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A global analysis of factors impacting the intensive and extensive margins of bilateral foreign direct investment

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KEYWORDS

extensive margin, foreign direct investment, gravity model, intensive margin

1 | INTRODUCTION

Recent theoretical models for foreign direct investment (FDI) rely on partial or general equilibrium (Anderson, Larch, & Yotov, 2017; Bergstrand & Egger, 2007; Markusen, 2002). Those models are mainly constructed for a world with two countries and derive the determinants of bilateral FDI by finding the analytical or numerical solutions for the equilibrium. Many empirical papers apply these models to analyse drivers of FDI, considering both home and host countries' characteristics. However, the majority of these studies, such as Davies (2008) and Araujo, Lastauskas, and Papageorgiou (2017), focus only on FDI from developed countries (DCs); FDI between less-developed countries (LDCs) has been neglected. In their extensive survey of FDI studies, Paul and Singh (2017) also show that there is still a need for a global study with an extensive sample to compare the results between different groups of countries. Furthermore, most of the previous studies ignore the fact that zero FDI is far more prevalent than positive FDI. Figure 1 indicates that 60–70% of country pairs do not invest in one another over the whole period, 2001–12. Simply pooling data of both zero and positive values into a one-stage regression such as OLS, tobit or Poisson pseudo-maximum likelihood (PPML) may lead to inappropriate results. Recent theories of FDI, as proposed by Razin and Sadka (2007) and Anderson et al. (2017), also separate determinants of zero and positive FDI which corresponds to the extensive and intensive margins of FDI, respectively. The extensive margin of FDI refers to the decision of whether or not to invest, while the intensive margin is concerned with the amount of FDI invested once the decision to invest is made.

This is the first study to apply the formal structural gravity model of FDI developed by Anderson et al. (2017) to find the determinants of both FDI margins, especially the role of technology capital. Using the biggest and most up-to-date data set of 110 countries over nine years, 2004–12, this is also the first study to examine the results for country groups by development extensively at a global level. There are only a very small number of empirical studies analysing the determinants of both FDI

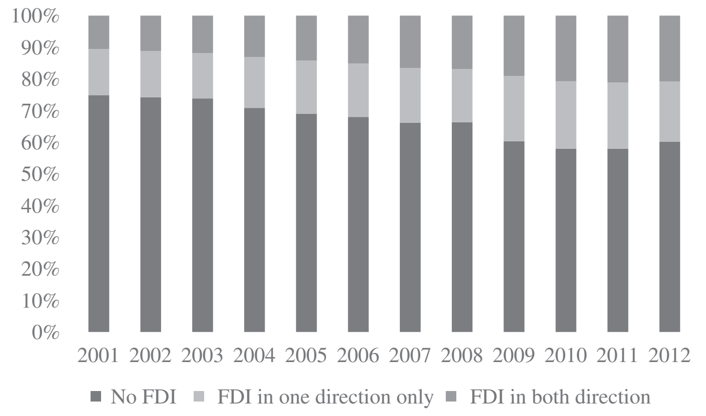

FIGURE 1 Distribution of country pairs based on direction of FDI stocks.
Data source: UNCTAD, 110 countries

margins, but they do not consider FDI between developing countries and do not apply panel methods. I find that source country technology capital has a significant and positive impact on both FDI margins and this result is consistent across different country groups. Bilateral investment treaties play a significant role only in determining the probability of investment. In addition, many variables, usually regarded as determinants of FDI, such as source country GDP, common currency, common religion and trade agreements, are not statistically significant in the case of FDI from LDCs.

The remainder of the paper proceeds as follows. The next section presents a literature survey of determinants of both margins of FDI. Section 3 describes the theoretical framework and hypotheses, while Section 4 discusses the multilateral resistance terms in empirical studies in international trade. Data and hypotheses are given in Section 5, followed by the methodology in Section 6. Section 7 presents the regression results. Section 8 concludes and suggests extensions and improvements for future studies. Also, details of data collection and data quality, and some additional regression results are reported in an Appendix S1.

2 | LITERATURE REVIEW

Although the general literature on determinants of FDI at the aggregate or bilateral levels is vast, there are only a handful of empirical studies analysing the drivers of both intensive and extensive margins of FDI. Razin and Sadka (2007) pioneer the development of FDI models explaining zero and positive FDI separately and then empirically test their theoretical models using OECD data. Besides typical gravity variables, the authors find that the intensive and extensive margins of FDI are not affected identically by the same factors such as corporate tax rates and set-up costs. Davies and Kristjánsdóttir (2010) investigate the impact of natural resources on FDI inflows to Iceland over the period 1989–2001. Their empirical results show that distance and trade openness play a more important role in the probability of investment than the investment amount. Cavallari and d'Addona (2013) examine FDI between 24 OECD countries from 1985 to 2007 and find a negative influence of output volatility on the extensive margin. Garrett (2016) employs data from 101 countries between 1995 and 2002 and finds the significant role of productivity thresholds in FDI decisions. Meanwhile, Araujo et al. (2017) focus on market entry costs as the key factor between the two margins and investigate outward FDI data from OECD countries to the rest of the world. Eicher, Helfman, and Lenkoski (2012) use a panel data set including 46 countries and estimate a wide variety of determinants of FDI. There are aspects of these studies that can be improved on.

In these studies, the estimation equations are all of the gravity type without a model clearly showing the functional form of the relationship. Particularly, their general or partial equilibrium models tend to show just the intuitive relationships between FDI and other variables. In addition, they all employ panel data but solely rely on pooled estimation techniques for the intensive margin (outcome equation) and/or the extensive margin (participation equation). Araujo et al. (2017) apply panel estimation for the volume equation but simply employ pooled probit for the participation equation. More suitable estimation methods for panel data may lead to significantly different results. In addition, Araujo et al.'s (2017) study does not control for time fixed effects in any of their estimations, and thus, their results can be affected by the time trend.

