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Exchange rates and foreign direct investment: theoretical models and empirical evidence*

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Over the past decades, growth in foreign direct investment (FDI) has stimulated significant attempts at developing theories that explain this trend. One line of this research explores the relationship between exchange rates and FDI. There is no consensus about the nature of this relationship in either the theoretical or empirical work. In this article, we critically appraise this body of work, and find the theoretical studies to be making ground in exploring the complexities of FDI, but the empirical evidence to be constrained by data problems.

Key words: exchange rate, foreign direct investment.

1. Introduction

Over the past decades, a striking feature of increased international economic integration has been the growth in foreign direct investment (FDI). During 2005, for example, world FDI inflows grew 28.9 per cent compared to a growth rate of 12.9 per cent for world exports (UNCTAD 2006). Growth in FDI has been accompanied by growth of theories that explain this trend. One line of research explores the relationship between exchange rates and FDI. This line emerged in part from the prospect of European monetary union, and in part from the US experience in the 1980s of a major inflow of FDI, at the same time that the US dollar experienced a sustained period of depreciation. It was considered that more traditional theories could not explain the facts of large short-term swings in FDI.

Australia has a long history of inflows of FDI and the beneficial contribution of these flows is evident. As can be seen in Figure 1, Australia experienced a depreciation of the exchange rate and an associated FDI inflow during the mid- to late-1980s similar to that of the USA. Inspection suggests that a relationship existed for a time, but may have dissipated.

FDI is complex and heterogeneous in nature. FDI decisions are made in the context of national customs, beliefs, social institutions and attitudes, all of which change over time. Two broad strands have been identified in the

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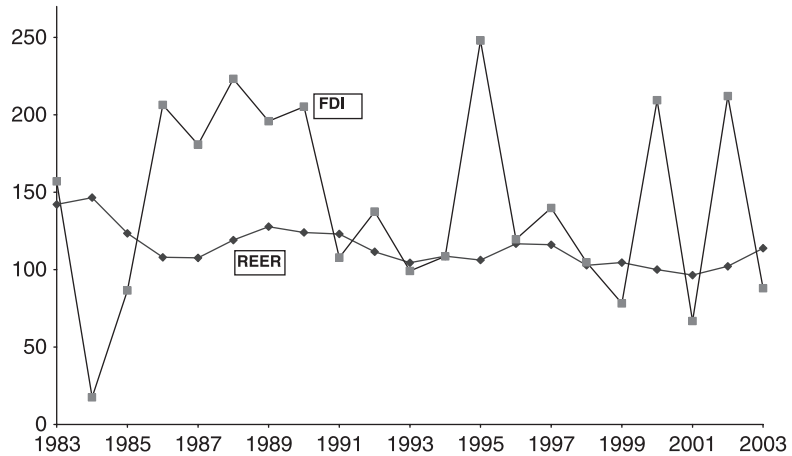

Figure 1 Australia's real effective exchange rate and IFDI.
Source: REER-International Financial Statistics (IFS), FDI-UNCTAD.

theoretical literature: the real options, and risk aversion approaches (Goldberg and Kolstad 1995). These strands are now joined by emerging work that considers heterogeneity of firm motives, firm productivity, exchange rate endogeneity and multilateral resistance. Some recent models make an important contribution in that they encompass existing alternative models, opening up the possibility of distinguishing between theoretical alternatives empirically. However, given the nature of FDI, it is likely that there will never be a single model that can integrate all its complexities. Indeed the sign on the predicted relationship between exchange rates and FDI varies across theoretical models and some models predict ambiguous outcomes. Taking into consideration the entire body of theoretical work, we are left with ambiguous predictions, and therefore it remains the task of empirical work to determine what, if any, the nature of the relationship may be.

Ambiguity at the theoretical level is clearly reflected in the empirical work. There is some consensus on the relationship between exchange rate levels and FDI flows, but none on volatility. Part of the explanation for the mixed evidence may lie in the heterogeneity of the empirical work itself, reflecting the theoretical ambiguity. Another part of the explanation may lie in the fact that the empirical work appears to be impaired by data constraints and specification problems. It is because of these problems that estimates of the relationship between exchange rates and FDI must be viewed with some suspicion.

The purpose of this article is to provide a comprehensive and critical appraisal of the literature, and to make an assessment of the conclusions that can be drawn from this work. The article proceeds as follows. In Section 2, a brief overview of theoretical arguments is provided. In Section 3, the empirical findings are considered, and developments in research are presented and discussed in the context of model specification. Section 4 concludes the analysis.

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2. Theoretical considerations

Theories about FDI-exchange rates linkages emerged in the 1970s and 1980s (for example, Kohlhagen 1977; Cushman 1985). Two theories that have been highly influential are Blonigen (1997) and Froot and Stein (1991). Froot and Stein used an imperfect capital markets approach to argue that exchange rates operate on wealth to affect FDI. Because of the assumption of imperfect capital markets, external sources for borrowing are more expensive than a firm's internal cost of capital. As a result, a host currency depreciation is predicted to have a positive effect on inbound FDI (IFDI), as it automatically increases the wealth of foreigners, allowing them to make higher bids for assets. Blonigen (1997) focuses on acquisitions FDI: a special case for exchange rate effects as the acquisition of a foreign target firm can provide firm specific assets. This theory assumes goods market segmentation, and postulates that foreign and domestic firms have the same opportunity to buy, but different opportunities to generate returns on assets in foreign markets. The profitability of all branches of a multinational firm may be increased after the acquisition of a foreign firm. For this reason, currency movements may affect relative asset valuations, and a depreciation of the host's currency increases IFDI.

