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Quantile regression for the FDI gravity equation☆

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ABSTRACT

Firm-level heterogeneity shapes foreign direct investment (FDI) flows, whereby a few firms are responsible for most of the world's FDI. Aggregate outcomes of FDI are highly skewed, and the estimates of FDI's antecedents vary largely depending on FDI level. The incidence of individual firms, however, varies across FDI's quantiles. To study the individual firms' effect on FDI flows, this study develops a quantile regression method for bilateral FDI panel data. This study estimates the differential incidence of individual firm-level projects on aggregate flows among 161 countries from 2003 to 2012. Results suggest that FDI's determinants vary across quantiles. In particular, the effect of individual projects on FDI flows increases in the upper quantiles. Policymakers may use this insight to target polices on the few to benefit the many.

1. Introduction

> Never in the field of human conflict was so much owed by so many to so few.
>
> [Churchill, 1940]

Only a few firms significantly affect investment flows, even though a single investment project may add up to several million dollars of capital investment and thousands of jobs. Few firms are also largely responsible for economic aggregate fluctuations like GDP (Gabaix, 2011) or industry sales (Di Giovanni & Levchenko, 2011; Di Giovanni, Levchenko, & Méjean, 2014). Mayer and Ottaviano (2008) decompose the number of foreign affiliates and average sales per affiliate for several European countries: "The happy few are leading the many." Few companies are responsible for most of the world's aggregate FDI, employment, and sales. Kleinert, Martin, and Toubal (2012) show that foreign affiliates are responsible for variations in the business cycle. Scholars stress the role of firm-level heterogeneity on aggregate outcomes (Behar & Nelson, 2014; Helpman, Melitz, & Yeaple, 2004). Most empirical research on FDI's antecedents, however, does not address these empirical observations in their estimates. This study fills this gap.

The gravity equation, the most successful empirical specification for bilateral FDI, does not account for firm-level movements at the aggregate level. Firm symmetry is a key assumption of the gravity model; traditional linear estimates suffer from a firm-level over-aggregation bias. Scholars use the distinction between the extensive (how many) and intensive margins (how much) to partially overcome this issue (Helpman, Melitz, & Rubinstein, 2008). In the extensive margin, all firms are equal: Millionaire investments are equivalent to humble investments.

Decomposing FDI into margins helps researchers understand FDI's underlying mechanisms (Berden, Bergstrand, & Etten, 2014; Gil-Pareja, Llorca-Vivero, & Paniagua, 2013; Paniagua & Sapena, 2014); nonetheless, several questions lack an answer: Do the determinants of FDI flows change with quantiles? Does the role of firm level vary across quantiles? How do individual projects affect aggregate flows? On which FDI level is the effect of the few most important? As a result, policies concerning FDI often miss their primary target.

Policymakers may target policies for the few or for the many. The identification of best-suited determinants for each level of FDI is relevant for policymakers, especially for investment promotion agencies (IPA). Policies intending to increase FDI in a particular region or country generally focus on increasing the investment leads, that is, the extensive margin (Loewendahl, 2001; Wells & Wint, 2000). However, scholars usually measure FDI policies' success at an aggregate level (UNCTAD, 2013b). Understanding the effect of individual projects on aggregate flows is therefore essential to determine the best-suited FDI policies,

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especially in a context of economic crisis where credit constraints affect the number of projects but not their size (Gil-Pareja et al., 2013).

To address these research questions, this study uses quantile regression (Koenker & Bassett, 1978). Quantile regression is more adequate than other methods to understand the relationship between variables whose effects may vary with outcome levels (Huarng & Yu, 2014). Quantile regression is popular to interpret results of skewed data like wages (Buchinsky, 1994), portfolio returns (Yu, Lu, & Stander, 2003), the Internet (Yu, 2011), business performance (Seo, Perry, Tomczyk, & Solomon, 2014), forecasting (Huarng & Yu, 2014), and international trade (Dufrénot, Mignon, & Tsangarides, 2010; Fidrmuc, 2009; Figueiredo, Lima, & Schaur, 2014). This study is the first to apply quantile regression to estimate bilateral FDI data in a gravity framework.

This study goes beyond previous studies in several ways. First, the study develops a quantile method to estimate the determinants of aggregate FDI flows. This study applies quantile regression for panel data (QRPD), a method that addresses fixed effects and omitted variable bias. Second, this study provides a rationale for interquantile coefficient variations. Third, this research studies the incidence of firm heterogeneity on FDI measuring the differential effect of individual projects on aggregate flows across quantiles. Results suggest that (1) FDI's determinants vary across quantiles and (2) firm heterogeneity has a greater effect in higher quantiles. This study analyzes bilateral FDI data for 161 countries between 2003 and 2012. Section 2 describes the empirical strategy, Section 3 discusses the results, and finally, Section 4 presents the conclusions.