Last but not least, all of these studies employ a Heckman selection process (heckit) to estimate determinants of zero and positive FDI. However, these studies do not employ a statistical test to show if the heckit estimation method is truly needed. If the participation and outcome equations are not correlated, for cross-sectional data the lognormal hurdle model is a better choice as it estimates the two margins separately and does not require a valid exclusion restriction. According to Wooldridge (2010), if we do not find a valid exclusion variable, regression results from heckit are imprecise due to the severe collinearity resulting from the inclusion of the inverse Mills ratio in the outcome equation. Some studies, such as Davies and Kristjánsdóttir (2010), Eicher et al. (2012) and Razin and Sadka (2007), have used a dummy for FDI in the past year as the exclusion variable. However, it is likely that the dummy also significantly impacts the volume of FDI as when the firm has invested in a country before, it would likely invest more or less in the following years due to the accumulation of investment experience in the host country. Araujo et al. (2017) use the cost to register a business as the threshold for the two margins. This is probably the closest indicator for the fixed set-up costs in the FDI literature so far and similar to the use of regulation costs for firm entry in Helpman, Melitz, and Rubinstein (2008). But, using indicators for set-up costs may likely reflect a country's investment environment in general. As a result, they may also significantly affect the amount of FDI if included in the outcome equation. Finding a valid exclusion variable for heckit is not an easy task. In this study, I do not find a strongly valid exclusion restriction variable for heckit.

3 | THEORETICAL FRAMEWORK AND HYPOTHESES

The gravity model of international trade has been widely applied for FDI. However, bilateral trade is not the same as bilateral FDI. In FDI, the firms invest and produce inside the host country and are affected directly by the features of the host country. Hence, it is desirable to construct a "formal" structural gravity model specifically designed for FDI. Fortunately, Anderson et al. (2017) have made a novel contribution to the FDI literature by developing the first formal structural gravity model specifically for bilateral FDI. Their model clearly shows the functional form of the relationship between FDI and its drivers. This model resembles, but is not identical to, the structural gravity model in international trade constructed by Anderson and van Wincoop (2003). FDI in this model is in the form of non-rival technology capital. This type of capital can be employed in multiple locations at the same time without reducing its value in any particular location. The standalone gravity system for FDI is as follows[1]:

[1]For more details about how to derive the gravity system for FDI, see Anderson et al. (2017). The time index t is suppressed for brevity as all variables are time-specific.

$$FDI_{ij} = \begin{cases} \frac{\beta\phi_j^2\eta_i^2}{1-\beta+\beta\delta_j}\omega_{ij}\frac{E_i}{P_i}\frac{Y_j}{M_i} & \text{if } \omega_{ij}M_i > 1 \\ 0 & \text{if } \omega_{ij}M_i \le 1 \end{cases}, \tag{1}$$

$$P_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{\pi_j}\right)^{1-\sigma} \frac{Y_j}{Y}, \tag{2}$$

$$\pi_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{P_i}\right)^{1-\sigma} \frac{E_i}{Y}, \tag{3}$$

where i denotes the source country; j denotes the host country; FDI_{ij} is FDI stocks from i in j; β is the discount factor in the consumer's utility function; ϕ_j is the production share of FDI; η_i is the share of technology capital; δ_j is the depreciation rate of technology capital[2]; ω_{ij} is country j's openness to FDI from country i; M_i is the technology capital stock; σ is the elasticity of substitution; P_i is the inward multilateral resistance term (IMR); π_j is the outward multilateral resistance term (OMR); Y is the total world income; E_i is the source country's expenditure; Y_j is the host country's production or income; and t_{ij} is trade costs from i to j.

Since η_i and M_i represent the share of global technology capital and the total amount of technology capital of the source country, respectively: $\eta_i = \frac{M_i}{\sum_i M_i} \Rightarrow M_i = \eta_i \sum_j M_i$. Also, according to Yao, Mela, Chiang, and Chen (2012), followed by Anderson et al. (2017), β is very close to 1 (~0.98). Therefore, for simplicity, setting $\beta = 1$ and replacing $M_i = \eta_i \sum_j M_i$, the structural gravity system becomes:

$$FDI_{ij} = \begin{cases} \frac{\phi_j^2\eta_i}{\delta_j}\omega_{ij}\frac{E_i}{P_i}\frac{Y_j}{(\sum_i M_i)} & \text{if } \omega_{ij}M_i > 1 \\ 0 & \text{if } \omega_{ij}M_i \le 1 \end{cases}. \tag{4}$$

Taking the log of Equation (4) for positive FDI leads to a log-linear equation for the intensive margin of FDI:

$$\ln FDI_{ij} = -\ln\left(\sum_i M_i\right) + \underbrace{\ln E_i + 2\ln\eta_i - \ln P_i}_{\text{Source country's characteristics}} + \underbrace{\ln Y_j + 2\ln\phi_j - \ln\delta_j}_{\text{Host country's characteristics}} + \underbrace{\ln\omega_{ij}}_{\text{Pair characteristics}}. \tag{5}$$

Equation (5) shows the three sets of FDI determinants and direction of impacts for variables of interest, with $\ln(\sum_i M_i)$ acting as the constant term. This equation implies a "strong" restriction on the parameters, that is, taking the values of either ±1 or 2 according to Equation (5). However, as I have to use a number of proxies for variables in the model in the regression analysis, the magnitude of estimated coefficients is prone to differ from these values. Thus, I will focus on testing the model's predictions on the direction of impacts rather than their magnitudes.

[2]Anderson et al. (2017) use δ_M to denote the depreciation rate of technology capital. However, I use δ_j to clarify that this is the depreciation rate in the host country j.