Beyond these models, the real options and risk aversion approaches are joined by emerging work that explores the effects of heterogeneity in FDI motive (Lin *et al*. 2006), firms with heterogeneous productivity along with endogenous exchange rates (Russ 2007a), and the notion of complex FDI with multilateral resistance. These theories provide different predictions for the response of FDI to exchange rate levels and volatility, and are discussed in more detail below.

2.1 Real options

This approach is based on that of Dixit and Pindyck (1994) who considered the effects of uncertainty on investment when decisions are irreversible. A firm can have an option to invest overseas, with exchange rate uncertainty potentially influencing the expected return on the option. Exchange rate uncertainty may increase the value of holding onto the option by not investing, whereas changes in exchange rate levels affect the price of the option. Examples can be found in Campa (1993), Darby *et al*. (1999) and Kogut and Chang (1996). Darby *et al*. (1999) present a model where the response of FDI is ambiguous. A different definition of option value is used in Aizenman (1992) and Sung and Lapan (2000). This is referred to as the 'production flexibility' approach in Goldberg and Kolstad (1995). Here, having plants in different countries creates the option to shift production among facilities in response to exchange rate movements. Aizenman (1992) allows for exchange rate endogeneity, and shows that a fixed exchange rate regime is more conducive to FDI. Sung and Lapan (2000) suggest that investment will change to the

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lowest cost location after an exchange rate movement, and the value of the option is positively related to uncertainty. They show that, with adequate exchange rate uncertainty, it is profitable for a multinational enterprise (MNE) to open plants at home and abroad, postponing production decisions until after an exchange rate shock. Kogut and Kulatilaka (1994) provide another variant of a real options model that predicts exchange rate volatility increases FDI.

The strength of this approach is that it highlights the effect that exchange rate movements may have on the timing of FDI, because a firm's decisions are to invest, wait, or to not invest, whereas under the risk aversion approach firms either invest or they do not. Hazard models are often used in empirical applications, and they fit neatly into the theoretical framework, describing the timing between appearance of an investment opportunity and the investment decision. Although the empirical models express the underlying theory more closely than those of the risk aversion approach, the counterpart to this is the unappealing behavioural assumption that firms adjust factors after the realisation of exchange rate shocks. Some researchers have argued that this may be a reasonable long-run assumption. However, focus in empirical work is more on short-run volatility, not long-run misalignment. It has been criticised by Jeanneret (2005) on the grounds that fluctuations in employment and capital expenditures are not large relative to exchange rate variability, and that it seems unrealistic to expect producers to keep some capacity idle.

2.2 Risk aversion

Under this approach, exchange rate risk arises due to the timing differences between investment and profits. Firms invest abroad when the expected returns equal the cost plus payment for the degree of risk introduced by exchange rate volatility. The most frequently cited models are those of Kohlhagen (1977), Itagaki (1981), Cushman (1985) and Goldberg and Kolstad (1995). Cushman (1985) argues that a risk adjusted expected real exchange rate appreciation lowers the foreign cost of capital, encouraging FDI. This positive effect may be offset by effects on inputs costs, or changes in output prices, making the exchange rate-FDI link indeterminate.

Extensions of Cushman's work include Goldberg and Kolstad (1995), Qin (2000), and Bénassy-Quéré *et al.* (2001). Goldberg and Kolstad incorporate the effect of a link between exchange rate shocks and foreign demand shocks. They argue that an increase in the foreign money supply increases demand, while raising foreign prices, which leads to a short-term real appreciation of foreign currency. As both shocks are positive, the covariance is positive. In this case, firms minimise the variance of expected profits and increase expected utility by higher foreign investment.

Bénassy-Quéré *et al.* (2001) examine the case of FDI to re-export. Risk-averse firms consider alternative locations for FDI, and try to reduce the effect of uncertainty on profits by exploiting exchange rate correlations between

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locations. The authors identify channels through which the exchange rate affects FDI. For a host currency appreciation these are through increased purchasing power of locals, and a reduced ability to compete due to higher local production costs. The appeal of this model is that it recognises that a decision to invest abroad in a particular country is not independent of conditions in alternative locations. In the spirit of Bénassy-Quéré *et al*. (2001), Barrell *et al*. (2004) present a model of FDI but introduce firms with market power.

Most of these models have more intuitive appeal than the real options work, but the empirical work is not as well-aligned with theoretical ideas. Typically, FDI flows are regressed on exchange rates, a volatility proxy, and various control variables, the choice of which is not well-guided by theory. Further research is clearly required to address this issue, and Chakrabarti (2003) provides such an attempt. He presents a model of spatial determinants of FDI, where the main aim is to provide an encompassing theoretical framework for empirical testing.