2. Empirical methodology

2.1. FDI quantile gravity equation

The gravity equation is the most popular empirical tool to estimate bilateral FDI. The empirical distribution of FDI data, however, renders traditional ordinary least squares (OLS) estimates of the gravity equation impractical. Standard linear regression techniques summarize the average relationship between a set of regressors and the outcome variable based on the conditional mean function $E(y|x)$, assuming this function as normal and symmetrically distributed. This procedure provides only a partial view of the relationship, especially when the data concentrate at different points in the conditional distribution of the dependent variable concentrate most of the data. Quantile regression provides that capability (Koenker & Bassett, 1978; Yu et al., 2003). In addition, quantile regression is more robust to outliers than least squares regression, and is semiparametric, avoiding assumptions about the parametric distribution of the error process (Conley & Galenson, 1998).

Applying quantile regression to the FDI gravity equation yields:

$$Q_\tau\left[\ln FDI_{ijt}|x_{ijt},\alpha_{ij}\right]=\alpha_{ij}+x_{ijt}\beta(\tau)+v_{ij}, \tag{1}$$

where i denotes the source country and j the host country; α_{ij} is the time-invariant country-pair fixed effects; $\beta(\tau)$ is the parameter of interest which varies with quantile $\tau\in(0,1)$; the error term v_{ij} is independent and identically distributed $v_{ij}\sim iidF_v(\mu,\sigma^2)$, where F_v is an unknown continuous distribution function of v_{ij},; and x_{ijt} is the standard set of gravity control variables observed at time t. Table 1 summarizes all variables.

The last column of Table 1 presents the expected sign change from lower to higher quantiles. Table 1 gives the hypothetical difference in the effect of FDI's determinants for low volumes and high volumes of FDI. The agglomeration phenomenon (i.e., firm proximity) gives the basis for the theoretical change of the coefficients' signs. The literature identifies firm-level advantages of agglomeration, namely increasing returns, technical externalities, knowledge spillovers, and transport costs (Chung & Song, 2004; Fujita & Thisse, 2013; Voinea & Van Kranenburg, 2011). As result, transactions costs (e.g., distance costs, language and cultural differences, and currency costs) diminish in the most crowded quantiles (i.e., the upper quantiles). Variables that favor FDI substitutes (i.e., free trade agreements, FTAs) reduce their impact in higher quantiles. Variables that ease FDI (i.e., bilateral investment treaties, BITs) increase their power in higher quantiles. In addition, benefits from greater demand and supply (i.e., Gross Domestic Products, GDPs) increase with quantiles.

Anderson and Van Wincoop's (2003) study on the gravity equation includes third-country effects or multilateral resistance. Multilateral resistance represents an index of inward and outward bilateral trade costs. All bilateral trade costs in the world contribute to the bilateral trade between country pairs. Otherwise, other variables in the equation, like the border dummy, might pick up this effect. The literature advocates for the use of fixed effects procedures to address problems arising from omitted variable bias and endogeneity related to multilateral resistance (Anderson, 2011).

The fixed effects specification of the gravity equation represents an empirical caveat for quantile regression. Scholars have yet to reach a consensus on how to introduce fixed effects on quantile regressions. Estimate interpretation varies greatly by method (Canay, 2011; Galvao, 2011; Harding & Lamarche, 2009; Koenker, 2004; Lamarche, 2010; Powell, 2013).

This study improves Canay's (2011) estimator with a quantile regression for panel data (QRPD) procedure. The fixed effects specification omits all time-invariant country pair variables (α_{ij}) because of perfect collinearity. This procedure eliminates location shift variables beforehand, making implementation computationally simple, regardless of

Table 1
Variable description and expected signs.

Variable	Description	Expected sign	Across quantiles
$\alpha_1 \ln D_{ij}$	Logarithm of distance in kilometers between country capitals	(−)	↘
$\alpha_2 border_{ij}$	Takes the value 1 when countries share a common border, and 0 otherwise	(+)	↘
$\alpha_3 col_{ij}$	Takes the value 1 if the two countries have ever had a colonial link, and 0 otherwise	(+)	↘
$\alpha_4 lang_{ij}$	Takes a positive value if both countries share the same official language	(+)	↘
$\alpha_5 rel_{ij}$	Is a composite index that measures the religious affinity between country pairs with values ranging from 0 to 1	(+)	↘
$\alpha_6 smctry_{ij}$	Is an indicator variable that indicates if both countries were part of the same country in the past	(+)	↘
$\alpha_7 locked_{ij}$	Is 1 if the host country is landlocked	(−)	↘
$\beta_1 \ln(GDP_{it}*GDP_{jt})$	Logarithm of the gross domestic products of home and host countries respectively	(+)	↗
$\beta_1 CC_{ijt}$	Takes the value if both countries have the same currency in year t	(+)	↗
$\beta_2 BIT_{ijt}$	Is a dummy that takes a value of one if the country pair has a bilateral investment treaty in force	(+)	↗
$\beta_3 FTA_{ijt}$	Is a dummy that indicates whether both countries have a free trade agreement in force	(+/−)	↘
$\beta_4 N_{ijt}$	Is the number of investment projects between home country i and host j in year t. The $\beta(\tau)$ associated to this variable is the FDI margin semi-elasticity.	(+)	↗