The share of FDI production in the host country is calculated as:

$$\phi_{jt} = \frac{\alpha_{j(t-1)}\left(\frac{FDI^{in}_{j(t-1)}}{K_{j(t-1)}}\right)}{1+\alpha_{j(t-1)}\left(\frac{FDI^{in}_{j(t-1)}}{K_{j(t-1)}}\right)},$$

where $FDI^{in}_{j(t-1)}$ is the total inward FDI stocks in year $(t-1)$; $K_{j(t-1)}$ is the physical capital stock in year $(t-1)$; and $\alpha_{j(t-1)}$ is the capital share of production in year $(t-1)$, which equals 1 minus the labour share of production, assuming that capital and labour are the only two factors of production.[3]

According to the gravity system, the extensive margin depends on only ω_{ij} and M_i, which neglects the fixed set-up costs in the host country that an FDI firm has to face when entering the foreign market. These costs, acting as investment thresholds, are particularly important for the FDI firm's initial decision of whether or not to invest (Araujo et al., 2017; Razin & Sadka, 2007). Therefore, in the estimated models, I augment set-up costs. Moreover, because it is not feasible to identify a priori variables that affect only either intensive or extensive margins, I will use the same set of variables in both margin estimations.

From Equation (5), we can employ a number of variables as potential determinants of bilateral FDI. To be clearer, GDPs of home and host countries can represent E_i and Y_j. Pair variables representing ω_{ij} are common language, common border, colonial relationship, common coloniser, common religion, common legal origin, common currency, bilateral investment treaty (BIT), preferential trade agreement (PTA) and distance. Other country-specific variables affecting FDI are the technical capital share of source country i (η_i), the technical capital depreciation rate in host country j (δ_j) and the FDI share of production in the host country j (ϕ_j). The expected signs of each variable on both margins, listed in Table 1, follow its coefficient sign in Equation (5). Set-up costs should have a negative impact on the probability of investment but no impact on the investment volume. Also, the key variable in this model, source country technology capital share, is expected to have a positive impact on bilateral FDI.

4 | DISCUSSION ON THE MULTILATERAL RESISTANCE TERMS

The multilateral resistance (MR) terms in the structural gravity model for FDI (P_i and π_j) are identical to the MR terms in the gravity model for trade. They represent the ease of market access to the home country and host country compared to the rest of the world. However, different from trade, in the final gravity system for FDI, the OMR term (π_j) is omitted. Anderson et al. (2017, p. 15) explain that "goods sold to *j* from *i* cannot be used elsewhere whereas *i*'s technology used in *j* has no effect on its utilization elsewhere." Theoretically, this can be true with the assumption of non-rival technology capital. However, in terms of empirical estimation, FDI data are literally in monetary value which reflects the transfer of both physical and implicit technology capital simultaneously. If in the form of physical capital, an amount of money sent from country *i* to country *j*, to build a factory, for example, cannot be used elsewhere. Therefore, the exclusion of an OMR term in the theoretical model is not appropriate in empirical analysis with aggregate FDI data.

[3]Anderson et al. (2017) calculate ϕ_{jt} by the same formula but using values of *FDI*, *K*, α in year *t* instead of year $(t-1)$ in their welfare analysis. This approach will lead to an obvious positive relationship between ϕ_{jt} and bilateral FDI from *i* to *j* as $d(\phi_{jt})/d(FDI_{ijt}) > 0$. Thus, I use lagged values of *FDI*, *K* and α to calculate ϕ.

TABLE 1 Variable explanation and expected sign

Variable group	Variable	Abbreviation	Expected sign	Data source
Dependent variable	Nominal FDI stocks, USD (log)	lstock	N/A	UNCTAD
	Nominal FDI flows, USD (log)	lflow	N/A	
Country-specific variable	Nominal GDP, USD (log)	lgdp_s	+	World Bank
		lgdp_h	+	
	Share of global technology capital $\eta \equiv$ share of global number of patent applications, [0, 1]	tech_s	+	World Bank, Own calculation
	Capital depreciation rate δ, [0, 1]	delta_h	−	Penn World Table 9.0
	Remoteness index	remote_s	−	Own calculation
		remote_h	−	
	Start-up costs, [0, 10] (rescale by dividing by 10)	start-up_h	+	World Bank
	Share of FDI in production ϕ, [0, 1]	phi_h	+	Own calculation
	Physical capital stock	K	N/A	Penn World Table 9.0
	Labour shares of production	1-α	N/A	
Pair variable	Bilateral investment treaty, dummy	BIT	+	UNCTAD
	Preferential trade agreement, dummy	PTA	+	World Bank
	Common currency, dummy	currency	+	De Sousa (2012)
	Distance, populated cities, Km (log)	ldist	−	CEPII
	Common border, dummy	border	+	
	Common spoken language, dummy	language	+	
	Common coloniser post 1945, dummy	coloniser	+	
	Ever in a colonial relationship, dummy	colony	+	
	Common legal origin, dummy	legal	+	CIA World Factbook, own calculation
	Common religion index, [0, 10] (rescale by dividing by 10)	religion	+	

The most difficult task with the MR terms is that their functional forms in Equations (2) and (3) are too complex to be calculated with real data. Feenstra (2004) performs estimations based on country fixed effects (FE) and finds that controlling for country FE gives consistent estimates, taking into account the MR terms. Therefore, in the trade literature, from the birth of the structural gravity model with the MRs, there is a tendency to estimate the model with country FE and pair variables and exclude all country-specific variables (Anderson, Vesselovsky, & Yotov, 2016; Fally, 2015; Helpman et al., 2008; Santos Silva, Tenreyro, & Wei, 2014). The main estimation equation in these studies is of the form:

$$Trade_{ij} = \beta_1 i - dummy + \beta_2 j - dummy + \beta_3 X_{ij} + \varepsilon_{ij}, \tag{6}$$

where X_{ij} is a vector of pair variables representing bilateral trade costs. The country dummies are time-invariant for cross-sectional data and time-varying for panels. Although theoretically, these pair variables are directional ($X_{ij} \neq X_{ji}$), in empirical practice almost all studies rely on non-directional (dyadic) variables such as common language, common border and distance for instance. This leads to $X_{ij} = X_{ji}$. For variables that are not pair variables, such as WTO membership, Helpman et al. (2008) construct a dummy for both countries being WTO members and a dummy for both not being WTO members. The regression results for the above set-up will give us some values for β_3. Then, for a particular pair (i, j) no matter what country is the importer or exporter, the marginal effect of X_{ij} on bilateral trade from i to j or from j to i is the same at β_3. This also means any asymmetry in bilateral trade between i and j completely depends on the dummies and the directional error term ε_{ij}. In other words, Equation (6) does not include specific factors explaining the heavily asymmetric features of those bilateral flows as shown in Figure 1.

