Imported Inputs and Productivity Spillovers from Foreign Direct Investment*

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Abstract

This paper considers how input market liberalization affects host country productivity spillovers from multinational corporation (MNC) investments. The standard "Backward Linkage" measure used to estimate technology and learning spillovers to local upstream suppliers––pioneered by Javorcik (2004) and replicated across several influential papers––implicitly assumes domestic and foreign firms share the same input structure. I show that this assumption constitutes an omitted variable bias of imported inputs in TFP spillover estimation. Using a novel Colombian firm panel that isolates imported from domestic inputs, mean backward linkage productivity spillovers reduce in half when the share of locally sourced inputs is adjusted to reflect MNCs' observably higher propensity to import inputs. However in some industries, productivity spillovers increase in response to the adjustment. I demonstrate that the sign and magnitude of this bias are proportional to the elasticity of substitution between imported and domestic inputs. The results highlight how input market liberalization (usually associated with increased FDI inflows) can have important feedback effects on local productivity spillovers from MNCs.

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1 Introduction

In the economic growth and trade literature, foreign direct investment (FDI)—foreign equity invested in domestic firms and multinational corporation (MNC) entry—is thought to be a key channel through which technology and innovation diffuse to developing country firms. To asses this claim, most empirical analyses measure three key trade-offs induced by FDI entry: (1) A within-industry *Horizontal* effect which either results in technology leakage and improved productivity from foreign competition, or market share crowd-out; (2) A between-industry *Forward* Linkage effect in which technology is shared through MNC sales of intermediate inputs to local firms; and (3) A *Backward* Linkage effect that arises when MNCs contract with local upstream suppliers in industries with whom there is no incentive to shield tacit knowledge about production processes, resulting in inter-industry learning.[1]

While the vast majority of papers find zero to negative Horizontal and Forward Linkage effects, these are almost always dwarfed by large and economically important Backward Linkage gains.[2] The rationale for this is relatively straightforward—although MNCs may adversely affect domestic firm productivity through downstream competition or by introducing costly advanced inputs, foreign firms transfer frontier technology and know-how to upstream suppliers at a rate that more than offsets these negative effects.[3] Supported by over a decade of findings such as these, academics and policymakers alike have identified capital market liberalization as a deep policy determinant of long run growth.[4]

This paper extends the conventional view by showing that input market liberalization (usually associated with increased FDI inflows) can have important feedback effects on the extent to which MNCs contract with local suppliers. Motivated by an emerging trade literature on the role of imported inputs in firm productivity growth,[5] I show that "standard" Backward Linkage productivity spillover specifications implicitly assume domestic and foreign firms share the same input structure and propensity to import inputs.[6] Yet this assumption contradicts a striking feature of trade data—MNCs import significantly more inputs than domestic firms. For example, in 2010 alone, US multinationals abroad accounted for roughly *half* of all US exports (BEA, 2012). In this paper, I explore the implications of relaxing the assumption that MNCs and domestic firms share the same import propensity, and ultimately show that

[1]Many studies also consider a within-firm foreign equity effect, however this has received less attention than the other spillover channels—especially Backward Linkages—and is beyond the scope of this paper.

[2]See Harrison and Rodríguez-Clare (2009) for a comprehensive survey of these empirical studies.

[3]Javorcik (2004) attributes negative Forward Linkage effects to input adjustment costs. In this paper, I thus also consider the lagged effects of Forward Linkages on future productivity to test this hypothesis.

[4]As early as 1997, 103 countries offered concessions, tax breaks, or subsidies to MNCs (**?**).

[5]See Amiti & Konings (2007), Kugler and Verhoogen (2008), Golberg et al. (2010), and Halpern et al. (2011) for recent evidence showing imported inputs and input tariffs play key roles in productivity growth.

[6]This insight was also made by Barrios et al. (2011) in simultaneously developed work, however the authors come to the opposite conclusion and implication of that made here. That is, with European data Barrios et al. (2011) show that revising the Backward Linkage measure results in a *larger* productivity spillover rather than smaller spillovers as is suggested here.

the assumption generates potentially large omitted variable bias from imported inputs in its key TFP spillover specification.

Using a novel Colombian firm panel that allows me to isolate imported from domestic inputs, I propose a micro-data *adjustment* to the input-output coefficients that are central to TFP spillover measures, making them more reflective of MNCs' observably higher import propensity.[7] I find that this adjustment reduces mean Backward Linkage productivity spillovers roughly in half—an economically meaningful difference that is robust across four out of five measures of firm revenue and TFP.[8] By empirically allowing MNCs to substitute foreign for domestic intermediate inputs, the intensity of contracting with local firms decreases, as do any productivity spillovers that may arise from sharing technology with those upstream partners. Some industries however, such as construction and mining, actually exhibit an *increase* in Backward Linkage TFP spillovers. This highlights the importance of precise measurement of TFP spillovers, and further suggests that the bias does not unambiguously overstate productivity gains.

This is also reassuring as it suggests that the main results are not driven by additional measurement error introduced by the proposed adjustment, as this could mechanically bias estimates toward zero. To address this attenuation bias concern more formally, I also simulate the amount of random measurement error that would need to be added to the Backward Linkage measure to attenuate estimates of spillovers to the observed level, and find that this would require the adjustment to produce approximately 25% random measurement error. Compared to the observed difference in firm distributions of the original and adjusted spillover measures—roughly 1% and 2% on average—we can confidently rule out attenuation bias as driving the strong decrease in Backward Linkage spillovers.

Because the equal import propensity assumption overstates MNC inputs sourced in the host country in a precise way, one can also derive an analytical expression for the omitted variable bias it produces. I show that the sign and magnitude of this bias are proportional to the elasticity of substitution between imported and domestic inputs under mild assumptions. If imported and domestic inputs are relative substitutes (complements), Backward Linkage spillovers are (under) overestimated. To test this prediction empirically, I specify a constant elasticity of substitution (CES) production function, and estimate substitution elasticity parameters within 3-digit industries following Feenstra (1994). As predicted, the CES parameter is positively correlated with the bias magnitude of the original Backward Linkage measure across all CES specifications.

The rest of the paper proceeds as follows: Section 2 discusses the administrative data used in this project, and relevant summary statistics. Section 3 presents the estimation strategy under the baseline

[7]As is shown in Table 1, the import intensity of output of MNCs is roughly 10 times higher than that of domestic firms in Colombia, the country studied in this paper.

[8]These results are also robust to the inclusion of export controls, and alternative specifications that restrict spillovers to occur within narrow industries and geographies.

assumption of equal import intensities, its associated shortcomings, and the omitted variable bias it produces. Section 4 outlines the micro-data adjustment made to the flawed Backward Linkage estimator, while Section 5 compares the results from baseline and adjusted estimators. Finally, Section 6 presents the CES estimation procedure and results on predicted correlations between bias and substitution terms, and Section 8 concludes.

2 Data and Summary Statistics

2.1 Colombian Firm-Level Administrative Data

To analyze import tendencies of both foreign and domestic firms requires rich data that can discern these features. I combine two sources of public micro-data from Colombia toward this end—a firm-level panel of financial statements from the country's main business registry *Superintendencia de Sociedades*, spanning all 59 3-digit industries of the Colombian economy from 1995 to 2011; and firm-level import and export data from the Colombian customs agency *Dirreción de Impuestos y Aduanas Nacionales* (DIAN), spanning 2007 to 2011. The two datasets can be merged due to a shared firm identifier in both data sets.

The data contain annual production function variables including total profit, operating revenue (sales), total reported costs, property, plants, and equipment (PP&E), investment, raw materials and non-material inputs, inventory, and short- and long-run labor obligations (wage payments). Importantly, the business registry also provides an indicator for firms with over 50% foreign equity, however the foreign equity share itself is not made public. Consequently, this paper defines MNCs as any firm with greater than 50% foreign equity, and identifies spillovers from such firms. Lastly, the data also contain 5-digit International Standard Industrial Classification (ISIC) industry codes and registration city, permitting further tests within industries and geographies. After sample restrictions to eliminate non-operating firms (any firm with zero revenue, labor, capital, or input values), the final sample comprises 138,411 observations of 28,449 domestic firms, and 4,739 observations from 936 MNCs.[9]

In Table 1, I present summary statistics on the main firm-level variables of the analysis. Means and standard deviations are broken out by three key analysis groups—domestic firms, multinational firms (firms that ever had greater than 50% foreign equity), and overall firms. All monetary variables are deflated to real 1999 Colombian Pesos (COP).[10] Consistent with the motivation at the onset of the

[9]While the summary statistics in Table 1 suggest a fairly balanced panel, I also re-run the analysis to restrict firms to those that survive the entire sample frame, allowing me to bound the main effects.

[10]Revenue is deflated by the annual Producer Price Index (PPI) provided by the Colombian Statistical Agency DANE for each producing industry, of which 31 deflators are matched to 59 3-digit industries in the panel. Year-by-industry PPI capital deflators are used to deflate capital and investment variables, while inputs, imports, and exports, are all deflated by year-by-industry PPI price indices for each of those categories. Lastly, the annual Consumer Price Index is used to deflate wages as well as service sector industry output. All industry codes are converted to ISIC version 3.1 for consistency

paper, multinational firms in Colombia import more inputs than domestic firms—$\ln(\mathbb{M}^F)$ in Table 1—and also exhibit higher *dispersion* in imports as indicated by the larger standard deviation. The higher import propensity of MNCs is particularly salient using a unitless measure such as import intensity of output—or $\mathbb{M}^F/Y$ in Table 1—which suggests that import intensities are on average 10 times larger for MNCs than for domestic firms.