2.3 Recent contributions

More recently, theoretical contributions have been made that consider the effects of heterogeneity in FDI motive (Lin *et al*. 2006), exchange rate endogeneity (Russ 2007a), and multilateral resistance (Egger *et al*. 2007). Contributions have also been made that synthesise earlier theoretical explanations into unified testable models (Buch and Kleinert 2006; Lin *et al*. 2006). These represent a welcome development as they provide a potential means by which previous work can be reconciled.

Russ (2007a) presents a general equilibrium model that allows for exchange rate endogeneity. The analysis indicates that an MNE's response to exchange rate volatility will differ depending on the source of the shocks. A positive shock to the host's money supply depreciates the host's currency, simultaneously increasing income, and sales by both domestic firms and MNEs in the host's market. Conversely, a contractionary monetary policy in the host generates a better exchange rate to convert profits, but reduces local sales. In comparison, a contractionary monetary shock in the foreign economy can adversely affect the value of the host currency without a counteracting effect on overseas sales. A companion paper, Russ (2007b), examines effects on first-time and veteran investors when exchange rate variation can be sourced to either foreign or domestic interest rate volatility. The implication of these for empirical work is that no prediction can be made about the correlation between FDI and exchange rate volatility, unless account is taken of the origin of the volatility. Employing a general equilibrium framework Contessi (2006) presents a model with firm heterogeneity, and endogenous exports and FDI. Among several analytical results from this model is the prediction that the pricing policy of MNEs can increase the volatility of the exchange rate. This, along with related findings Shrikhande (2002), Lubik

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and Russ (2006) (and the references therein), highlights the endogeneity issue.

Emerging work that is motivated by presentation of a theoretical framework capable of encompassing competing explanations for FDI includes Buch and Kleinert 2006 and Lin *et al*. 2006. Lin *et al*. (2006) focus on the way exchange rate volatility affects FDI timing and propose a model with heterogeneous firm motives. They identify the channels through which volatility affects FDI presented earlier. They argue that the exposure of profit to exchange rate risk might vary with FDI motive, predicting that firms with market-seeking motives respond to volatility by delaying FDI, and that firms with export-substituting motives respond more quickly to volatility if risk aversion is great enough. Here the idea is that market-seeking FDI might increase the exposure of profits to exchange rate risk, whereas export-substituting FDI reduces it. The authors demonstrate the importance of considering diversity of investment motivation, by showing that real options and risk aversion models are special cases of their model.

Buch and Kleinert (2006) use a partial equilibrium analysis, where firms produce domestically and abroad, to encompass the competing explanations of Blonigen and Froot and Stein. Their model predicts that an appreciation of the home country currency increases FDI due to goods markets frictions. The same appreciation will also boost FDI via the wealth effect.

Xing and Zhao (2008) complement the literature by presenting another means apart from relative wealth and costs, through which exchange rates can affect FDI. They introduce a role for reverse imports as a means via which exchange rates affect FDI. They propose a two-country model with oligopolistic markets to examine the linkages among reverse imports, FDI and exchange rates. They predict that exchange rate changes, wage and capital cost differentials, and barriers in brand name recognition contribute positively to Japanese FDI in China and reverse imports. Through FDI, a Japanese firm seeks relatively cheap Chinese inputs following a Yen appreciation. This appreciation also increases Japanese reverse imports (due to barriers in brand name recognition in Japan) and causes a decrease of exports from domestic Chinese firms.

Theoretical models that focus on bilateral FDI flows assume that they are independent of FDI decisions to other countries. Clearly, this is a restrictive assumption, and more work is now emerging that builds on Bénassy-Quéré *et al*. (2001), by taking account of host market interdependencies. Xing and Wan (2004) examine how currency devaluation affects the relative comparative advantage of FDI recipients. This model is in the spirit of Xing and Zhao (2008) in its role for reverse imports, but focuses on relative exchange rates and the effects these have on relative costs. They show that if a FDI recipient's exchange rate appreciates more than that of a rival, its relative FDI will be diverted to the rival.

As part of emerging literature on multilateral resistance, Egger *et al*. (2007) present a three-country model of exports and FDI. They track two channels for effects of the exchange rate. First, a positive bilateral effect following a host currency appreciation that raises MNE profits from affiliates (revenue

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effect). Second, an induced increase in relative production costs following the same bilateral appreciation (competition effect). This has a negative effect on bilateral activity of MNEs, because costs are higher relative to other economies that serve the host country with exports. The third country exchange rate effects are the reverse of the bilateral effects: a negative revenue effect, and a positive competition effect. Which of the competition or revenue effects dominates is determined by skilled labour endowments, transport and foreign investment costs. Where skilled labour is abundant and transport costs high, the model predicts that the third country exchange rate effect will be positive. In Bénassy-Quéré *et al*. (2001) the exchange rate effects of third countries come through correlations that affect location choice of risk averse firms, which invest in countries whose exchange rates are negatively correlated to other exchange rates as a way of diversifying FDI. However, the response of firm's FDI activity to exchange rates in Egger *et al*. (2007) is determined by factor endowment, transport and FDI costs.