Moreover, global trade changes dramatically over time, whereas Equation (6) relies on almost all time-invariant or dummy variables such as common language, distance and common border. Estimation will give values for the βs, and all the dummies' values stay the same over time (either 0 or 1). Even if X_{ij} includes some dummies such as sharing a free trade agreement, which may change value from 0 to 1 after some year, these variables' values only change once and then stay unchanged for the rest of the period of analysis. These time-invariant variables do not explain considerably time-varying bilateral trade. Thus, all the weight is put on the error term and the time-varying country dummies.

The fundamental interest of this study is to find the determinants of the bilateral FDI flows, following Anderson et al.'s (2017) theoretical model and applying panel estimation methods. And, the key driver is the source country technology capital share, which is a country-specific variable. Meanwhile, the results of country-specific variables become meaningless with the inclusion of country FE since the FE will absorb the impacts of these variables (Head & Mayer, 2014; Yotov, Piermartini, Monteiro, & Larch, 2016). Given this trade-off, I do not apply country FE in this study as a mean to control for the MR terms. Instead, I follow Baldwin and Harrigan (2011) in using a proxy for the MR terms:

$$Remoteness_i = \left(\sum_j \frac{Y_j}{dist_{ij}} \right)^{-1} (i \neq j).$$

This proxy is the inverse of Harris's (1954) market potential index. It offers a number of advantages: it does not rule out country-specific or monadic variables; it does not require complex estimation methods to deal with the extremely high number of dummies; it is close to the idea of the MR terms because it takes into account global income and trade costs ($dist_{ij}$); and it also represents what the MR terms stand for the ease of market access to that country compared to the rest of the world.

5 | DATA AND HYPOTHESES

5.1 | Country-specific variables

The data set includes 110 countries from 2004 to 2012. There are 11,990 directional pairs or 5,995 nondirectional pairs (dyads). Technology capital share, η, is calculated by the country share in the total global number of patent applications by its residents. The capital depreciation rate, δ, is defined as the depreciation rate of technology capital in the model. However, regarding data availability, there is only the capital depreciation rate of physical capital. Following Anderson et al. (2017), I also use data on the physical capital depreciation rate for δ.

To capture the fixed set-up costs that may affect the investment decision, I use data on starting business distance-to-frontier scores from the World Bank's (2017) Doing Business Database. This score records the official procedures, their time and costs, and minimum capital requirements that a firm needs to undergo in order to start-up a business. As higher scores mean lower start-up costs, I take 100 minus this score to get the fixed start-up costs for each country.

5.2 | Pair variables

Anderson et al. (2017) assume the dependent variable is FDI stocks while Razin and Sadka (2007) use FDI flows. Therefore, I will employ both data series. Among other pair variables, I constructed the common religion index and common legal origin. Important notes on FDI data, BIT, common religion and legal origin are presented in the Appendix S1. Common language takes the value of 1 if a language is spoken by at least 9% of the population in both countries.

Lastly, Equation (5) implies that all variables in the estimation equation are to be in the logarithmic format. Nevertheless, as Head and Mayer (2014) emphasise, the multiplicative form of the gravity model in international trade simply results from its historical usage to resemble the gravity equation in physics. It does not strictly mean that all variables must be in the logarithmic form. I follow the conventional application in the literature to take the log of only continuous unrestricted variables (FDI, GDP and distance). The other variables, including dummies, indexes or share variables, are kept unchanged or rescaled only as they contain numerous zero observations and would be unidentified if logarithmically transformed. The list of variables and data sources is illustrated in Table 1. Variable endings: "_s" denotes source country and "_h" denotes host country; variables without these endings are pair-specific.

6 | METHODS AND PRELIMINARY TESTS

For the extensive margin of FDI—the probability to invest—the estimation equation is:

$$P\left(decision_{ijt}=1|X,\, c_{ij}\right)\equiv G\left(X\beta, c_{ij}\right), \tag{7}$$

where $decision_{ijt}$ is the binary response of whether to invest or not; X is the vector of explanatory variables listed in Table 1; $G(.)$ is an unknown function of X and c_{ij}; c_{ij} represents the unobserved effects.

Common panel methods to estimate Equation (7) are the linear probability model (LPM), pooled probit, random effects (RE) probit, fixed effects (FE) logit and Chamberlain's correlated random effects probit (CRE). LPM does not produce good estimates of the average partial effects (APEs) if the covariates have a wide range of values (Wooldridge, 2010), which is the case in this global study. Also, the FE logit model is unable to estimate the APEs. Therefore, I will not present results from LPM and FE logit for the extensive margin.

For the intensive margin of FDI—the amount of positive investment—according to Equation (5), the general estimation equation is:

$$\ln FDI_{ijt} = \beta_0 + \beta_1 X + \lambda_t + c_{ij} + u_{ijt}, \tag{8}$$

where the general error term comprises three components: time effects (λ_t), pair effects (c_{ij}) and the remaining idiosyncratic component (u_{ijt}), which is similar to other studies on bilateral data such as Baltagi, Egger, and Pfaffermayr (2008), Egger, Loretz, Pfaffermayr, and Winner (2009) and Baltagi, Peter, and Michael (2015).

Common panel estimators for Equation (8) are pooled OLS (POLS), random effects (RE), fixed effects (FE) and first differencing (FD). In POLS, c_{ij} is included in the error term, and thus, POLS will be biased and inconsistent if c_{ij} is correlated with any element in X. Also, since POLS ignores the correlation of the error terms over time, its standard errors are usually underestimated (Cameron & Trivedi, 2005). I perform both the AR(1) selection correlation test (Wooldridge, 2010) and Breusch and Pagan (1980) LM test for the presence of unobserved effects and compare RE versus POLS. Results show that the c_{ij} terms are present and RE outperforms POLS. While RE treats c_{ij} as being distributed independently of the regressors, FE assumes that c_{ij} is correlated with the regressors. The Hausman test shows that the unobserved effects are correlated with covariates, and thus, FE is better than RE. Besides FE and RE, researchers can also apply FD to remove the unobserved effects. However, FD requires data to be available in adjacent time periods. Using FD in my sample would lead to a significant drop in the number of observations as I am dealing with positive FDI separately from zero FDI. Therefore, I do not apply FD in this study.