Figure 1 further plots kernel histograms of logged firm imports and import intensities, and shows that these features are not just unique to the first two moments of the data. Instead, the entire distribution of firm imports is right-shifted for MNCs. Together, these stylized facts help confirm that import heterogeneity may be an important feature to consider when studying the total effects of MNC entry on domestic firm productivity.[11]

2.2 Constructing Input-Output Tables from National Accounts Data

Critical for the measurement of Backward and Forward Linkages, the national accounts division of the Colombian national statistics agency *Departamento Administrativo Nacional de Estadística* (DANE), maintains annual Supply and Use tables detailing which industries produce and consume which commodities across 59 3-digit ISIC industries—information taken from survey and census data detailing transactions between firms of diverse industries.[12] Following the most highly cited procedure for converting such tables into symmetric industry-by-industry matrices (Guilhoto and Filho, 2005), I generate annual input-output tables of total sales between industries in Colombia.[13] The components of these j-by-k matrices form the basis for input-output coefficients α_{jk}, input shares of output which play a key role in TFP spillover measures. These measures are precisely defined in the next section, and their virtues and limitations are discussed in detail in Section 3.1.

3 Estimation with Equal Import Intensities

This section describes the baseline strategy used to identify the effects of MNC presence on domestic firm TFP in the literature, assuming MNCs and domestic firms share the same import propensities.

First specify a simple Cobb-Douglas production function for domestic firm i in 3-digit industry j and

[11]MNCs on average, also have higher profits and revenue, and lower costs, suggesting higher productivity than domestic firms (as would be expected), further validating the Business Registry's indicator for what comprises a multinational firm in Colombia.

[12]Supply and Use tables are at the commodity-by-industry level. Another commonly used input-output table is the "Make" table, which is simply a transposed Supply table at the industry-by-commodity level.

[13]This procedure weights commodity production shares by industry, by commodities used by each industry, such that each cell reflects one industry's use of products from another given industry. The Matlab code, assumptions, and adaptations of the Guilhoto and Filho (2005) procedure for the case of Colombia are available at `http://assets.wharton.upenn.edu/~bhyman/ColombiaFDI/GBPCOL2000.m`.

year t, where revenue Y is a function of capital expenditures K, labor expenditures L, intermediate input expenditures M, and revenue-TFP A.

$$Y_{ijt} = A_{ijt} K_{ijt}^{\beta_1} L_{ijt}^{\beta_2} M_{ijt}^{\beta_3} \tag{1}$$

Taking logs, we can isolate firm TFP as the dependent variable. While below, TFP is expressed as a predicted Solow residual, in practice I also semi-parametrically control for the potential endogeneity of inputs following Olley and Pakes (1996), Levinsohn and Petrin (2003), and Ackerberg et al. (2006), resulting in a robust set of TFP measures.[14]

$$TFP_{ijt} \equiv \widehat{\varepsilon_{ijt}} = ln(Y)_{ijt} - \hat{\beta}_1 ln(K)_{ijt} - \hat{\beta}_2 ln(L)_{ijt} - \hat{\beta}_3 ln(M)_{ijt} \tag{2}$$

With firm TFP estimated, we next define several FDI spillover channels. The main insight from Javorcik (2004) is that we can specify between-industry productivity spillover channels from MNCs as a linear combination of between-industry input-output transaction data and within-industry foreign market shares (*Horizontal*), as follows:

$$Horizontal_{jt} = \frac{\sum_{i \in MNC} Y_{ijt}}{\sum_{i \in AllFirms} Y_{ijt}} \tag{3}$$

$$Backward_{jt} = \sum_{k \neq j} \alpha_{jkt} Horizontal_{kt} \tag{4}$$

$$Forward_{kt} = \sum_{j \neq k} \alpha_{jkt} Horizontal_{jt} \tag{5}$$

$Horizontal_{jt}$ is simply the foreign share of output in industry j in year t. Turning to $Backward_{jt}$, we first define α_{jk} which reflects the input share of industry k revenue paid to industry j, as calculated from the 3-digit j-by-k input-output tables discussed in Section 2. $Backward_{jt}$ is thus the row-sum of sales from domestic upstream industry j to all downstream industries k weighted by the *downstream* foreign presence in each purchasing industry k—a measure of domestic input sales to MNCs. $Forward_{kt}$ is the column-sum of industry k purchases from all industries j weighted by the *upstream* foreign presence in each selling industry j—or MNC input sales to domestic firms.[15] To illustrate the intuitive appeal of

[14] Investment and raw materials are used as the required proxies for Olley and Pakes (1996) and Levinsohn and Petrin (2003) methods respectively. To estimate TFP using Ackerberg et al. (2006), I follow Jagadeesh Sivadasan's estimation routine (`http://webuser.bus.umich.edu/jagadees/other/acf_code.html`).

[15] In practice, when *Forward* is the measure of interest the foreign share of production *Horizontal* is purged of export sales, which is made possible given the richness of the firm-level data. The main results are also robust to using either revenue (output) as the denominator in α_{jk}, or the sum of inputs in the denominator.

such measures, Javorcik (2004) explains: “Suppose that the sugar industry sells half of its output to jam producers and half to chocolate producers. If no multinationals are producing jam but half of all chocolate production comes from foreign affiliates, the Backward variable will be calculated as follows: 0.5 * 0 + 0.5 * 0.5 = 0.25.”

This paper is concerned with mechanical (non-classical) measurement error in the *Backward* effect due to overstated linkages in α_{jk}. To make this clear notationally, rewrite *Backward* with superscript D to denote its dependence on input-output coefficients α^D_{jkt} that assign large weight to *domestic* firm input demand, and thus *domestic* inputs. The main estimating equation is a TFP spillover specification with controls (such as exports) and fixed effects to help control for MNC selection of time- or industry-invariant characteristics such as industry profitability and business cycle peaks and troughs:

$$TFP_{ijt} = \theta_1 Horizontal_{jt} + \theta_2 Backward^D_{jt} + \theta_3 Forward_{jt} + \boldsymbol{X}_{ijt}\beta + \iota_i + \lambda_t + \varepsilon_{ijt} \tag{6}$$

Identifying Assumption: Identification of θ_2 requires any measurement error in *Backward* to be classical (random), such that $E[\epsilon_{ijt} * Backward^D_{jt} | Horizontal_{jt}, Forward_{jt}, \boldsymbol{X}_{ijt}, \iota_i, \lambda_t] = 0$. I show below however, that *Backward* mechanically over-weights *domestic* inputs, forcing MNCs to source according to the *domestic* firm input structure. Stated differently, foreign and domestic firms are assumed to have the same import propensity, overstating domestic input sales to import-intensive MNCs. In the rest of the paper I explore the implications of relaxing this strong assumption, and find that doing so can fundamentally alter the effects of FDI on host country firm productivity.

3.1 Measurement Error from Import Propensity Assumption

While pioneering in its approach, the Javorcik (2004) estimator relies on national input-output table aggregates which I argue contain important mechanical measurement error. To see this, first consider a standard simplified input-output coefficient matrix $\boldsymbol{\alpha}$, recalling that superscript D and F indicate dependence on largely *domestic* and *foreign* inputs respectively:

Standard Input-Output Table with Implied Weight on Domestic Firm Linkages

	Agriculture	Manufacturing	Services
Agriculture	0.46	$.33 = \frac{10^D}{30^{D+F}}$	0.35
Manufacturing	0.24	0.14	.05
Services	0.20	0.20	0.48
Imported Inputs	.10	$.33 = \frac{10^F}{30^{D+F}}$	.12
$Horizontal_k$ (MNC Share)	.30	.20	.40
$TotalOutput_k$	15	30	20

Each α_{jk} cell in the top 3x3 matrix is calculated by summing the total sales from supplier sector j to downstream industry k, and then dividing by the total country output (revenue) in sector k which is noted in the last row of the table. This yields the direct input requirements from sector j per unit of output in sector k. Considering α_{12}, domestic suppliers (denoted with superscript D) sell 10 million pesos of agricultural inputs to produce 30 million pesos of total manufacturing output.

To isolate the total sales from domestic input suppliers j to foreign MNCs *alone* (the object of interest), the Javorcik (2004) innovation is to weight the row-sum of any input sector j by the foreign share of output in each buying sector k ($Horizontal_k$ in the table above), capturing the local upstream effects of foreign presence in downstream sectors. Consider for example, total backward linkages to agriculture in the above table:

$$Backward^D_{1t} = 0.46 * 0.3 + 0.33 * 0.2 + 0.35 * 0.4 = 0.344 \tag{7}$$

While this insight generated a wave of new work on FDI, the method masks important heterogeneity in import intensity between domestic and MNC firms. To see this, now consider the ideal, but unobservable, input-output table:

Ideal (Unobservable) Input-Output Table: Isolated MNC Linkages

	Agriculture	Manufacturing	Services
Agriculture	.46	$.067 = \frac{10^D - 8^F}{30^{D+F}}$	.35
Manufacturing	.24	.14	.05
Services	.20	.20	.48
Imported Inputs	.10	$.60 = \frac{10^D + 8^F}{30^{D+F}}$	.12
$Horizontal_k$ (MNC Share)	.30	.20	.40
$TotalOutput_k$	15	30	20

Here, the precise measurement error is highlighted in indicated by the additional term 8^F. If MNCs in manufacturing are more likely to *import* agricultural inputs, as reflected by subtracting 8 million pesos of domestic inputs and re-assigning them to imports, the *Backward* measure in (7) sums to 0.2914, a roughly 14% measurement error which always overstates the true linkages so long as foreign manufacturing firms have a larger import propensity than domestic manufacturing firms. That is, purchases from MNCs of local goods need to be scaled down to reflect imported inputs.

3.2 Measurement Error Generates Omitted Variable Bias from Imported Inputs

This section explores the implications of relaxing the identifying assumption stated in Section 3.1. Suppose the true econometric model is as follows:

$$TFP_{ijt} = \theta_1 Horizontal_{jt} + \theta_2^* Backward_{jt}^* + \theta_3 Forward_{jt} + \boldsymbol{X}_{ijt}\beta + \iota_i + \lambda_t + \varepsilon_{ijt} \tag{8}$$

but the true effect $Backward_{jt}^*$ is proxied with error by $Backward_{jt}^D$:

$$Backward_{jt}^* = \delta_0 + \delta_1 Backward_{jt}^D + v_{jt} \tag{9}$$

Plugging (9) into (8) yields:

$$\begin{aligned} TFP_{ijt} = {} & \theta_2^*\delta_0 + \theta_1 Horizontal_{jt} + \theta_2^*\delta_1 Backward_{jt}^D + \theta_3 Forward_{jt} \\ & + \boldsymbol{X}_{ijt}\beta + \iota_i + \lambda_t + \theta_2^* v_{jt} + \varepsilon_{ijt} \end{aligned} \tag{10}$$

To evaluate how the proxy may generate bias, consider the following cases implied by (10):[16]

- *Case #1 - Consistent Estimates, Inflated Standard Errors:* If $E[v_{jt} * Backward_{jt}^D|...] = 0$ in (9), we simply have an additional error term $\theta_2^* v_{jt}$ that inflates standard errors, and can identify $\theta_2^*\delta_1$ in (10) as the coefficient of interest θ_2 in (6).