In summary, predictions from the body of theoretical work are ambiguous, across and within models. Given the nature of FDI, it seems reasonable that no single model can encompass FDI behaviour. The predicted relationship between exchange rates and FDI varies depending on factors such as configuration of revenues and costs, FDI types, or source of exchange rate shock. The implication of ambiguity at the theoretical level is that it remains the task of empirical work to determine the nature of the relationship on a case by case basis. Unsurprisingly, ambiguity at the theoretical level is reflected in the empirical work. Explanations for the mixed empirical findings may lie in the heterogeneity of the work, reflecting the ambiguous theoretical predictions, and also may be due to data problems and model specification issues.

3. Empirical evidence and model specification issues

3.1 Empirical evidence

Turning first to the most general observation on this body of empirical work, it is evident that the greatest constraint facing researchers is the paucity of data. The empirical evidence is characterised by compromises between the most theoretically appropriate approach and what is possible given this constraint. A major source of data is capital flows from the balance of payments. These data have the advantage of being internationally comparable, but because growth in FDI is a relatively recent phenomenon, the time-series data currently available are for fairly short time spans making estimation difficult. Also, FDI inflows and outflows are defined as net changes in asset holdings that obscure nuances in the behaviour of FDI flows. In this regard, count data appear to provide better information, but the drawback with count data is that information on the total amount of investment occurring is lost. The most commonly used data set, Thomsons, does not have the information on the amount of flows for firms not listed on the stock

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exchange. Another major problem with balance of payments data is that FDI flows may not be disaggregated beyond the manufacturing sector level. More disaggregated data are available for some countries (for example from the US Bureau of Economic Analysis), but they do not always have a foreign counterpart to facilitate spatial analysis of FDI flows. Furthermore, such data are often confidential in nature, hence difficult to access. Therefore, typically, at the firm level, little exists unless it has been collected for other purposes, such as business registers or enterprise surveys, and so may be inadequate in some way. Because most theoretical models are firm investment decision representations, firm level data are required, but such data are the least available.

A summary of empirical findings is presented in Appendix 1. The collection of studies is not exhaustive, but hopefully representative enough. The obvious feature of this body of work is that is has mostly been conducted on aggregated data. Theory suggest that the response of FDI to exchange rates may differ among industries and by FDI motive, so exchange rate–FDI linkages are likely to be revealed at disaggregated levels. Unfortunately, because most of the evidence exists at the aggregate data level, these linkages may be masked, and the results probably suffer from aggregation bias. Froot and Stein (1991) found that IFDI to the US was negatively correlated with the US dollar. However, disaggregating FDI inflows by industry, the coefficient significance varies. This outcome is common to many studies that combine aggregate and disaggregate analyses, suggesting that aggregate studies mask important differences across industries.

With this caveat in mind and turning first to exchange rate level effects, there seems to be reasonably strong support, with exceptions, for the proposition that a depreciation of the host country's currency encourages FDI inflows. For the results at the aggregate level, 64 per cent of these papers find that a depreciation of the host country's currency increases IFDI. The remainder find that the exchange rate is insignificant, that a host appreciation increases IFDI, or that results are mixed. This holds broadly for studies with industry data, but, for firm level studies, all found significant exchange rate effects: either increased IFDI after a depreciation of the host's currency, or a significant response determined by FDI motive (for example Lin *et al*. 2006).

Focusing on subgroups by country, most evidence for the USA, supports the proposition that a dollar depreciation increases IFDI (Goldberg and Kolstad 1995; Froot and Stein 1991; McCorriston and Sheldon 1998). However, exceptions are Campa (1993) and Alba *et al*. (2005) who find a dollar appreciation increases IFDI, and exchange rate levels are found to be insignificant in Tomlin (2000) and Amuedo-Dorantes and Pozo (2001). For the Australian evidence, Faeth (2005) finds mixed results, and Yang *et al*. (2000) find the exchange rate to be insignificant for a similar time span, Tcha (1997) finds a significant response. For European economies, Gast (2005) finds an appreciation of the home country increases FDI outflows. A similar result is found in Kosteletou and Liargovas (2000), but De Sousa and Lochard (2004) find the exchange rate is insignificant.

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Turning next to evidence on volatility, we see that it is quite mixed. Of the studies that include a volatility variable, almost half find a significant negative effect, less than 15 per cent find a significant positive effect, with the remaining evidence inconclusive or mixed. For the papers using industry data, most found volatility depressed FDI. A major problem for the applied econometrician is the choice of volatility proxy. Theoretically, a distinction can be made between variability or volatility on the one hand, and uncertainty on the other. Variability usually means risk and uncertainty implies exchange rate movements are unexpected. In some work, it is not clear exactly what is meant by volatility, and the term is sometimes used interchangeably with uncertainty to the confusion of the reader. Most of the theoretical work models variability (for example, Cushman 1985; Goldberg and Kolstad 1995; Bénassy-Quéré *et al*. 2001), others model uncertainty (for example, Sung and Lapan 2000; Kiyota and Urata 2004). Typically, researchers use a standard deviation measure to proxy variability. Where uncertainty is the key concept, GARCH measures are often used.