Another way to allow for the correlation between c_{ij} and X is to use the Chamberlain–Mundlak device. I refer to this method as the Chamberlain–Mundlak random effects (CMRE) model. Adding the Chamberlain–Mundlak device to control for the correlation between the unobserved effects and covariates is also the practice in Egger and Nelson (2011) with PPML estimation and in Araujo et al. (2017) with RE tobit estimation. CMRE can be applied to both linear and non-linear models, and it can produce consistent estimation even if some of the time-invariant variables in the model are correlated with c_{ij} (Egger & Nelson, 2011).

For the sake of comparison, I will report results from heckit, which is most commonly used in the previous studies on the two margins of FDI. Also, since the work of Santos Silva and Tenreyro (2006), PPML has become one of the most popular estimation methods for gravity equations, and thus, I also include results from PPML.

So far, I have discussed methodologies for the intensive and extensive margins of FDI separately. Meanwhile, estimating only positive FDI values in the amount equation can lead to selection bias if the mechanisms generating the zero and positive FDI are correlated. I have tested for selection bias, following Wooldridge (1995). The selection bias test shows that the null hypothesis of no selection bias cannot be rejected (p-value = 0.911 for FDI stocks and 0.661 for FDI flows). Therefore, I investigate determinants of intensive and extensive margins of FDI separately. In all results, I always control for time trend effects by including year dummies in each regression.

7 | RESULTS

7.1 | The extensive margin

Coefficients from pooled probit, RE probit or CRE probit are not comparable; thus, results in Table 2 for the extensive margin are the APEs which can convey both the magnitude and the direction of the impact. The rho value in the RE probit results is close to 1 (= 0.885 for stocks and 0.714 for flows) and statistically significant at the 1% level; thus, RE probit is better than pooled probit and there is an unobserved effect present (StataCorp, 2017; Wooldridge, 2010). However, pooled probit is the only estimator that has been used in the previous studies on the extensive margin of FDI.[4] CRE should be given preference as it allows for the correlation between explanatory variables in X and the unobserved effects (Wooldridge, 2010). Another striking feature in Table 2 is that APEs' magnitudes vary considerably across estimators. Since there is no model selection test to choose between RE probit and CRE, I draw conclusions from both methods and focus on the direction of impact only.

Robust covariates which have a statistically significant positive impact on the investment decision across estimators as well as FDI data types are GDPs of both countries (lgdp_s, lgdp_h), technology capital share of the source country (tech_s), host country FDI share of production (phi_h), bilateral investment treaty (BIT), preferential trade agreement (PTA), common currency, border, language, colonial relationship and legal origin. On the other hand, start-up costs of the host country (start-up_h) and distance negatively influence the investment probability at the 1% significance level.

Some variables show different results according to whether stocks or flows are considered. Particularly, common coloniser has a positive and highly significant effect in the results for FDI stocks but is statistically insignificant in the FDI flow results. By contrast, common religion has a positive and significant influence on FDI flows but not on FDI stocks. As explained in the Appendix S1, FDI flow data provide more accurate observations on the yearly probability to invest. Hence, FDI flow results should be given more preference in these cases.

Lastly, conflicting results are seen for capital depreciation rates (delta_h) and remoteness (remote_h) of the host country. Results on these variables are either statistically insignificant or opposite according to different estimation methods for the same type of FDI data. Thus, I do not draw conclusions about the impact of these variables on the extensive margin.

7.2 | The intensive margin

Results for the intensive margin are illustrated in Table 3. According to the diagnostic tests discussed above, I omit results from RE and POLS. The number of observations in heckit and PPML is considerably higher than the other methods because these two estimators deal with both zero and positive FDI simultaneously. For Heckit, I use start-up costs as the exclusion variable for both types of FDI. The validity of this variable as an exclusion restriction will be discussed later on.

I first apply PPML without country fixed effects to include all variables in the regressions (Table 3, columns (4) and (9)). There is some divergence in the results between one-stage regression PPML and two-stage regressions for panel data. According to panel estimation methods, BIT has a positive impact on the probability of investment (Table 2) but no statistically significant impact on the investment volume (Table 3, columns (1), (2), (6) and (7)). By contrast, in both PPML and Heckit results BIT surprisingly has a negative and statistically significant effect on the amount of FDI (Table 3, columns (3), (4), (8) and (9)). Further, common border and religion are shown to positively affect

[4]Those studies employ Heckit which estimates the extensive margin by pooled probit.

TABLE 2 Results for the extensive margin (APEs)