- *Case #2 - Classical Measurement Error (Attenuation Bias):* If $E[v_{jt} * Backward_{jt}^*|...] \neq 0$ in (9), then we have attenuation bias which drives estimates toward zero at a rate proportional to the relative variance of the true measure and the measurement error.

- *Case #3 - Omitted Variable Bias from Imported Inputs:* If $E[v_{jt} * Backward_{jt}^D|...] \neq 0$, then the bias is ambiguous. However, because the mis-measurement here is argued to be *mechanical*, we can derive an analytical expression for the bias. If $Backward_{jt}^D$ reflects the impact of largely *domestic* input linkages on TFP, and this covaries with the impact of omitted (un-separated) and largely

[16] These cases need not be mutually exclusive, however it is argued in Section 5 that Case #3 is of greatest concern, as Cases #1 and #2 can be ruled out as driving the main results.

imported input linkages on domestic supplier TFP ($\equiv Backward^F_{jt}$), this produces the following omitted variable bias formula:

$$\theta_2 = \theta_2^* + \theta_4 \underbrace{\frac{Cov[Backward^F_{jt}, Backward^D_{jt}|...]}{Var[Backward^D_{jt}|...]}}_{\equiv \rho_t}. \tag{11}$$

Here, the biased estimate θ_2 from (6) is a function of the true estimate θ_2^* and a bias term. θ_4 is the coefficient from regressing TFP on the omitted variable $Backward^F_{jt}$ were it included in the original estimation equation (6). To sign the bias in 11, we can sign θ_4 and ρ_t independently.

Sign(θ_4): In words, θ_4 is the impact of MNCs importing inputs on the TFP of domestic suppliers of those *same* inputs. We know from recent research that own-industry TFP and imported inputs are positively correlated (Amiti & Konings (2007), Kugler and Verhoogen (2008), Golberg et al. (2010), and Halpern et al. (2011)). It thus follows that if foreign firms have a stronger propensity to import, increases in foreign firm TFP likely occur at the expense of domestic input sourcing, such that $\theta_4 < 0$ (by assumption).

Sign(ρ_t): Using the definitions of ρ_t in 11 and *Backward* from 4, we can write:

$$\rho_t \equiv \frac{Cov[\sum_k \alpha^D_{jkt} Horizontal_{kt}, \sum_k \alpha^F_{jkt} Horizontal_{kt}]}{Var[Backward^D_{jt}|...]} \tag{12}$$

Define input-output matrices $\mathbf{A}^D, \mathbf{A}^F \in R^{jXk}$ with column vectors $\boldsymbol{\alpha}^D_k, \boldsymbol{\alpha}^F_k \in R^j$, and $\mathbf{h} \in R^k$ a vector of *Horizontal* share components each denoted by H_k. Using the linearity properties of covariance,[17] we can re-write (12) (within each period t) as follows:

$$\begin{aligned}
\rho &= Var[Backward^D_j|...]^{-1} Cov[\mathbf{A}^D\mathbf{h}, \mathbf{A}^F\mathbf{h}] \\
&= Var[Backward^D_j|...]^{-1} \sum_{1\leq d,f\leq k} Cov[H_d \boldsymbol{\alpha}^D_d, H_f \boldsymbol{\alpha}^F_f] \\
&= Var[Backward^D_j|...]^{-1} \sum_{1\leq d,f\leq k} H_d H_f Cov[\boldsymbol{\alpha}^D_d, \boldsymbol{\alpha}^F_f] \\
&= \underbrace{Var[Backward^D_j|...]^{-1}\mathbf{h}'}_{>0} \sum_{1\leq d,f\leq k} Cov[\boldsymbol{\alpha}^D_d, \boldsymbol{\alpha}^F_f] \underbrace{\mathbf{h}}_{>0}
\end{aligned} \tag{13}$$

Because the components $\mathbf{h}$ are non-negative by definition, this expression makes clear that what ultimately drives the omitted variable bias term is whether domestic and foreign input varieties are net

[17] Or skip directly to the result by using an analog of the following covariance property: if $\boldsymbol{X}$ is a random vector with covariance matrix $\sum(\boldsymbol{X})$ and $\boldsymbol{A}$ is a matrix that can act on $\boldsymbol{X}$, then $\sum(A\boldsymbol{X}) = A\sum(\boldsymbol{X})A'$.

complements or substitutes.[18] If domestic and imported inputs are net substitutes (complements), then the covariance term is negative (positive), resulting in upward (downward) bias. Intuitively, the elasticity of substitution between imported and domestic inputs drives the bias because the main estimating equation is in some sense *omitting* the impact of import-intensive MNCs on domestic supplier TFP through the equal import propensity assumption.

This also provides the foundation for a strong robustness test on whether an adjustment to the *Backward* proxy actually purges it of its measurement error. For any proposed improvement, the result above predicts that the magnitude of the bias between the original and adjusted measures should be proportionate to the degree of substitutability between domestic and imported inputs σ, such that that $Corr(\theta^*_{2,j} - \theta_{2,j}, \sigma^j) > 0$. In the next section I propose such an improvement, and in Section 6, test for this correlation directly.

4 Estimation with Adjusted Backward Linkages

In this section I propose an "adjustment" to the Backard Linkage spillover measure that relaxes the strong assumption that MNCs and domestic firms have the same import propensity. Using firm micro-data on domestic and imported inputs by both domestic firms and MNCs, we can re-scale each input-output coefficient to approximate the ideal, unobserved input-output matrix. The ideal adjustment would be as follows:

$$Backward^{FirstBest}_{jt} = \sum_k \alpha_{jkt}(1 - \alpha^D_{jkt})Horizontal_{kt} \tag{14}$$

where α^D_{jkt} sums firm inputs from sector j to *domestic-only* firms in sector k and divides by the sum of all-firm output in sector k (implementing the operations in red in Section 3.1), leaving only sales to multinational firms. However, as is the case in Javorcik (2004), despite the increasing availability of detailed administrative data, separate input-output linkages for domestic and MNC firms are rarely available.[19] Instead I use micro-data to generate new input-output coefficients by domestic and MNC firms. The adjustment is as follows:

$$Backward^{Adjusted}_{jt} = \sum_k \alpha_{jkt}\tilde{\alpha_{kt}}Horizontal_{kt} \tag{15}$$

[18] For an alternative and perhaps more intuitive proof of this result, see Appendix A.

[19] Javorcik (2004) is careful to recognize this data limitation as well, however does not have the rich micro-data to explore its consequences more deeply.

where

$$\tilde{\alpha_{kt}} \equiv \frac{\bar{\alpha_{kt}}^{MNC}}{\bar{\alpha_{kt}}^{AllFirms}} = \frac{(\sum_{i\in MNC} \frac{m^D_{ikt}}{Y_{ikt}})/N^{MNC}}{(\sum_{i\in AllFirms} \frac{m^D_{ikt}}{Y_{ikt}})/N^{AllFirms}}$$

is an adjustment factor calculated from firm data that can isolate domestic inputs m^D from total inputs, and represents the average fraction of the overall domestic input-output coefficient in downstream industry k attributable to MNC purchases.[20] This adjustment is always less than unity if MNCs have a lower domestic input (or higher import) propensity than domestic firms, and thus scales down potentially overstated input-output coefficients to better approximate the first-best coefficients in equation (14). The main exercise of this paper will thus be to compare the original base specification to the following, where we now substitute the new adjusted Backward measure for the original measure:

$$TFP_{ijt} = \theta_1 Horizontal_{jt} + \theta_2 Backward^{Adjusted}_{jt} + \theta_3 Forward_{jt} + \boldsymbol{X}_{ijt}\beta + \iota_i + \lambda_t + \varepsilon_{ijt} \qquad (16)$$

In Table 2 I present summary statistics for the FDI spillover measures tested in this paper, including the adjusted Backward Linkage measure just defined. The average *Horizontal* foreign market share is 4.4% in a given 3-digit industry, however with a standard deviation of about 10% there is ample variation in MNC entry both within and across industries.[21] Secondly, the average firm *Backward* Linkage measure is indeed reduced when the adjustment is applied. The way in which this reduction occurs is discussed at length in Section 5.

5 Main Results

We begin by estimating total factor productivity (TFP). Table 3 shows production function estimation results using standard methods from the industrial organization literature.[22] Across all specifications, output elasticities for capital are roughly twice as large as for labor in Colombia, broadly consistent with other country studies of firm productivity in Colombia.[23] The output elasticities also suggest that the aggregate production function in Colombia is roughly constant returns to scale. Figure 2 further

[20] In practice, domestic input flows m^D_{ikt} are not directly observed but are instead proxied by a time-varying panel variable that sums domestic inventory and raw material stock and subtracts out imports. This distinction however should be of little concern, as the adjustment measure reflects a unitless *ratio* of domestic and foreign values whose variation of interest is the cross-sectional difference between original and adjusted measures. Furthermore, when compared to a secondary firm measure of domestic input flows (m^{D2}_{ikt}) which scales input-output coefficients by the panel output variable, both domestic input measures share similar summary statistics (see $\mathbb{M}^D$ and $\mathbb{M}^{D2}$ in Table 1.)

[21] See Appendix B for annual time-series variation in *Horizontal* by 1-digit industry.

[22] For exposition, I present aggregate production function estimates in Table 3, however in subsequent tables (as well as in Figure 2), TFP is estimated within broad 1-digit categories when estimated by OLS.