Much has been written on the shortcomings of volatility proxies (for example, Lanyi and Suss 1982; Arize 1997). In practice, there are two solutions to the problem: employ one measure that most closely represents the theoretical concept or include several different measures to determine the sensitivity of the results. The latter approach works well if results are robust, but is awkward if they are not, because there is no basis to accept one result over another. For example, Amuedo-Dorantes and Pozo (2001) focus on the most appropriate proxy and find a GARCH measure is significant, but not a standard deviation measure. This does not imply that GARCH is the best measure, simply that results can be sensitive to choice of measure. Some argue that the choice probably makes little difference statistically (for example, Carruth *et al*. 2000). Instances where this is the case are Iannizzotto and Miller (2005), and Clare (1992).

Beyond this, some intriguing questions emerge from the use of volatility proxies. Firstly, as Medhora (2002) notes, where the researcher is interested in uncertainty, measured variability is only a proxy for the latent variable of uncertainty. Low levels of measured variability could be associated with measures of high uncertainty and vice versa. Whether any findings adequately reflect the relationships between FDI response to exchange rate uncertainty or investor's expectations is an open question. Secondly and related to this, is the question of what effects these proxies might be picking up. Volatility could be proxying for some other factor that is excluded (for example, if the exchange rate is endogenous, its variability reflects underlying volatility in macroeconomic fundamentals as in Russ (2007a)). The problems associated with volatility proxies raise interesting issues, which may be largely unresolvable, but do provide fertile ground for future research.

In summary, the problem of aggregation bias may be generating mixed results. As such, a strong case can be made for the use of firm level data. However, data problems are probably only part of the explanation for the

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mixed empirical evidence. Another is model specification, and before leaving the empirical evidence we discuss developments in the context of particular categories of econometric models: hazard models, binary and count data models, time series and pooled data regression models.

3.2 Hazard rate models

These models are often used to assess the impact of exchange rate volatility on the timing of investment. One appeal of hazard analysis is that it comes closer to the ideas underlying some of the theory than the empirical models used to assess the risk aversion approach. In hazard models, the observations are defined as time spells between a start date when an investment opportunity is created, and an investment date. The dependent variable is the hazard rate or likelihood of a firm to invest in each period. Cox's proportional hazard model is a semi-parametric form (as the baseline hazard is not estimated) often used in the literature. The conditional probability that investment happens at time $t + \Delta t$ given that it has not occurred at time t, is estimated as a function of time varying 'covariates', amongst them an exchange rate measure. The model assumes proportionality (a multiplicative relationship between baseline hazards and the covariates), that the effect of the covariates is log-linear, and that the baseline hazard is the same for all firms. The proportionality assumption allows the baseline to remain unspecified.

Kogut and Chang (1996) use Cox's proportional hazard model to estimate investment delays for the FDI of Japanese companies into the USA. They find that an appreciation of the Yen increases the likelihood of FDI, and that earlier investments in US market serve as 'platforms' for later entry. Lin *et al*. (2006) estimate a hazard model for Taiwanese FDI into China, and find that firm motives matter. Specifically, exchange rate volatility delays market seeking FDI, but hastens export substituting FDI.

One of the difficulties with the application of this model is the collection of data on investment delays, and in particular it is difficult to pinpoint an exact starting time for investment opportunities. This will be especially so for research on FDI, as many different policy changes have freed up international production, and these have been introduced at different times. On the basis that there was little investment by Japanese firms before the mid 1970s, Kogut and Chang (1996) assume a starting point to be 1976, but this is slightly arbitrary. Things are more clear-cut in Lin *et al*. (2006) because Taiwanese firms were prohibited from investing in China before 1987, defining the creation date for investment opportunity. The fall of the Berlin Wall is selected as the creation date of an investment opportunity in Altomonte and Pennings (2004), and they control for mismeasurement in their investment spell data by including a variable that measures the time pattern of liberalisation.

Of particular interest in this field is whether to estimate a parametric or a semi-parametric model. The assumption of proportionality in Cox's model allows the baseline hazard to remain unspecified, thus avoiding any bias from

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baseline hazard misspecification, albeit being less efficient if the baseline is properly specified. Box-Steffensmeier and Jones (2004) put forward an argument in favour of Cox's model, on the grounds that the baseline hazard can be thought of as a statistical 'nuisance', in that often there is no theoretical interest in the underlying hazard itself. Instead theory has more to say about relationships in terms of predictions about the covariate estimates. Given that misspecification bias is arguably a worse problem than inefficiency, the question is whether the interpretation or information in the baseline is sufficiently interesting to warrant estimation of a parametric form.

Altomonte and Pennings (2004) argue just this point. They claim that a greater understanding of the relationship between investment and uncertainty can be gained by estimating the baseline. Within the context of real options theory, there is a value of earnings that triggers investment, and firms require a higher profitability when uncertainty increases. Increased uncertainty also increases the value of the option to delay investment, and the authors focus on the question of whether this actually delays investment. They present reasons why increased uncertainty may not delay investment, citing Sarkar (2000), who suggests that high levels of volatility increase the probability that the threshold value for investment is reached. That is, there may be non-linearities in the relationship between uncertainty and the probability of investment occurring, and under certain conditions uncertainty might have a positive effect on investment. When an investment opportunity is new, the hazard rate increases in uncertainty, but if the opportunity exists for longer, the hazard rate declines. Although their application is for FDI and profit uncertainty, the results have the same implications for work on exchange rates. The authors estimate both Cox's model and a parametric specification that allows for non-linearities in the baseline hazard. They discriminate between the specifications by testing whether the baseline hazard is constant over time, and reject Cox's specification. The findings indicate that uncertainty does negatively affect investment, but the relationship between investment and uncertainty works through the effect of uncertainty on profitability, not on the option value of waiting to invest.