	Expected sign	FDI stocks Pooled probit (1)	RE probit (2)	CRE probit (3)	FDI flows Pooled probit (4)	RE probit (5)	CRE probit (6)
lgdp_s	+	0.076***	0.077***	0.021***	0.062***	0.060***	0.043***
		(0.002)	(0.001)	(0.007)	(0.001)	(0.001)	(0.007)
lgdp_h	+	0.046***	0.049***	0.030***	0.041***	0.040***	0.022***
		(0.001)	(0.001)	(0.007)	(0.001)	(0.001)	(0.007)
tech_s	+	0.444***	0.412***	0.267**	0.475***	0.378***	0.199***
		(0.065)	(0.074)	(0.115)	(0.044)	(0.042)	(0.068)
delta_h	−	−0.876***	−0.432*	0.750*	−0.944***	−0.502**	1.085**
		(0.254)	(0.224)	(0.452)	(0.229)	(0.196)	(0.429)
remote_s	−	−0.541***	−0.280***	−0.070	−0.526***	−0.421***	−0.181*
		(0.068)	(0.060)	(0.105)	(0.059)	(0.048)	(0.094)
remote_h	−	0.309***	0.010	−0.213**	0.327***	0.096**	−0.207**
		(0.065)	(0.058)	(0.106)	(0.050)	(0.044)	(0.088)
startup_h	−	−0.021***	−0.009***	−0.004***	−0.009***	−0.007***	−0.004**
		(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
phi_h	+	0.233***	0.202***	0.173***	0.363***	0.294***	0.169***
		(0.030)	(0.022)	(0.027)	(0.027)	(0.023)	(0.039)
BIT	+	0.071***	0.044***	0.010	0.064***	0.051***	0.012
		(0.006)	(0.006)	(0.008)	(0.005)	(0.004)	(0.008)
PTA	+	0.087***	0.052***	0.012*	0.062***	0.038***	0.009
		(0.007)	(0.006)	(0.007)	(0.006)	(0.005)	(0.006)
currency	+	0.121***	0.060***	0.021	0.025**	0.015*	0.012
		(0.018)	(0.013)	(0.014)	(0.011)	(0.009)	(0.012)
ldist	−	−0.069***	−0.089***	−0.067***	−0.064***	−0.064***	−0.055***
		(0.005)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)
border	+	0.061***	0.051***	0.060***	0.053***	0.043***	0.047***
		(0.020)	(0.019)	(0.019)	(0.016)	(0.015)	(0.014)
language	+	0.018**	0.027***	0.029***	0.021***	0.021***	0.019***
		(0.009)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)
coloniser	+	0.064***	0.064***	0.069***	0.012	0.011	0.016
		(0.013)	(0.011)	(0.010)	(0.014)	(0.012)	(0.012)
colony	+	0.037	0.059***	0.038*	0.047***	0.050***	0.042***
		(0.023)	(0.020)	(0.020)	(0.016)	(0.015)	(0.015)
legal	+	0.022***	0.027***	0.020***	0.007	0.009*	0.004
		(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
religion	+	0.003**	0.001	0.002	0.008***	0.007***	0.008***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log pseudo-likelihood		−37,380.916	−20,630.852	−20,360.993	−33,229.182	−23,942.92	−23,807.614
Observations		103,005	103,005	103,005	103,005	103,005	103,005

Note: Standard errors in parentheses: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

TABLE 3 Results for the intensive margin

		FDI stock					FDI flows				
	Expected sign	FE (1)	CMRE (2)	Heckit (3)	PPML without FE (4)	PPML with FE (5)	FE (6)	CMRE (7)	Heckit (8)	PPML without FE (9)	PPML with FE (10)
lgdp_s	+	0.494***	0.430***	0.910***	0.583***		0.686***	0.575***	0.807***	0.554***	
		(0.081)	(0.080)	(0.029)	(0.064)		(0.107)	(0.104)	(0.029)	(0.057)	
lgdp_h	+	0.356***	0.355***	0.733***	0.784***		0.355***	0.366***	0.672***	0.749***	
		(0.071)	(0.071)	(0.021)	(0.037)		(0.091)	(0.090)	(0.022)	(0.035)	
tech_s	+	2.611***	2.775***	1.565***	5.513***		2.101***	2.253***	2.100***	5.098***	
		(0.554)	(0.552)	(0.600)	(0.952)		(0.618)	(0.610)	(0.529)	(0.843)	
delta_h	−	1.520	1.806	2.859	7.761		21.641***	21.920***	−2.447	−1.169	
		(5.084)	(5.025)	(3.704)	(6.444)		(6.683)	(6.483)	(3.443)	(6.811)	
remote_s	−	−0.781	−1.300	−6.868***	−10.913***		−1.243	−1.682	−7.590***	−10.915***	
		(0.973)	(0.969)	(0.845)	(2.548)		(1.186)	(1.159)	(0.831)	(2.090)	
remote_h	−	2.452***	2.562***	6.656***	6.122***		−3.800***	−3.485***	5.792***	3.333**	
		(0.879)	(0.875)	(0.822)	(1.279)		(1.230)	(1.204)	(0.799)	(1.375)	
startup_h	−	−0.015	−0.013		−0.031		−0.062***	−0.055**		−0.029	
		(0.017)	(0.017)		(0.080)		(0.022)	(0.022)		(0.074)	
phi_h	+	2.969***	2.947***	6.303***	4.926***		2.314***	2.063***	6.732***	7.111***	
		(0.323)	(0.317)	(0.522)	(0.720)		(0.639)	(0.625)	(0.403)	(0.672)	
Observations		27,951	27,951	103,005	103,005	103,559	21,193	21,193	103,005	103,005	99,625
BIT	+	0.050	0.032	−0.410***	−0.713***	−0.166	0.048	0.016	−0.377***	−0.615***	−0.015
		(0.089)	(0.088)	(0.084)	(0.126)	(0.152)	(0.104)	(0.103)	(0.077)	(0.111)	(0.159)
PTA	+	0.132**	0.135**	0.762***	0.671**	0.653***	0.056	0.047	0.440***	0.401	0.552***
		(0.059)	(0.059)	(0.093)	(0.291)	(0.172)	(0.070)	(0.070)	(0.086)	(0.274)	(0.206)

(Continues)

TABLE 3 (Continued)

