDP Volatility Host</td>
<td>0.044* (0.007)</td>
</tr>
<tr>
<td>Inflation Rate Host</td>
<td>0.001b (0.001)</td>
</tr>
<tr>
<td>Openness Source</td>
<td>0.002b (0.001)</td>
</tr>
<tr>
<td>Openness Host</td>
<td>0.012c (0.002)</td>
</tr>
<tr>
<td>Distance (1000 km)</td>
<td>-0.051c (0.007)</td>
</tr>
<tr>
<td>Common Language</td>
<td>0.906c (0.093)</td>
</tr>
<tr>
<td>Common Border</td>
<td>0.458c (0.127)</td>
</tr>
<tr>
<td>Both in EMU</td>
<td>0.105c (0.026)</td>
</tr>
<tr>
<td>Both in FTA</td>
<td>0.145c (0.021)</td>
</tr>
<tr>
<td>R² Within</td>
<td>0.57</td>
</tr>
<tr>
<td>R² Between</td>
<td>0.56</td>
</tr>
<tr>
<td>R² Overall</td>
<td>0.61</td>
</tr>
<tr>
<td>Number of observations</td>
<td>6087</td>
</tr>
<tr>
<td>OLS Fixed Effects Model</td>
<td>Yes</td>
</tr>
<tr>
<td>GLS Random Effects Model</td>
<td>Yes</td>
</tr>
<tr>
<td>Controlled Time Effects</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes:
Heteroskedasticity-robust standard errors reported in parentheses.

a, b, c relate to coefficients respectively significant at the 95, 99, 99.9% confidence level.

D 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 4: Exchange Rate Volatility Effects on FDI with a Distance Breakdown

*Estimation:* Fixed Effects OLS with Time Dummies and Time Trend

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
<td>All Data</td>
<td>All Data</td>
<td>&lt; 2500</td>
<td>&gt; 2500</td>
</tr>
<tr>
<td><strong>Distance Breakdown</strong></td>
<td>-0.029&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>-0.037&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.025&lt;sup&gt;c&lt;/sup&gt; (0.005)</td>
<td></td>
</tr>
<tr>
<td>Exchange Rate Volatility:</td>
<td>-0.031&lt;sup&gt;c&lt;/sup&gt; (0.014)</td>
<td>0.008 (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.013 (0.008)</td>
</tr>
<tr>
<td>0 &lt; Distance &lt; 1000</td>
<td>0.013 (0.008)</td>
<td>0.013 (0.008)</td>
<td>0.013 (0.008)</td>
<td>0.013 (0.008)</td>
</tr>
<tr>
<td>1000 &lt; Distance &lt; 2000</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
</tr>
<tr>
<td>2000 &lt; Distance &lt; 6000</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
</tr>
<tr>
<td>6000 &lt; Distance &lt; 9000</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
</tr>
<tr>
<td>9000 &lt; Distance</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.008)</td>
</tr>
<tr>
<td>Interacted with Distance (1000 km)</td>
<td>0.050&lt;sup&gt;c&lt;/sup&gt; (0.009)</td>
<td>0.050&lt;sup&gt;c&lt;/sup&gt; (0.009)</td>
<td>0.050&lt;sup&gt;c&lt;/sup&gt; (0.009)</td>
<td>0.050&lt;sup&gt;c&lt;/sup&gt; (0.009)</td>
</tr>
<tr>
<td>Ln GDP Source</td>
<td>1.158&lt;sup&gt;c&lt;/sup&gt; (0.091)</td>
<td>1.251&lt;sup&gt;c&lt;/sup&gt; (0.095)</td>
<td>1.190&lt;sup&gt;c&lt;/sup&gt; (0.185)</td>
<td>1.483&lt;sup&gt;c&lt;/sup&gt; (0.119)</td>
</tr>
<tr>
<td>Ln GDP Host</td>
<td>0.710&lt;sup&gt;c&lt;/sup&gt; (0.083)</td>
<td>0.670&lt;sup&gt;c&lt;/sup&gt; (0.084)</td>
<td>0.298&lt;sup&gt;c&lt;/sup&gt; (0.132)</td>
<td>0.959&lt;sup&gt;c&lt;/sup&gt; (0.110)</td>
</tr>
<tr>
<td>GDP Volatility Host</td>
<td>0.046&lt;sup&gt;c&lt;/sup&gt; (0.007)</td>
<td>0.045&lt;sup&gt;c&lt;/sup&gt; (0.007)</td>
<td>0.035&lt;sup&gt;c&lt;/sup&gt; (0.011)</td>
<td>0.046&lt;sup&gt;c&lt;/sup&gt; (0.009)</td>
</tr>
<tr>
<td>Inflation Rate Host</td>
<td>0.001&lt;sup&gt;c&lt;/sup&gt; (0.001)</td>
<td>0.002&lt;sup&gt;c&lt;/sup&gt; (0.001)</td>
<td>0.002&lt;sup&gt;c&lt;/sup&gt; (0.001)</td>
<td>0.001 (0.001)</td>
</tr>
<tr>
<td>Openness Source</td>
<td>0.003&lt;sup&gt;c&lt;/sup&gt; (0.001)</td>
<td>0.003&lt;sup&gt;c&lt;/sup&gt; (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.005&lt;sup&gt;c&lt;/sup&gt; (0.001)</td>
</tr>
<tr>
<td>Openness Host</td>
<td>0.002&lt;sup&gt;c&lt;/sup&gt; (0.003)</td>
<td>0.002&lt;sup&gt;c&lt;/sup&gt; (0.003)</td>
<td>0.005&lt;sup&gt;c&lt;/sup&gt; (0.001)</td>
<td>0.000 (0.001)</td>
</tr>
<tr>
<td>Both in EMU</td>
<td>0.055 (0.026)</td>
<td>0.021 (0.027)</td>
<td>-0.044&lt;sup&gt;a&lt;/sup&gt; (0.029)</td>
<td>0.008 (0.097)</td>
</tr>
<tr>
<td>Both in FTA</td>
<td>0.114&lt;sup&gt;c&lt;/sup&gt; (0.010)</td>
<td>0.114&lt;sup&gt;c&lt;/sup&gt; (0.020)</td>
<td>0.057&lt;sup&gt;c&lt;/sup&gt; (0.022)</td>
<td>0.340&lt;sup&gt;c&lt;/sup&gt; (0.063)</td>
</tr>
<tr>
<td>R² Within</td>
<td>0.57</td>
<td>0.57</td>
<td>0.60</td>
<td>0.56</td>
</tr>
<tr>
<td>R² Between</td>
<td>0.38</td>
<td>0.37</td>
<td>0.31</td>
<td>0.53</td>
</tr>
<tr>
<td>R² Overall</td>
<td>0.44</td>
<td>0.43</td>
<td>0.38</td>
<td>0.59</td>
</tr>
<tr>
<td>Number of observations</td>
<td>6087</td>
<td>6087</td>
<td>3061</td>
<td>3026</td>
</tr>
<tr>
<td>Controlled Time Effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes:
- Heteroskedasticity-robust standard errors reported in parentheses.
- <sup>a</sup>, <sup>b</sup>, <sup>c</sup> relate to coefficients respectively significant at the 95, 99, 99.9% 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 5: Exchange Rate Volatility Effects on FDI with Dynamic GMM