General conclusions cannot be drawn from this data set alone, except to say that actually estimating the baseline hazard may provide richer information, depending on the theoretical context. Misspecification bias is arguably a worse statistical problem than inefficiency, the question is whether the interpretation or information in the baseline is sufficiently interesting or not. If there is something to be gained informationally, then the trade off is not just between efficiency and bias, but between both information and efficiency on the one hand and bias on the other. Where theories of investment behaviour are less focused on time dependency and more focused on the relationship between the occurrence of FDI and exchange rate covariates, use of Cox's model is appropriate. Finally, it is easy to test the assumption of proportionality underlying Cox's model, so it should not go untested in empirical work.

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3.3 Qualitative dependent variable and count data models

Where available data is limited, it may be possible to construct a data set of entry counts or foreign vs. domestic investment events from historical records. These types of model may be useful where there are data on entry numbers, but no identifiable investment opportunity starting date. Urata and Kawai (2000) use a logit model for the location choice of Japanese manufacturing firms, and find a positive relationship between a host currency depreciation and FDI entry, and a negative effect from exchange rate volatility. With a focus on exchange rate endogeneity, Russ (2007b) employs single equations and a Poisson model to explore difference between first-time and veteran investors for the OECD. Behaviour is found to vary between investor type, and to depend on the source of volatility.

Controversial areas in this modelling approach centre round the appropriate model specification for count data, and the possible presence of temporal FDI interdependence. Campa (1993) explores the determinants of FDI entries into US industries using a Tobit model. The number of FDI entries is the dependent variable. He finds that an expected dollar appreciation increases FDI, that volatility deters entry, and that sunk costs are significant. However, Tomlin (2000) criticises the use of Tobit models for count data. Tomlin analyses the sensitivity of the results to specification of the dependent variable, estimating a count data model (zero inflated Poisson (ZIP)) and a Tobit model. The results are sensitive to specification, and in particular, the exchange rate is insignificant in the statistically preferred model. Tomlin concludes that misspecification bias can arise from modelling discrete data with continuous distributions. This criticism cannot, however, be levelled at the use of Tobit model in Campa *et al*. (1998), where the dependent variable is continuous, and where negative and significant exchange rate effects were found.

Other examples that report ZIP estimates are Blonigen (1997) and Buch and Kleinert (2006). Blonigen (1997) found evidence in favour of his theoretical model using data for the USA. Buch and Kleinert (2006) use sectoral data for German outbound FDI (OFDI). Their focus was to distinguish between the explanations of Blonigen and Froot and Stein, and they find evidence in favour of the goods market imperfections assumptions from Blonigen (1997).

Iannizzotto and Miller (2005) use firm level data to test the effects of the exchange rate on IFDI to the UK. Statistical testing rejects the ZIP in favour of a standard Poisson model. They conclude that a real appreciation of Sterling reduced UK IFDI.

Alba *et al*. (2005) criticise the standard ZIP model by introducing the idea of FDI interdependence over time. The authors use a panel data Markov ZIP (MZIP) model for IFDI to the USA. The idea of interdependence is linked to the favourability of a foreign investment environment. Rival firms follow other investors into a favourable, and out of an unfavourable environment. Interdependence takes account of unmeasurable factors, such as corporate rivalry, domestic investment conditions, and interactions with rivals in other

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foreign markets. Interdependence in the MZIP model is characterised by the existence of both favourable and unfavourable FDI states. They explore interdependence by comparing the ZIP and MZIP models, finding that inference differs. Again, this suggests that different models for FDI lead to different results about parameter significance. Their findings reconfirm those of Campa (1993), and they provide evidence that FDI is interdependent over time. When industries are favourable to FDI, exchange rates have their greatest impact.

3.4 Single equation time series models and panel data models

Much of this work builds on the model of Froot and Stein (1991): a regression of aggregate FDI/GDP on exchange rates and a trend variable. Froot and Stein found that IFDI to the USA was negatively correlated with the US dollar. They disaggregate FDI inflows, and find that results vary across industries. Similar results can be found in Dewenter (1995), Goldberg and Kolstad (1995), McCorriston and Sheldon (1998), Gopinath *et al*. (1998) and Kiyota and Urata (2004). An obvious problem with the simplest versions of such a regression is bias that may arise from the lack of controls. Most researchers do include some controls, and there is quite a broad range considered in the literature. Unfortunately, there is not much guidance from theory on the appropriate set of controls, which raises the question of what effect the choice set of variables will have on the estimates.

One alternative to times series analysis is a panel data model, and of these, gravity models have been popular. A typical gravity equation includes the exchange rate level and volatility, and other variables allowing for distance and country effects. Estimation of these models has generated significant negative (Bénassy-Quéré *et al*. 2001; Gast 2005) and positive (Görg and Wakelin 2002), as well as insignificant coefficients (De Sousa and Lochard 2004; Jeanneret 2005). To some extent, gravity models are associated with a standard set of controls, but they are not guided by any particular theoretical model of FDI.