[23] See for example Eslava et al. (2004) for a comparison. One important difference is that this paper's measure for total inputs is taken by multiplying input-output coefficients by firm-level output as no input flow value was available. This is not to be confused with the measure of domestic inputs used in the adjustment factor, which is a panel stock value less imports.

displays predicted TFP values at the firm-level. All four TFP distributions are relatively smooth and symmetric. OLS, Olley-Pakes, and Ackerberg-Caves-Frazier standard deviations range between .3 and .5, while Levinsohn-Petrin features a larger standard deviation of roughly 3.3. Differences in these measures however are of little concern, as the main variation of interest in this paper is the cross-sectional difference between variants of the *Backward* TFP spillover measure.

Turning to the main results, Table 4 compares coefficients from the base specification in equation (6), with the adjusted specification from equation (16). Panel A presents results in logs and levels, while Panel B presents results in standardized variables for comparability with other papers—that is, dividing both dependent and independent variables by their sample standard deviations. Odd-numbered columns reflect base specification models with the original *Backward* measure, while even-numbered columns are specifications with the adjusted *Backward* measure. When *Log(Output)* is the dependent variable of interest (technically log revenue), factors of production are included as controls in the regression.

The coefficients on *Backward* and *Backward - Adjusted* in Panel A show that across 4 out of 5 TFP and revenue outcome measures, the overall effect of downstream foreign investment on upstream domestic firm productivity is positive and highly statistically significant, but estimates reduce roughly in half when comparing original and adjusted measures (odd and even columns pairwise). Magnitudes in Panel A are large because the average exchange rate over the sample frame was roughly 1 US dollar to 2000 Colombian pesos (COP). Interpretations of *Backward* and *Backward - Adjusted* coefficients in Panel A thus reflect how much more (less) revenue in real 1999 Colombian pesos, domestic firms incurred due to foreign presence in downstream sectors for the same level of inputs.

To contextualize these magnitudes and compare them to estimates from other papers, Panel B implements the same regressions in standardized variables. In Panel B, estimates reduce by well over a half when using the adjusted *Backward* measure. Interpreting coefficients from the Olley-Pakes regressions—columns (5) and (6) of Panel B—a one standard deviation increase in Backward Linkages results in a .62 standard deviation increase when using the original *Backward* measure, but only a .21 standard deviation increase when using the *Backward - Adjusted* measure. With an average Olley-Pakes TFP value of 2.42 and a standard deviation of .43, these correspond to an 11.5% and 4.1% TFP increase respectively when evaluated at the mean. The effect size of 11.5% on the original *Backward* measure is also remarkably similar to the 15% output response to the one-standard deviation *Backward* increase found in Javorcik (2004).

Across specifications in both panels, the coefficient on *Horizontal* is negative but not always statistically distinguishable from zero. Furthermore, an increase in *Forward* linkages is also negatively associated with domestic firm productivity in the same industry. These effects are consistent with Aitken and Harrison (1999) and Javorcik (2004) respectively. To explore how this implicates the total effect of FDI on local firms, in the last two rows of each panel I add together the coefficients on *Backward* (*Backward - Adjusted*) and *Forward* to generate a net FDI impact value, and display the F-statistic on a joint hypothesis test that the sum of these measures are statistically different than zero. Moving from odd to even columns in Panel B, the net effect of FDI changes from positive to negative in all output and TFP measures, suggesting that the adjusted *Backward* effect is large enough to reverse the overall sign of the impact of FDI on local firm productivity. Importantly however, F-tests on these effects do not always reject the null hypothesis that the net effect of FDI is zero. Interpreting these results conservatively, we can at the very least confidently reject the claim that FDI generates *large* net productivity benefits to domestic firms in Colombia.[24]

All specifications contain firm and year fixed effects to help control for MNC selection of time- or industry-invariant characteristics such as industry profitability and business cycle peaks and troughs, so results should be interpreted as average within-firm responses to increased FDI. While the preferred specifications in Table 4 do not contain export controls,[25] the main results are robust to their inclusion. I instead focus on the more conservative estimates in Table 4 as the paper's preferred estimates as lower bound on the bias. Lastly, it bears noting that the lower reported observation counts here reflect the limited sample period over which there is sufficient import data to implement the adjustment to the *Backward* variable. While the estimates in Table 4 are generated by restricting the sample to those years (2007-2011), the results are also robust to including all years and allowing firm fixed effects to be estimated from the full sample.

In Table 5 and Table 6 I further disaggregate these effects by broad 1-digit ISIC industries and focus on OLS productivity estimates. Table 5 reports OLS production function output elasticities by 1-digit industry, and Table 6 reports analogous estimates of the main results by industry. The disaggregated results first suggest that overall effect reflects a weighted average of both positive and negative net FDI effects across industry groupings, whose effect sizes vary between -1.3 and 1.7 standard deviations according to Panel B. Furthermore, some industries exhibit a positive *Horizontal* effect, such as *Manufacturing*, *Construction*, and (private) *Services* sectors, while more extractive sectors such as *Mining* exhibit strongly negative competition effects. Unlike in Table 4, the net effect is also statistically detectable across most industries, as indicated by high F-statistics.

When looking for which industries drive the overall decrease in *Backward* linakge TFP spillovers, it

[24] I exclude *Horizontal* from the net effect to focus on the more prominent trade-off in the literature between positive *Backward* and negative *Forward* spillovers, as most studies find no statistically significant evidence of *Horizontal* effects. Including *Horizontal* would in fact make baseline effects *even more* negative.

[25] The main results are actually even stronger when including export controls as shown in Table 9 in the Appendix. Note that Table 9 does not include imported input controls as they are already accounted for in the first stage TFP estimation.

appears that (private) *Service*, *Public* service, and *Manufacturing* industries are responsible, although coefficients on manufacturing are not statistically different from zero (though their net effect is statistically significant when combined with Forward linkages). These three 1-digit industries are also among the top five of ten in imported inputs and import intensity of output, providing further support for the hypothesis that the bias is related to the equal import intensity assumption. Overall, in conjunction with the main effects, these results suggest that there may in fact be several industries in which FDI is a burden rather than a boon to domestic firm productivity.

5.1 Measurement Error Simulation

One concern raised early in the paper is that the adjusted *Backward* measure may be introducing its own *new* measurement error which attenuates coefficient estimates toward zero (see Case #1 in Section 3.1). As Table 6 demonstrates however, some industries such as *Construction* and *Mining* actually exhibit an *increase* in Backward Linkages, which would normally be precluded by an attenuation bias story. To test this more formally, I perform a measurement error simulation that loops through the base specification adding artificial error from a random uniform distribution with a larger and larger support to the original *Backward* linkage measure, re-estimating the coefficient on *Backward* in each iteration.

Figure 3 shows the results from that simulation, where the top horizontal red line indicates the coefficient estimate on *Backward* from column (3) of Panel A in Table 4 (5.401), while the lower red line indicates the coefficient estimate on *Backward - Adjusted* from column (4) of Panel A in Table 4 (2.423). The simulation suggests that the adjustment itself would need to generate roughly 25% *unintended* measurement error in *Backward* for coefficients to reach their observed values. To assess whether this is feasible, I also plot the distribution of both the original and adjusted *Backward* measures in Figure 4, which shows that the average difference between original and adjusted measures is on average only between 1% and 2% (interpreting log differences as percentages).

These two observations combined suggest that the change in Backward Linkage TFP spillovers is in fact due to an improvement rather than added measurement error.

6 Elasticity of Substitution Predictions and Results

Section 3.1 showed that the omitted variable bias found in each industry j is predicted to be proportionate to the elasticity of substitution between domestic and imported inputs. Here we test that prediction. Toward this end, we first add flexibility to the production function such that Y_{ijt} takes constant-elasticity-of-substitution (CES) arguments in foreign and domestic inputs.

$$Y_{ijt} = A_{ijt} K_{ijt}^{\beta_1} L_{ijt}^{\beta_2} \mathbb{M}_{ijt}^{\beta_3} \tag{17}$$

$$\mathbb{M}_{ijt} = (b_{ijt}^D (m_{ijt}^D)^{\frac{\sigma_j - 1}{\sigma_j}} + b_{ijt}^F (m_{ijt}^F)^{\frac{\sigma_j - 1}{\sigma_j}})^{\frac{\sigma_j}{\sigma_j - 1}} \tag{18}$$

Here, total inputs $\mathbb{M}$ are a composite of domestic m^D and foreign m^F (imported) inputs. Each b term represents the relative importance of each input variety to the firm. This functional form permits the estimation of the substitution parameter σ_j. To estimate σ_j, I make small adaptations to a widely used method developed in Feenstra (1994), tailored to the context of Colombian input and import micro-data.

Feenstra Method and Adaptations. Feenstra (1994) estimates substitution elasticities between imported and domestic varieties within goods across countries to calculate price index responses to trade liberalization that account for utility from the increased variety of goods available to consumers. In the context of this paper, there is no analagous utility function, however the same set-up can be used to estimate a demand equation that isolates logged market shares for imported and domestic input varieties on the left-hand side, as a function of observables in the Colombian data on the right-hand side. To do this, denote $\mathbb{P}_{jvt}$ the price index of each industry-j specific input variety v (now subscripting D and F as domestic and foreign varieties) in year t. First order conditions with respect to each input variety m_{ivjt} yield firm input demand and expenditure share formulas.[26]

$$m_{ivjt} = \mathbb{P}_{vjt}^{-\sigma_j} b_{ivjt} \underbrace{\left(\sum_v b_{ivjt} \mathbb{P}_{vjt}^{1-\sigma_j} \right)^{\frac{1}{1-\sigma_j}}}_{\phi_{ijt}} \tag{19}$$

$$s_{ivjt} = \left(\frac{\mathbb{P}_{vjt}}{\phi_{ijt}} \right)^{1-\sigma_j} \underbrace{b_{ivjt}}_{assumed\, random} \tag{20}$$

While Feenstra (1994) observes good-specific price indices but is limited to aggregate expenditure (import) share data across countries, in this paper however, price data is limited to aggregate annual input and import indices (not good- or industry-specific as one cannot separate the industry-level producer price index into input and import price indices), but highly detailed firm-level and thus industry-level expenditure share data are observed. To account for this difference, assume that the price index above can be decomposed such that we can write $\mathbb{P}_{vjt} = \mathbb{P}_{vt}\mathbb{P}_{jt}$.[27] Summing (20) over i and taking logs, demand can be re-written as a function of observables and year, industry, and industry-year fixed effects to control

[26]This also generates the familiar constant elasticity relative demand formula $\frac{m_{iFjt}}{m_{iDjt}} = \left(\frac{\mathbb{P}_{Djt}}{\mathbb{P}_{Fjt}}\right)^{-\sigma_j}$.