		FDI stock					FDI flows				
	Expected sign	FE (1)	CMRE (2)	Heckit (3)	PPML without FE (4)	PPML with FE (5)	FE (6)	CMRE (7)	Heckit (8)	PPML without FE (9)	PPML with FE (10)
currency	+	0.232*	0.227*	0.787***	0.270	0.064	0.336**	0.329**	0.612***	0.182	−0.216
		(0.125)	(0.125)	(0.151)	(0.176)	(0.206)	(0.154)	(0.147)	(0.142)	(0.162)	(0.190)
ldist	−		−0.619***	−0.745***	−0.578***	−0.405***		−0.529***	−0.799***	−0.528***	−0.292***
			(0.058)	(0.060)	(0.094)	(0.075)		(0.049)	(0.054)	(0.093)	(0.085)
border	+		0.444***	0.389**	0.036	0.452***		0.273*	0.202	−0.039	0.462**
			(0.162)	(0.171)	(0.385)	(0.170)		(0.140)	(0.150)	(0.324)	(0.199)
language	+		0.960***	0.964***	0.520***	0.436**		0.684***	0.761***	0.581***	0.531***
			(0.107)	(0.113)	(0.166)	(0.178)		(0.096)	(0.103)	(0.156)	(0.173)
coloniser	+		0.428**	0.578***	0.800**	0.461		0.519***	0.554**	0.845**	0.832**
			(0.178)	(0.214)	(0.359)	(0.349)		(0.181)	(0.230)	(0.396)	(0.398)
colony	+		1.210***	1.215***	0.954***	0.642***		0.923***	0.949***	0.726***	0.376**
			(0.192)	(0.189)	(0.211)	(0.186)		(0.156)	(0.159)	(0.205)	(0.168)
legal	+		−0.089	−0.054	−0.345	−0.269*		−0.196***	−0.152**	−0.420*	−0.337**
			(0.080)	(0.083)	(0.299)	(0.150)		(0.069)	(0.076)	(0.225)	(0.159)
religion	+		0.044**	0.061***	0.053	0.213***		0.035**	0.064***	0.058	0.177***
			(0.018)	(0.020)	(0.062)	(0.033)		(0.015)	(0.017)	(0.043)	(0.032)
Observations		27,951	27,951	103,005	103,005	103,559	21,193	21,193	103,005	103,005	99,625

Note: Standard errors in parentheses: $*p < 0.1$; $**p < 0.05$; $***p < 0.01$.

both margins according to panel estimators but are not statistically significant in the case of PPML. FE and CMRE are the two panel methods that can show which variables have a robust and significant impact on bilateral FDI even after controlling for the unobserved fixed effects. Results from FE and CMRE are particularly similar in terms of both signs and significance levels. Meanwhile, PPML and Heckit are pooled methods which ignore the panel effects. Therefore, I give more preference to the panel results in this case.

In order to test the robustness of the preferred panel methods, I re-estimate PPML, but include country fixed effects to deal with the MR terms. The empirical trade literature has moved towards the fixed effects approach in recent years as the method does not require strong structural assumptions on the underlying model (Head & Mayer, 2014). Fally (2015) also find that PPML with fixed effects gives close correspondence to the theoretical MR terms. In a panel set-up, the fixed effects are time-varying country fixed effects. As discussed in Section 4, one of the limitations of this approach is that it excludes all country-specific variables from regression. Nevertheless, if the remaining pair variables give similar results to FE and CMRE, my choice of the panel estimations as well as the model specification with proxies for MR terms in this study will be more convincing. Results for these robustness checks are included in Table 3—column (5) for stocks and column (10) for flows. After controlling for the fixed effects, all the contradictions between PPML and panel methods (FE and CMRE) disappear. BIT's coefficients are no longer statically significant in PPML results for both stocks and flows. By contrast, common border and religion are positive and highly statistically significant in the PPML results. These results are very similar to FE and CMRE, which gives a strong support to these preferred panel estimators. Therefore, for the rest of the empirical analysis, I will rely on FE and CMRE results only.

The typical gravity variables show a statistically significant impact on the volume of FDI across estimators and FDI data types, which is similar to the results on the extensive margin. GDPs (lgdp_s, lgdp_h), the source country's global share of patents (tech_s), and the host country's FDI share of production (phi_h) all positively affect the amount of bilateral FDI at the 1% significance level. These results confirm Anderson et al.'s (2017) prediction on the role of technology/knowledge capital: this capital encourages FDI to flow from technology capital abundant countries to scarce countries due to diminishing returns to scale of technology capital. Technology capital also has a positive influence on the investment probability, according to results for the extensive margin. In addition, common currency, border, language, coloniser, colony and religion all positively affect FDI, which is opposite to the impact of distance.

Besides the similarities, results on FDI flows and stocks are different for a number of variables. To be clearer, capital depreciation rates (delta_h) are not statistically significant in the results for FDI stocks but are highly significant in the case of FDI flows in both FE and CMRE results. According to the law of diminishing marginal return of capital, FDI should flow from capital abundant countries to capital-scarce countries whose capital depreciation rates are lower. However, the positive impact of delta_h on FDI flows seems to follow the Lucas paradox (Lucas, 1990) where the majority of capital still goes to developed countries whose capital depreciation rates are high. Although delta_h has the opposite sign to the theory predictions, the original concept from Anderson et al.'s (2017) model is the depreciation rate of technology capital whereas I am forced to use the depreciation rate of physical capital. Thus, unexpected results here can be attributed to the use of an indirect and maybe not suitable proxy for technology capital depreciation. More directly related to the theory are results on tech_s, which are consistent with the theory predictions. Further, host country's start-up costs (start-up_h) and common legal origin are negative and statistically significant only in the results for FDI flows. I believe the differences between results on stocks and flows are mainly due to the nature of each data series. A variable may have a significant impact on the yearly FDI flows but that impact is substantially small compared to the cumulative FDI stock value, and thus, it does not manifest in the results for FDI stocks.[5]

Lastly, empirical evidence shows that there is no strongly valid exclusion restriction for Heckit in this FDI study. Results on start-up costs and common legal origin indicate that these variables are valid exclusion variables for FDI stocks but not for FDI flows. BIT significantly affects the extensive but not the intensive margin of both FDI data series, according to panel estimators. However, although not shown, if BIT is included in the pooled OLS regression, it is highly significant. Therefore, BIT is still not a valid exclusion variable for Heckit.

7.3 | Results on different groups of countries

Blonigen and Wang (2004) claim that although theories are supposedly constructed for the entire global economy, FDI to LDCs and DCs are affected differently. They suggest FDI research to consider different groups of countries based on development levels. Previous studies, such as Blonigen, Davies, and Head (2003) and Araujo et al. (2017), rely on data from the OECD so they cannot analyse FDI between non-OECD countries. Blonigen, Davies, Waddell, and Naughton (2007) and Asiedu and Lien (2011) do investigate results by country development groups but they employ only aggregate, not bilateral, FDI data of the receiving country. Therefore, these studies are unable to investigate the direction of FDI according to the development levels of both sending and receiving countries. This is the first global study that extensively investigates the bilateral FDI data across all combinations of country groups: DCs to DCs, DCs to LDCs, LDCs to DCs and LDCs to LDCs. The country list is reported in the Appendix S1.