The issue of fragility of coefficient estimates to changes in the mix of included variables is considered in Chakrabarti (2001). He uses extreme bounds analysis (EBA) to explore the robustness of estimates of coefficients on the determinants of FDI to changes in the conditioning information set. That is, there may be competing regressions for the relationship between FDI and exchange rates, and the estimated sign on the exchange rate coefficient may depend on which set of regressors is included. EBA defines variables as 'free' (always included) or 'doubtful' (should possibly be included). A focus variable is chosen, and regressions are estimated with different combinations of the doubtful, and all the free variables to see if the coefficient on the focus variable changes sign and significance. Positive coefficients tend to be generated when exchange rates are combined with openness, domestic investment, and government consumption, but when domestic investment is omitted, negative coefficients are generated. There are, of course, problems associated with

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EBA, which are outlined in McAleer *et al*. (1985). For example, there is often not adequate diagnostic validation presented for the models that produce the bounds. More fundamentally, they show that coefficient fragility depends on the classifications of variables in the regressions as either doubtful or free. These criticisms reintroduce to EBA the possibility of selectivity in reporting that motivate its use. Indeed, the fact that there is no single theoretical model of FDI, implies that there is really no consensus about the set of free variables. Beyond this, the problem of coefficient fragility is common to most econometric modelling, but it may be a particularly sensitive area for FDI modelling, given the lack of theoretical guidance and the absence of availability of data on controls under consideration.

Another issue in the empirical work is temporal parameter stability. The general argument is made, that investors were less capable at managing exchange rate risk in years immediately after exchange rate floats, but that over time managerial capabilities have improved and availability of risk management products has grown. Stevens (1998) uses the specification of Froot and Stein (1991) to test for stability. He finds that the sign and significance of the estimate changes between sub-samples. Ihrig and McIntyre (1999) respond by establishing a business cycle link between FDI and exchange rates. They show a statistically temporally stable relationship between FDI exchange rates and net worth when they isolate the business cycle component of IFDI.

More recently, Jeanneret (2005) questions the persistence of a negative relationship between FDI and exchange rate volatility for OECD countries. He estimates a gravity model and finds the negative effect of exchange rate volatility declines over time. Görg and Wakelin (2002) also find a declining negative impact of volatility.

In summary, there is a weakness in the body of empirical evidence mostly due to unavoidable data problems. This constraint has led to very little firm level research, and this is the level at which the most informative results can be expected. The evidence is quite mixed, especially for volatility effects. This lack of consensus might be partly due to the heterogeneity of the studies, reflecting the complex nature of FDI itself. Because of this complexity, it may be only reasonable to suggest that the exchange rate will have an ambiguous effect which is reflected in theoretical and empirical work. Alternatively, empirical models may yield mixed results because of model specification and data issues. Given the fact that results are not robust to changes in model specification, researchers should always invest efforts in some basic specification tests. In reality, both factors are probably contributing to the empirical state of play in this field.

4. Concluding comments

In this study, an evaluation of the empirical evidence and theoretical literature on exchange rates and FDI has been presented. At the theoretical level,

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a lot of ground has been gained. Some recent contributions encompass earlier alternative models, offering a way to reconcile studies empirically. Other emerging work focuses on exploration of the complexities of FDI. In particular, different behavioural assumptions about FDI motive, and investment environment, have increased understanding of FDI-exchange rate links. Further research in this direction would yield valuable insights into when and how exchange rates may be important for FDI. Most of the work that models FDI, exports and exchanges rates assumes that modes of entry are substitutes. There is a fair amount of empirical evidence on intra-firm trade between parent and foreign affiliate firms, so an interesting avenue for exploration might be the introduction of some complementarity between FDI and exports. Further work on the way different macroeconomic shocks affect FDI-exchange rate interaction will also be valuable for those involved with monetary policy, and to improve appreciation of the regional distribution of FDI. Although not covered in this review, research into currency crises and the composition of capital flows is another worthy area for exchange rate-FDI research.

Unfortunately, as Blonigen (2005) points out, the empirical work is currently not as rich as the theoretical work in this area. We suggest that this is mainly because it is impaired by data problems and model specification issues. Work in this area is likely to be challenging for some time due to data constraints. Initially, most progress is likely to be made at the micro level, and researchers may have to rely on firm or industry survey data. The collection of such data could also allow researchers to explore the use of firm specific measures of uncertainty and exchange rate expectations. There is a great deal of room for research into different measures of exchange rate variability. As an alternative to survey information, count data will continue to be useful, and we are currently focused on testing some of the propositions explored in this article for FDI in food manufacturing. As the phenomenon of FDI evolves, more and better data should become available, opening up the possibility that more satisfactory progress can be made. However, to an extent, progress at the macro level will require time for an adequate span of data for researchers to be able to pick up and distinguish dynamic effects of exchange rates.