[27]Because expenditure shares vary by industry, one can still combine variation in expenditure shares and aggregate input and import variety industries to estimate meaningful substitution elasticities.

for fixed characteristics (assuming that b_{ijvt} and thus $\sum_i b_{ijvt}$ are mean zero random tastes).[28]

$$
\begin{aligned}
log(s_{vjt}) &= (1-\sigma_j)log(\mathbb{P}_{vt}) + (1-\sigma_j)log(\mathbb{P}_{jt}) - (1-\sigma_j)log(\phi_{jt}) - log(b_{ivjt}) \\
&= (1-\sigma_j)log(\mathbb{P}_{vt}) + f_j + f_{jt} + f_t + \varepsilon_{vjt} \qquad (21)
\end{aligned}
$$

The supply side follows Feenstra (1994) and assumes Dixit-Stiglitz style mark-ups that yield a supply curve that is multiplicative in terms that vary at the jt level and others that are a function of stochastic inverse supply elasticity and technology terms ω_j and η_{jvt}, which are absorbed by the same fixed effects used in the demand equation yielding supply in logs:

$$
\begin{aligned}
log(\mathbb{P}_{vt}) &= log(\mathbb{P}_{vt}) + log(\mathbb{P}_{jt}) \\
&= log\left(\sum_v exp\left(\frac{-\eta_{vjt}}{\omega_j}\right)\mathbb{P}_{vt}^{\frac{1+\omega_j}{\omega_j}}\right) + log\left(\frac{\eta_{vjt}}{1+\omega_j}\right) + log\left(s_{vjt}^{\frac{\omega_j}{1+\omega_j}}\right) \\
\implies log(\mathbb{P}_{vt}) &= \frac{\omega_j}{1+\omega_j}log(s_{vjt}) + f_j + f_{jt} + f_t + \delta_{vjt} \qquad (22)
\end{aligned}
$$

Finally, Feenstra (1994) shows that we can combine supply and demand by multiplying error terms to attain a compact structural estimation equation (assuming demand and supply shifters ε and δ are orthogonal) that yields a closed-form solution for σ_j if $\sigma_j > 1$:[29]

$$
log(\mathbb{P}_{vjt})^2 = \gamma_{1j}log(s_{vjt})^2 + \gamma_{2j}log(s_{vjt})log(\mathbb{P}_{vjt}) + f_j + f_{jt} + f_t + \frac{\varepsilon_{vjt}\delta_{vjt}}{1-\sigma_j} \qquad (23)
$$

$$
\begin{aligned}
\sigma_j &= 1 + \left(\frac{2\hat{\rho}_j - 1}{1-\hat{\rho}_j}\right)\frac{1}{\hat{\gamma}_{2j}} \qquad (24) \\
\hat{\rho}_j &= \frac{1}{2} - \left(\frac{1}{4} - \frac{1}{4 + (\hat{\gamma}_{2j}^2/\hat{\gamma}_{1j})}\right)^{1/2}
\end{aligned}
$$

In practice, I estimate σ_j within 3-digit ISIC categories such that only year fixed effects are needed as additional controls in the regression. Table 7 shows the results from this estimation. Of the 59 3-digit industries in the Colombian economy, 44 had sufficient price index and import micro-data overlap to be included in the analysis. The final table displays 41 of these industries. *Coffee Beans*, *Gas*, and *Waste Product* industries were eliminated due to insufficient observations in the sample period for which import expenditure shares are available (2007-11). 39 out of these 41 industries have estimated substitution elasticities over 1, the majority of which fall in the 2 to 4 range. Reassuringly, sectors such as *Financial*

[28] Feenstra (1994) uses first differences instead of fixed effects, but these are functionally equivalent here.
[29] For a discussion of the limitations of the identifying assumption here, see Soderbery (2015).

Intermediation have very high substitution elasticities, whereas non-durables such as *Meat and Fish Products* feature lower elasticities.

Only two industries had σ estimates less than 1, which are non-admissible in the Feenstra routine: *Other Transport Services* and *Social and Health Services.* Rather than implementing a grid search for these two industries as in Broda and Weinstein (2004) and Soderbery (2015), because so few industries were not admissible, I display correlations both including and omitting their estimates from the correlation coefficients. Figure 5 shows the results from correlating these substitution elasticities with the bias calculated from subtracting the original *Backward* coefficient from the adjusted coefficient in each 3-digit industry j.

Across all four TFP measures, the amount of bias is increasing in the elasticity of substitution. The red line plots the unrestricted linear fit, the green line restricts the fit to values of σ that are greater than 1, and the orange line restricts σ within 1 and 4 to test its sensitivity to outliers. While there is a clear positive trend across all specifications and restrictions, only three of the twelve fitted lines are statistically significant at the 10%-level, however it bears noting that the correlation coefficients reflect a bi-variate regression with no controls to improve efficiency.

To check whether this correlation is consistent with the analytical sign in Section 3.3, note that several 3-digit industries are biased downward rather than upward. As discussed, this can only happen if the elasticity of substitution is low ($\sigma < 1$), or there are positive effects of import-intensive MNCs on upstream suppliers ($\theta_4 > 0$). Figure 5 shows that downward-biased industries have low substitution elasticities. While suggestive that imported and domestic inputs are more complementary in those industries, Table 6 showed that some industries exhibit positive *Horizontal* spillovers (technology leakage or competition effects), which may cause the downward bias here. Regardless of the ultimate driver, the correlation pattern is consistent with the analytical sign and provides further suggestive evidence that the *Backward* linkage bias is driven by imported inputs.

7 Robustness

While imported inputs appear to play an important role in estimating TFP spillovers from MNCs, they enter the omitted variable bias in a complicated way such that one cannot simply include them as controls in the regression.[30] One may however, be concerned that further omitted variables or selection concerns may differentially affect *Backward* and *Backward - Adjusted* estimates in the cross-section. In Appendix C, I show that the main results are robust to the inclusion of export controls. I also show that results are robust to limiting the sample to surviving (right-censored) firms, which helps circumvent selection

[30] One additional reason for this is they are already accounted for in the first stage TFP estimation.

concerns regarding the entry and exit of import-intensive MNCs. Lastly, I also show that the results are not being driven by allowing input-output coefficients to vary by time. When fixing input-output coefficients at the values calculated in the first year of the panel, the main results remain in tact.

One final inquiry relates to why *Forward* linkages are so persistently negative, as found both here, in Javorcik (2004), and in other papers. I first implement a fix similar to the *Backward* linkage adjustment, which scales each row of the input-output table by the share of MNC sales relative to domestic firm sales in each *selling* sector (purging the measure of exports). Unlike with *Backward* linkages however, MNCs sales of intermediates in the host country should not result in understated linkages. Appendix E shows that domestic firms actually have *higher* export intensities than foreign firms. If anything, negative effects found from unadjusted forward linkages should in fact become more negative when adjusted to reflect the fact that MNCs have a larger share of their sales within the country. Lastly, I examine whether strongly negative Forward linkage effects persist when considering lagged specifications, as Javorcik (2004) implied that strong negative effects emanate from MNCs imposing large adjustment costs on domestic firms when introducing higher-quality inputs. If this is indeed the case, one should see the reversal of negative Forward linkage effects over time [results pending].

8 Discussion

Global FDI inflows reached USD $1.46 trillion in 2013 (UNCTAD, 2014), capping a remarkable trend in the growth of capital flows and relocation of multinational firms over the preceding two decades. For developing countries that have received an increasing share of these flows and continue to offer deferential FDI incentives, the question of whether and how FDI generates net benefits or costs to local firms remains important. Whereas the economic rationale for trade liberalization relates to the gains from trade, the long-run gains from FDI are predicated on strong positive technology externalities or productivity *spillovers* from MNCs to local firms. A long and influential empirical literature (starting with Aitken and Harrison (1999)) has thus focused on identifying whether large externalities from FDI exist, and through which channels they diffuse (Javorcik, 2004).[31]

Since the pioneering work of Javorcik (2004), a broad consensus has emerged that most of the productivity gains from FDI percolate through Backward Linkages to MNCs—knowledge acquired by local suppliers when contracting with foreign firms at the Pareto technology frontier. Yet a newer literature on the role of imported inputs in firm productivity growth suggests that the most productive firms become that way in part through importing inputs, motivating a fresh look at how Backward Linkage productivity

[31]Not discussed in this paper, is an equally large literature concerning the gains from FDI in the financial intermediation sector, where externalties emanate from imperfect capital markets.