Results on the intensive and extensive margins are relatively similar for each data series as shown in the previous tables of results. Hence, in the robustness check with different country groups, I present results with the direction of impact for only the intensive margin, based on FE and CMRE, for brevity. Detailed results are in Table S5 and Table S6 in the Appendix S1. The first four columns in Table 4 summarise results from panel estimations for global FDI stocks and flows from the previous sections for both margins to compare with results for country groups. The rest of the table presents results for different country groups for the intensive margin only.

First, a number of variables are robust across the four different country groups. They are host country GDP (gdp_h), source country's technology global share (tech_s), FDI share of production in the host country (phi_h), common language, colonial relationship and distance. The robust and positive impact of tech_s on FDI stocks also confirms the theory emphasising technology capital as an important driver of FDI. A country, no matter what development group it belongs to, sends more FDI abroad if its share of global technology is higher. Similar to the global results, the host country's capital depreciation rates (delta_h) have a positive and statistically significant impact on FDI flows across all country groups except LDCs to LDCs.

FDI from DCs (DCs to DCs and DCs to LDCs) benefits from a common currency and is negatively affected by start-up costs. In addition, it is only for FDI from DCs that both PTA and BIT are significant influences. PTA has a positive impact on FDI from DCs to either DCs or LDCs, while BIT benefits FDI between DCs and LDCs. Dixon and Haslam (2016) also find that BITs have different effects for different country groups in the case of FDI in Latin America.

Another noticeable feature in Table 4 is that FDI from LDCs to either DCs or LDCs is not significantly driven by many covariates. The source country's GDP, start-up costs, PTA, common currency and legal origin show no statistically significant impact on FDI from LDCs once controlling for the unobserved effects in the panel. Meanwhile, the remoteness of the source country (remote_s) has a positive and strongly

[5]See the Appendix S1 for more details about bilateral FDI data.

TABLE 4 Summary results for country groups

		Extensive margin		Intensive margin									
		Global		Global		DCs to DCs		DCs to LDCs		LDCs to DCs		LDCs to LDCs	
	Expected signs	Stock (1)	Flow (2)	Stock (3)	Flow (4)	Stock (5)	Flow (6)	Stock (7)	Flow (8)	Stock (9)	Flow (10)	Stock (11)	Flow (12)
lgdp_s	+	+	+	+	+	+	+	+	+				
lgdp_h	+	+	+	+	+	+	+	+	+	+		+	+
tech_s	+	+	+	+	+	+		+		+	+	+	+
delta_h	−	?	?		+		+		+		+		
remote_s	−	−	−							+			
remote_h	−	?	?	+	−			+	−				-
startup_h	−	−	−		−	−	−		−				
phi_h	+	+	+	+	+	+	+	+	+	+		+	+
BIT	+	+	+					+		+			
PTA	+	+	+	+			+	+					
currency	+	+	+	+	+	+	+	+					
ldist	−	−	−	−	−	−	−	−	−	−	−	−	−
border	+	+	+	+	+							+	+
language	+	+	+	+	+	+	+	+		+	+	+	+
coloniser	+	+		+	+					+	+		+
colony	+	+	+	+	+	+	+	+	+	+	+	+	+
legal	+	+	+		−			−	−				
religion	+	+	+	+	+	+		+	+	+	+		
Observations		103,005	103,005	27,951	21,193	9,203	6,971	9,468	7,540	4,492	3,195	4,788	3,487

Note: (?), significant and conflicting results; (−), negative impact; (+), positive impact; empty cells, no statistically significant impact.

significant effect only in the case of FDI stocks from LDCs to DCs. These results suggest that FDI from LDCs may be determined by other specific factors rather than just conventional variables. Thus, there is a need to develop more theories and empirical works to explain FDI from LDCs in particular.

Interestingly, common border is not significant in any groups except LDCs to LDCs. LDCs generally have less international investment experience. When they invest in other LDCs, they also face higher risks in terms of political stability, expropriation risk and infrastructure quality. Therefore, they may prefer to invest in other LDCs which are contiguous. Investing in a neighbouring country can reduce these risks to some degree as they would understand the situation better than for more distant countries.

Lastly, similar to the global results, host country remoteness (remote_h) shows contradictory results. Anderson et al. (2017) do not include OMR in their theoretical model. They claim that OMR should not be a significant determinant of FDI as technology capital is non-rival and can be employed in multiple locations. The ambiguous impact of remote_h, a proxy for OMR, in this study seems to be consistent with the original assumption in the theoretical model.

8 | CONCLUSION

8.1 | Results from the global sample on the two margins reveal the following groups of bilateral FDI drivers

Many variables demonstrate consistent results across both margins. Having a positive impact are GDPs, source country technology capital share, host country FDI share in production, PTA, common currency, common border, common religion, common language and colonial relationship. In contrast, distance is a significant deterrence in both margins.

Bilateral investment treaties have a positive impact on the investment probability but no statistically significant effects on the investment volume.

Results on FDI flows and stocks can lead to different conclusions, and each data series has its own advantages and disadvantages. Therefore, research on determinants of FDI should utilise both data series to find the robust factors.

8.2 | Results on country groups lead to additional findings

The robust positive impacts of the source country's technology capital share on FDI stocks across different country groups and margins, strongly confirm the theory's prediction that technology capital is a key driver of FDI.

Host country capital depreciation rates have a statistically significant and positive impact on FDI flows across different countries groups, which is consistent with the Lucas paradox.

Some variables affect only a specific country group, such as common currency and the host country's start-up costs for FDI from DCs and common border for FDI from LDCs to LDCs. Also, FDI from DCs benefits from both PTA and BIT. That the effects of bilateral agreements, PTA and BIT, differ across country pairs or margins is worthy of more study.

Various insignificant results found in the case of FDI from LDCs point to the need for more theoretical and empirical work to identify the distinctive factors driving this specific direction of FDI.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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