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Appendix 1 Regression results from empirical studies on exchange rate – FDI linkages

Study	Major findings
Froot and Stein (1991)	Host currency depreciation increases IFDI
Klein and Rosengren (1994)	Host depreciation increases IFDI (relative wealth effect)
Bayoumi and Lipworth (1998)	OFDI to host increases after host currency depreciation
Goldberg and Klein (1998)	Exchange rates significant for SE Asia, not Latin America
Feliciano and Lipsey (2002)	Host currency depreciation increases foreign acquisitions but is insignificant for new establishments
Matteson and Koo (2002)	Exchange rate level insignificant, volatility effect negative
Ihrig and McIntyre (1999)	FDI-exchange rate link exists in filtered not raw data
Cushman (1985)	Level mixed significance, significant reductions of FDI for expected real appreciation of the foreign currency, significant increases FDI associated with risk
Cushman (1988)	Expected $US appreciation reduces IFDI, increased exchange rate risk positively correlated with FDI
Goldberg and Kolstad (1995)	If demand and exchange rate shocks are correlated, volatility increases FDI
Bénassy-Quéré *et al*. (2001)	Host currency depreciation increases FDI, volatility decreases FDI, significant exchange rate interdependence effects
Urata and Kawai (2000)	Levels and volatility significant – signs mixed for different industries
Kosteletou and Liargovas (2000)	For large countries causality runs from exchange rate to FDI, causality is bi-directional for small countries-mixed sign on exchange rate
Amuedo-Dorantes and Pozo (2001)	Levels insignificant, volatility affects FDI negatively
De Menil (1999)	Volatility has positive effect on FDI
Chakrabarti and Scholnick (2000)	Level and volatility insignificant, skewness significant: relatively large devaluations generate mean reverting expectations, increasing IFDI
Campa *et al*. (1998)	Host currency depreciation increases IFDI
Kiyota and Urata (2004)	Host currency depreciation increases IFDI, volatility affects FDI negatively
Bailey and Tavlas (1991)	Volatility insignificant
Gopinath *et al*. (1998)	Volatility reduces FDI, appreciation of US$ increases OFDI and sales
Blonigen (1997)	Host currency depreciation increases IFDI
McCorriston and Sheldon (1998)	Host currency depreciation increases aggregate IFDI, results mixed for industry
Harris and Ravenscraft (1991)	Wealth gains after cross-border take overs positively related to host currency depreciation
Kogut and Chang (1996)	Home currency appreciation increases OFDI
Swenson (1993)	Host currency depreciation increases IFDI
Dewenter (1995)	Host currency depreciation increases absolute IFDI, not FDI relative to domestic investment
Lafrance and Tessier (2001)	Volatility and level insignificant
Jeanneret (2005)	Volatility effect negative, decreasing over time

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Appendix 1 *Continued*

Study	Major findings
Crowley and Lee (2003)	Volatility effect differs across countries
Campa (1993)	Volatility deters FDI, level effect is positive
Görg and Wakelin (2002)	Exchange rate significant, effect differ across locations, volatility has positive effect except for France
Pain and Van Welsum (2003)	Host currency depreciation increases IFDI – volatility increases FDI
Barrell and Pain (1996)	Expected short term exchange rate changes affect timing of investment – expected appreciation of $US delays OFDI
Ricci (1998)	Volatility promotes agglomeration effects of FDI, except for small countries
Tcha (1997)	Negative effect for inbound, positive effect for outbound
Faeth (2005)	Exchange rate effect positive contemporaneously, negative after 1 lag.
Yang *et al*. (2000)	Exchange rate insignificant
Xing and Wan (2004)	If host currency appreciates relative to source country currency more than that of rival host, FDI increases to rival host
Lin *et al*. (2006)	Level-positive for market seeking, negative for export substituting, exchange rate trend – positive, results depend on firm motive:–volatility delays market-seeking FDI, accelerates export-substituting FDI
Tomlin (2000)	Exchange rate level and volatility insignificant-exchange rate drift-significant and incorrect sign
Brzozowski (2006)	Volatility and uncertainty negatively affect FDI
Trevino *et al*. (2002)	Exchange rate insignificant
Iannizzotto and Miller (2005)	Volatility insignificant
De Sousa and Lochard (2004)	Volatility negatively affects FDI, level insignifiant
Becker and Hall (2003)	Volatility negatively affects FDI-exchange rate covariances significant, appreciation of Sterling reduces IFDI
Clare (1992)	Volatility negatively affects FDI
Marchant *et al*. (1999)	Exchange rate insignificant
Buch and Kleinert (2006)	Exchange rate effects operate via goods not capital markets frictions
Barrell *et al*. (2004)	Volatility effect negative-market power doesn't reduce impact of exchange rate uncertainty – exchange rate correlations affect location choice
Gast (2005)	Exchange rate insignificant
Ning and Reed (1995)	$US depreciation stimulates OFDI
Alba *et al*. (2005)	Volatility insignificant. FDI interdependent: a favourable state for FDI and strong US dollar increase IFDI
Halicioglu (2001)	Exchange rate insignificant
Egger *et al*. (2007)	Exchange rate effects differ between USA and Japan: $US depreciation increases both Japanese and US OFDI
Grosse and Trevino (1996)	$US depreciation increases IFDI
Russ (2007b)	FDI behaviour differs between veteran and first time investors, and effects depend on source (domestic or foreign) of interest rate volatility that drives exchange rate risk

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