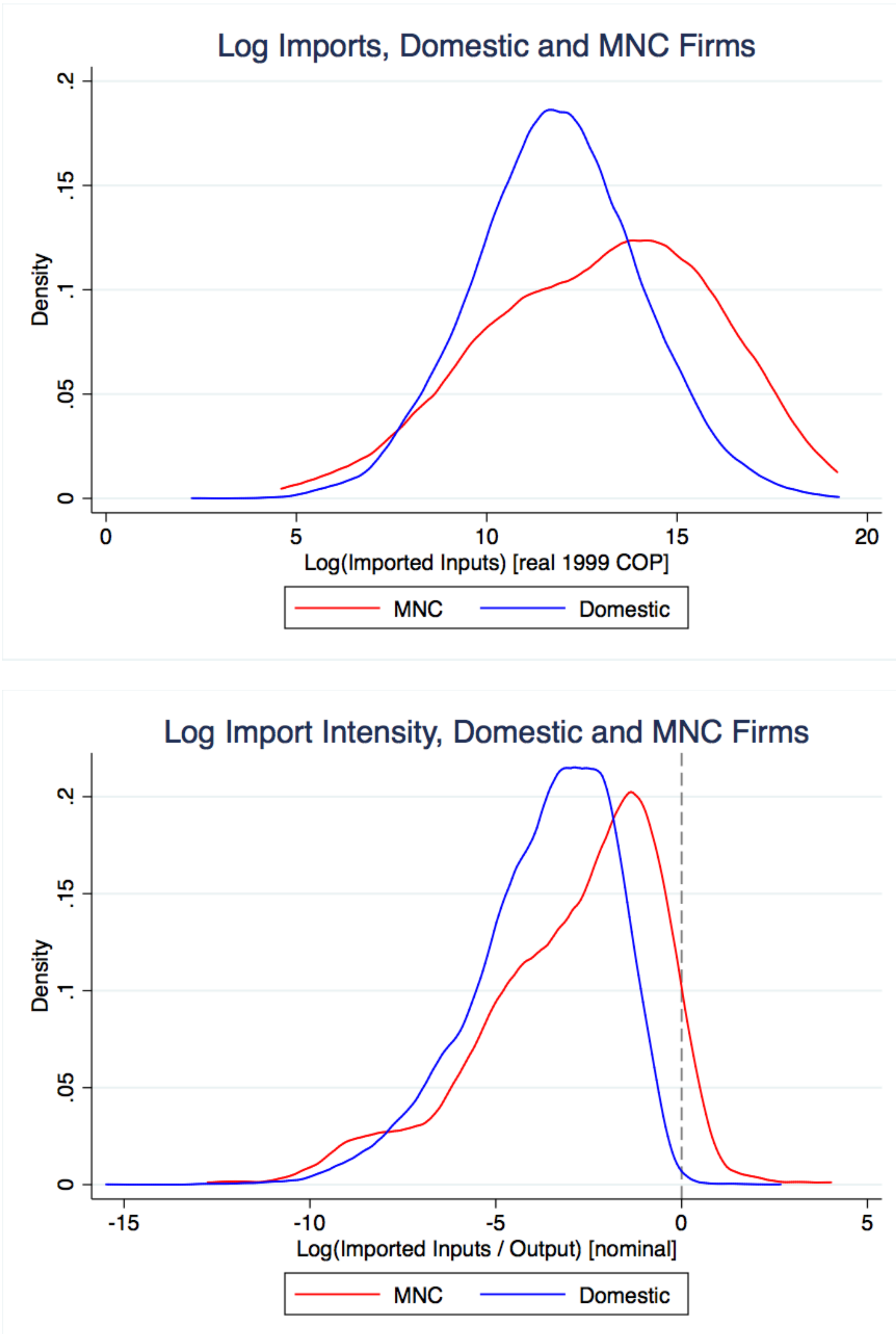
spillovers occur if MNCs are largely importers rather than domestic-sourcers of inputs.

In this paper, I show that "standard" Backward Linkage productivity spillover specifications implicitly assume domestic and foreign firms share the same input structure and propensity to import inputs. Using a novel Colombian firm panel that allows me to isolate imported from domestic inputs, I propose a micro-data *adjustment* to the input-output coefficients that are central to TFP spillover measures, making them more reflective of MNCs' observably higher import propensity. I find that this adjustment reduces mean Backward Linkage productivity spillovers roughly in half—an economically meaningful difference that is robust across four out of five measures of firm revenue and TFP. By empirically allowing MNCs to substitute foreign for domestic intermediate inputs, the intensity of contracting with local firms decreases, as do any productivity spillovers that may arise from sharing technology with those upstream partners. Some industries however, such as construction and mining, exhibit an *increase* in Backward Linkage TFP spillovers. This highlights the importance of precise measurement of TFP spillovers, and further suggests that the bias does not unambiguously overstate productivity gains. I show that the magnitude and sign of the bias are analytically proportional to the elasticity of substitution between domestic and imported inputs. In addition to robustness tests confirming that measurement error in the adjusted measure cannot be driving the overall results, I estimate substitution elasticities between domestic and imported inputs, and find correlation coefficients that are broadly consistent with this prediction.

Overall, these results suggest that productivity spillovers may vary largely by industry. They also highlight how input market liberalization can have adverse feedback effects by strengthening MNCs competing for foreign market share. While recent work has begun to explore interactions between foreign affiliate and input quality choices (see for example Antras and Rossi-Hansberg (2008) and Fieler et al. (2014)), more theoretical precision is needed to understand what assumptions may generate diverse interactions between FDI and imported inputs at the industry level.[32] Overall, this paper highlights the importance of properly accounting for heterogeneity in imported inputs when estimating TFP spillovers from FDI. More empirical work is needed to understand whether this reduction is specific to Colombia, or instead a widespread problem in the literature.

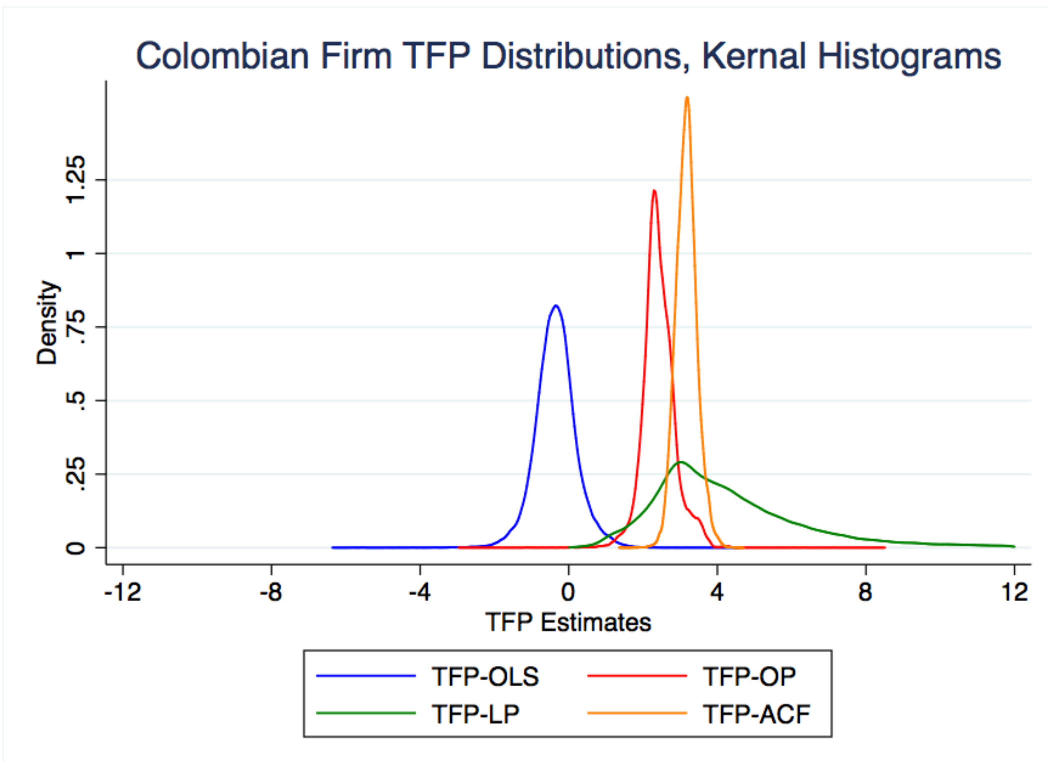
[32] Particularly interesting is what appears to be a Forward Linkage puzzle—if imported inputs are so complementary to firm productivity then why do so many studies on FDI consistently find *negative* Forward Linkage TFP effects from MNC sales of productive inputs to domestic firms?

Figure 1. Domestic and MNC Import Propensities (2007-11), Kernal-Smoothed Histograms



Notes. Firms with import intensity above 1 (0 in logs) are largely import-export MNCs.

Figure 2. Firm TFP Distributions by OLS (Solow residual), Olley-Pakes, Levinsohn-Petrin, and Ackerberg-Caves-Frazier Methods



Notes. TFP distributions reflect estimates from full sample (1995-2011).

Figure 3. Attenuation Bias Check - Measurement Error Simulation of Backward Variable

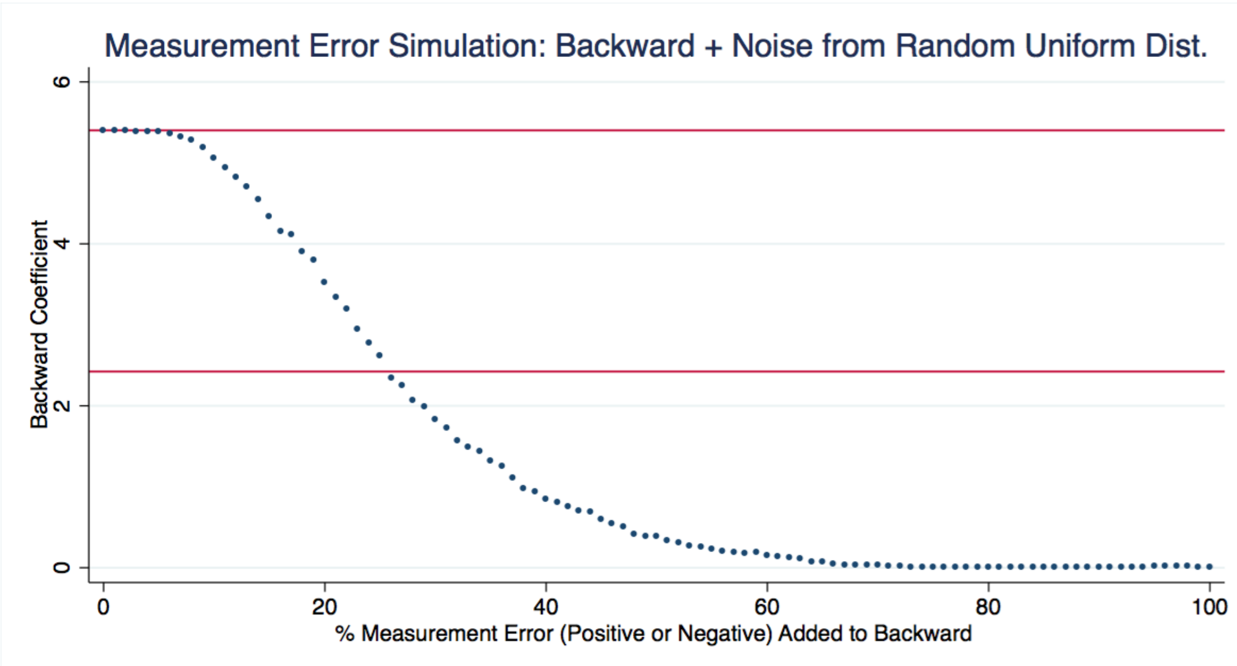


Figure 4. Standard vs. Adjusted *Backward* Measure ('07-11), Kernal-Smoothed Histograms