*Estimation:* 2-step system GMM estimation (except Model N, 1-step and Model O, OLS FE) with Windmeijer (2005) Finite Sample Robust Correction and Time Effects

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Ln Outward FDI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>I</td>
</tr>
<tr>
<td><strong>Lag structure</strong></td>
<td>t-2</td>
</tr>
<tr>
<td><strong>Lagged Dependent Variable</strong></td>
<td>0.847(^c) (0.021)</td>
</tr>
<tr>
<td><strong>Exchange Rate Volatility</strong></td>
<td>-0.003 (0.004)</td>
</tr>
<tr>
<td><strong>Ln GDP Source</strong></td>
<td>0.165(^c) (0.036)</td>
</tr>
<tr>
<td><strong>Ln GDP Host</strong></td>
<td>0.139(^c) (0.040)</td>
</tr>
<tr>
<td><strong>GDP Volatility Host</strong></td>
<td>-0.005 (0.013)</td>
</tr>
<tr>
<td><strong>Inflation Rate Host</strong></td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td><strong>Openness Source</strong></td>
<td>0.001 (0.001)</td>
</tr>
<tr>
<td><strong>Openness Host</strong></td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td><strong>Distance (1000 km)</strong></td>
<td>-0.009 (0.004)</td>
</tr>
<tr>
<td><strong>Common Language</strong></td>
<td>0.163(^c) (0.053)</td>
</tr>
<tr>
<td><strong>Common Border</strong></td>
<td>0.141 (0.116)</td>
</tr>
<tr>
<td><strong>Both in EMU</strong></td>
<td>0.033 (0.033)</td>
</tr>
<tr>
<td><strong>Both in FTA</strong></td>
<td>0.026 (0.028)</td>
</tr>
</tbody>
</table>

**Specification tests (p-values)**

|  |  |  |  |  |
|---|---|---|---|
| (a) Hansen Test | 0.541 | 0.491 | 0.541 | Within: 0.76 |
| (b) First-Order Correlation | 0.000 | 0.000 | 0.000 | Between: 0.94 |
| Second-Order Correlation | 0.256 | 0.250 | 0.260 | Overall: 0.92 |
| Number of observations | 418 | 379 | 418 |  |
| Number of observations | 5357 | 5357 | 5357 | 5357 |  |
| Specification tests (p-values) |  |  |  |  |
| (a) Hansen Test | 0.541 | 0.491 | 0.541 | Within: 0.76 |
| (b) First-Order Correlation | 0.000 | 0.000 | 0.000 | Between: 0.94 |
| Second-Order Correlation | 0.256 | 0.250 | 0.260 | Overall: 0.92 |
| Number of observations | 418 | 379 | 418 |  |
| Number of observations | 5357 | 5357 | 5357 | 5357 |  |
| Specification tests (p-values) |  |  |  |  |
| (a) Hansen Test | 0.541 | 0.491 | 0.541 | Within: 0.76 |
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| Second-Order Correlation | 0.256 | 0.250 | 0.260 | Overall: 0.92 |
| Number of observations | 418 | 379 | 418 |  |
| Number of observations | 5357 | 5357 | 5357 | 5357 |  |

**Notes:**

*Heteroskedasticity-robust standard errors reported in parentheses.*

\(^a, ^b, ^c\) relate to coefficients respectively significant at the 95, 99, 99.9% confidence level.