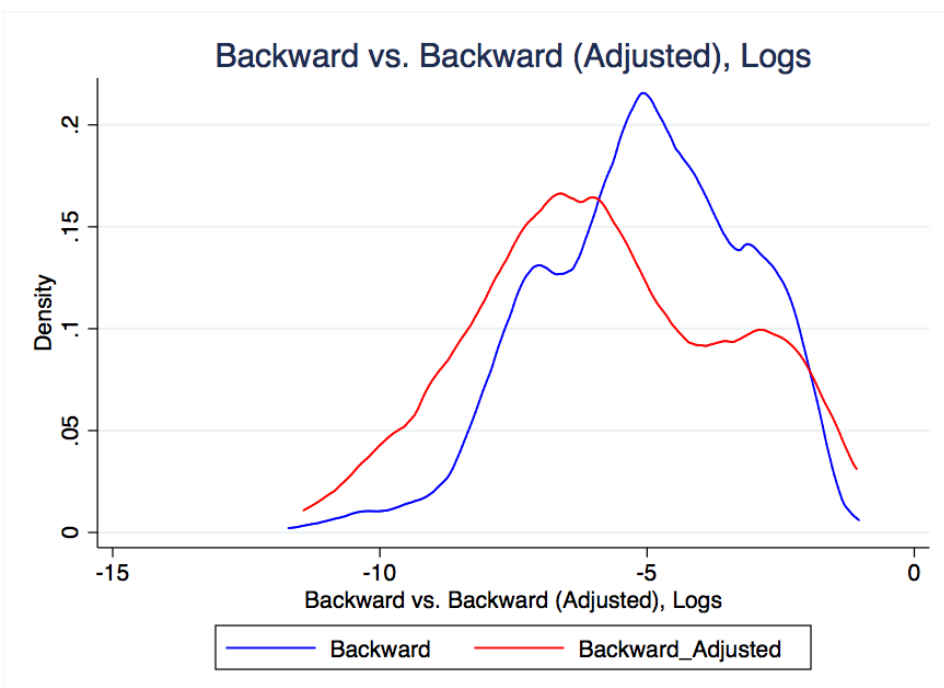


Figure 5. Correlation Between Elasticity of Substitution and *Backward* Coefficient Bias

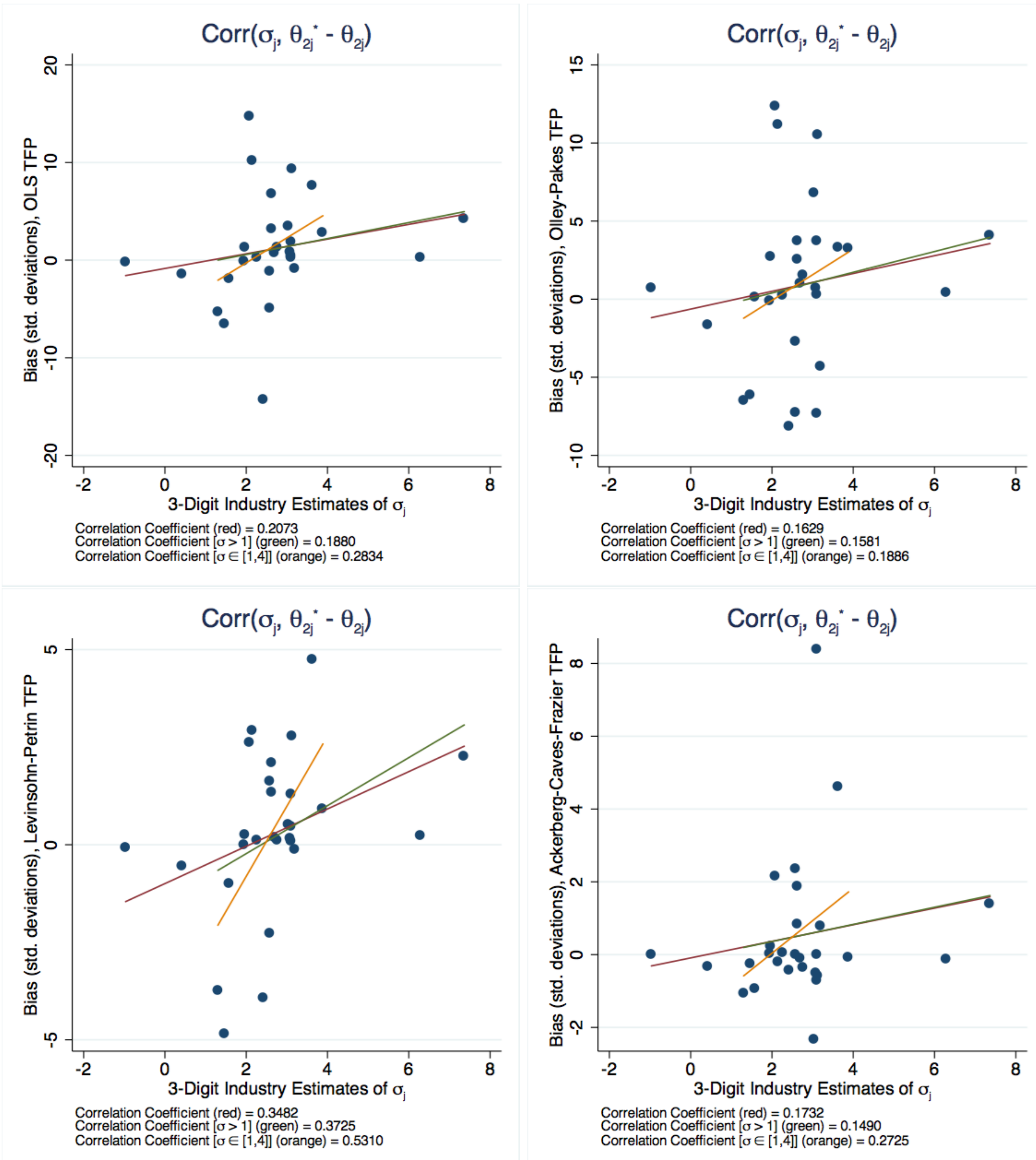


Table 1. Summary Statistics - Colombian Firm Panel Variables (1995 - 2011)

	Domestic Firms	**Multinational Firms**	**All Firms**
ln π - Log Profit (post-tax)	11.570	12.733	11.595
	(1.903)	(3.012)	(1.942)
ln Y - Log Total Revenue (sales)	14.665	14.831	14.670
	(1.771)	(2.525)	(1.794)
ln C - Log Reported Total Costs (Admin., Delivery, Operating)	15.005	14.609	14.993
	(1.651)	(2.978)	(1.709)
ln K - Log Property, Plants, and Equipment (PPE)	14.150	13.812	14.139
	(1.617)	(2.710)	(1.665)
ln L - Log Wage Payments (Short and Long-Run Obligations)	10.100	10.623	10.112
	(1.785)	(2.141)	(1.796)
ln $\mathbb{M}$ - Log Total Inputs (Domestic + Imported)	12.466	13.159	12.478
	(2.096)	(2.603)	(2.108)
ln $\mathbb{M}^D$ - Log Dometic Inputs (from Input-Output Table)	13.836	13.907	13.838
	(1.896)	(2.609)	(1.918)
ln $\mathbb{M}^{D2}$ - Log Domestic Inventory (Materials + Inventory)	12.288	12.776	12.295
	(2.056)	(2.539)	(2.063)
ln $\mathbb{M}^F$ - Log Imported Inputs	11.829	12.955	11.876
	(2.197)	(2.966)	(2.246)
$\mathbb{M}^D/Y$ - Domestic Input Itensity of Output (nominal)	0.368	0.297	0.366
	(0.247)	(0.177)	(0.246)
$\mathbb{M}^F/Y$ - Imported Input Intensity of Output (nominal)	0.030	0.319	0.037
	(0.150)	(2.521)	(0.425)
ln Exports	12.609	12.174	12.597
	(2.593)	(3.918)	(2.637)
ln Investment in PPE	11.426	11.240	11.424
	(3.047)	(2.757)	(3.045)
Years Firm in Panel	10.685	10.739	10.687
	(5.168)	(5.067)	(5.165)
No. of Observations	138,411	4,739	143,150
No. of Firms	28,449	936	29,369

Notes. Varibles in real 1999 COP unless indicated. Panel data from Colombian corporate business registry *Superintendencia de Sociedades*, and span 1995 to 2011. Import and export data from Colombian customs agency *DIAN*, and span 2007-11. Input-Output tables are annual from Colombian statistics agency *DANE*, assembled using alterations of Matlab procedure from Guilhoto and Filho (2005). Full sample contains 28,449 unique domestic firms and 936 foreign firms. The smaller DIAN sample contains 16,245 unique domestic firms. Summary statistics above reflect full sample, and are restricted to firms with non-zero operating revenue, labor, capital, and materials.

Table 2. Variation in FDI Spillover Measures

	Mean	**Standard Deviation**	**Min**	**Max**
Horizontal (Foreign Market Share of Revenue)	0.044	0.102	0.000	1.000
Backward Linkage Sales (to MNCs)	0.028	0.043	0.000	0.355
Backward Linkage Sales (to MNCs) - Adjusted	0.009	0.033	0.000	0.547
Forward Linkage Sales (from MNCs)	0.004	0.014	0.000	0.430
No. of Observations	143,150			
No. of Firms	29,639			

Notes. Horizontal revenue shares calculated within 59 3-digit industries. *Backward* and *Forward* values are firm-specific. See Appendix B for futher time-series variation in foreign revenue shares by 1-digit industry in Colombia.

Table 3. Production Function Estimation Results

	OLS	**Olley -Pakes**	**Levinsohn -Petrin**	**Ackerberg-Caves-Frazier**
Log(Capital)	0.271***	0.105***	0.183***	0.129***
	(0.00214)	(0.00173)	(0.00346)	(0.00231)
Log(Labor Payments)	0.106***	0.0570***	0.102***	0.055***
	(0.00137)	(0.00226)	(0.000812)	(0.00136)
Log(Total Inputs)	0.703***	0.783***	0.700***	0.775***
	(0.00243)	(0.00283)	(0.00168)	(0.00231)
Sum of Coefficients	1.081	0.959	0.985	0.985
No. of Observations	138,826	138,826	138,826	138,826
No. of Firms	29,369	29,369	29,369	29,369

Notes. Standard errors heteroskedastik-robust for OLS, O-P, L-P, bootsrapped for A-C-F according to Jagadeesh Sivadasan block routine. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Main Effects of Foreign Direct Investment on Domestic Firm TFP

Panel A. In Logs and Levels

VARIABLES	(1) Log Output	(2) Log Output	(3) TFP (OLS)	(4) TFP (OLS)	(5) TFP (OP)	(6) TFP (OP)	(7) TFP (LP)	(8) TFP (LP)	(9) TFP (ACF)	(10) TFP (ACF)
Horizontal	-2.165**	-2.356**	-2.259**	-2.574**	-2.597**	-2.897**	-5.833	-6.388	0.0275	0.0811
	(0.943)	(1.120)	(1.037)	(1.271)	(1.147)	(1.407)	(3.763)	(4.529)	(0.0530)	(0.0689)
Backward	5.215***		5.401***		6.253***		14.28**		-0.0483	
	(1.511)		(1.444)		(1.665)		(6.146)		(0.0479)	
Backward - Adjusted		2.224***		2.423***		2.737***		6.115**		-0.0759**
		(0.577)		(0.594)		(0.678)		(2.426)		(0.0386)
Forward	-8.852***	-8.680**	-8.972***	-8.895***	-10.36***	-10.28***	-32.82***	-32.67***	-0.0492	-0.0587
	(3.214)	(3.351)	(3.035)	(3.202)	(3.460)	(3.659)	(10.74)	(11.21)	(0.0512)	(0.0500)
Observations	38,036	38,036	38,036	38,036	38,036	38,036	38,036	38,036	38,221	38,221
R^2	0.700	0.692	0.307	0.292	0.351	0.329	0.026	0.025	0.035	0.035
Number of Firms	16,504	16,504	16,504	16,504	16,504	16,504	16,504	16,504	16,582	16,582
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Export Controls	No	No	No	No	No	No	No	No	No	No
Net Effect (Backward + Forward)	-3.637	-6.456	-3.571	-6.472	-4.103	-7.542	-18.54	-26.55	-0.0974	-0.135
F-statistic (Net Effect=0)	8.636	0.0352	10.90	0.0359	11.11	0.0342	4.366	0.0111	0.275	0.0110

Panel B. In Standardized Variables

VARIABLES	(1) Log Output	(2) Log Output	(3) TFP (OLS)	(4) TFP (OLS)	(5) TFP (OP)	(6) TFP (OP)	(7) TFP (LP)	(8) TFP (LP)	(9) TFP (ACF)	(10) TFP (ACF)
Horizontal	-0.124**	-0.135**	-0.415**	-0.473**	-0.615**	-0.686**	-0.181	-0.198	0.00994	0.0293
	(0.0539)	(0.0640)	(0.191)	(0.234)	(0.272)	(0.333)	(0.117)	(0.140)	(0.0191)	(0.0249)
Backward	0.125***		0.418***		0.623***		0.186**		-0.00734	
	(0.0364)		(0.112)		(0.166)		(0.0802)		(0.00728)	
Backward - Adjusted		0.0406***		0.142***		0.207***		0.0606**		-0.00876**
		(0.0106)		(0.0349)		(0.0514)		(0.0240)		(0.00445)
Forward	-0.0702***	-0.0689**	-0.229***	-0.227***	-0.341***	-0.338***	-0.141***	-0.141***	-0.00246	-0.00294
	(0.0255)	(0.0266)	(0.0774)	(0.0817)	(0.114)	(0.120)	(0.0462)	(0.0482)	(0.00257)	(0.00251)
Observations	38,036	38,036	38,036	38,036	38,036	38,036	38,036	38,036	38,221	38,221
R^2	0.700	0.692	0.307	0.292	0.351	0.329	0.026	0.025	0.035	0.035
Number of Firms	16,504	16,504	16,504	16,504	16,504	16,504	16,504	16,504	16,582	16,582
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Export Controls	No	No	No	No	No	No	No	No	No	No
Net Effect (Backward + Forward)	0.0552	-0.0282	0.189	-0.0846	0.283	-0.131	0.0450	-0.0800	-0.00980	-0.0117
F-statistic (Net Effect=0)	0.00220	2.883	0.000445	2.644	0.00208	2.753	0.00537	1.326	0.0300	0.874

Standard errors clustered at the 5-digit industry level. *** p<0.01, ** p<0.05, * p<0.1. When Log(Output) is the dependent variable, production factors are included as controls.

Table 5. Production Function Estimation Results by 1-Digit Industry (OLS)

	Agriculture	**Mining**	**Petroleum**	**Manufacturing**	**Construction**	**Utilities**	**Services**	**Transportation**	**Financial**	**Public**
Log(Capital)	0.197***	0.280***	0.144***	0.331***	0.151***	0.219***	0.218***	0.313***	0.156***	0.316***
	(0.00500)	(0.0373)	(0.0266)	(0.00705)	(0.00375)	(0.0324)	(0.00305)	(0.0119)	(0.00765)	(0.00414)
Log(Labor Payments)	0.164***	0.158***	0.162***	0.0832***	0.0460***	0.0658***	0.0282***	0.145***	0.0935***	0.123***
	(0.00405)	(0.0165)	(0.0184)	(0.00222)	(0.00348)	(0.0173)	(0.00172)	(0.00865)	(0.00865)	(0.00407)
Log(Total Inputs)	0.759***	0.679***	0.774***	0.644***	0.860***	0.777***	0.819***	0.629***	0.851***	0.672***
	(0.00604)	(0.0408)	(0.0290)	(0.00734)	(0.00433)	(0.0314)	(0.00319)	(0.0134)	(0.00890)	(0.00528)
Sum of Coefficients	1.120	1.117	1.080	1.058	1.057	1.062	1.065	1.088	1.100	1.111
No. of Observations	12,991	1,095	1,282	39,046	13,556	267	45,701	5,935	2,999	15,954
No. of Firms	2,091	279	330	6,383	3,240	76	10,342	1,392	684	4,552

Standard errors heteroskedastik-robust. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6. Effects of Foreign Direct Investment on Domestic Firm TFP, OLS by 1-Digit Industry

Panel A. In Logs and Levels

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
VARIABLES	Agricult.	Agricult.	Mining	Mining	Manufact.	Manufact.	Construct.	Construct.	Services	Services	Transport.	Transport.	Public	Public
Horizontal	-4.658	-4.367	-5.104**	-5.884**	2.513***	2.449***	19.84***	1.941***	4.481*	10.18***	-0.107	0.114	-13.65***	-1.254
	(4.235)	(4.463)	(2.008)	(1.996)	(0.743)	(0.699)	(0.641)	(0.229)	(2.676)	(3.253)	(0.197)	(0.106)	(3.444)	(4.741)
Backward	-2.778**		-25.69		1.528		-89.63***		15.02***		-2.310**		25.39***	
	(1.040)		(41.01)		(1.940)		(3.772)		(1.499)		(1.068)		(5.774)	
Backward - Adjusted		-2.519**		6.418**		0.673		13.17***		6.663***		-2.002**		1.852
		(1.032)		(2.589)		(0.892)		(0.554)		(0.300)		(0.756)		(2.065)
Forward	-26.36**	-28.07***	26.13	74.67	-0.724	-0.550	-103.1***	-32.95***	-7.660***	-8.492***	-10.91**	-13.17***	-10.80	-29.05
	(9.571)	(9.572)	(37.00)	(50.21)	(1.084)	(1.109)	(3.725)	(2.063)	(0.894)	(0.754)	(5.104)	(4.533)	(10.81)	(33.56)
Observations	4,269	4,269	361	361	10,772	10,772	5,028	5,028	12,666	12,666	753	753	3,400	3,400
R^2	0.630	0.629	0.617	0.621	0.759	0.759	0.385	0.385	0.790	0.785	0.375	0.400	0.664	0.577
Number of Firms	1,452	1,452	183	183	3,813	3,813	2,073	2,073	6,391	6,391	426	426	1,827	1,827
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Export Controls	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Net Effect (Backward + Forward)	-29.14	-30.59	-0.379	-0.369	0.804	0.123	-192.7	-19.79	7.359	-1.829	-13.22	-15.18	14.59	-27.20
F-statistic (Net Effect=0)	2.011	1.586	0.547	0.0262	3.639	7.253	486.7	1108	25.13	27.58	5.229	7.382	22.13	0.0479

Panel B. In Standardized Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
VARIABLES	Agricult.	Agricult.	Mining	Mining	Manufact.	Manufact.	Construct.	Construct.	Services	Services	Transport.	Transport.	Public	Public
Horizontal	-0.856	-0.802	-0.938**	-1.081**	0.462***	0.450***	3.645***	0.357***	0.823*	1.870***	-0.0197	0.0209	-2.508***	-0.230
	(0.778)	(0.820)	(0.369)	(0.367)	(0.137)	(0.128)	(0.118)	(0.0421)	(0.492)	(0.598)	(0.0362)	(0.0195)	(0.633)	(0.871)
Backward	-0.215**		-1.987		0.118		-6.932***		1.162***		-0.179**		1.964***	
	(0.0805)		(3.172)		(0.150)		(0.292)		(0.116)		(0.0826)		(0.447)	
Backward - Adjusted		-0.148**		0.377**		0.0395		0.774***		0.391***		-0.118**		0.109
		(0.0607)		(0.152)		(0.0524)		(0.0326)		(0.0176)		(0.0444)		(0.121)
Forward	-0.672**	-0.716***	0.667	1.905	-0.0185	-0.0140	-2.631***	-0.841***	-0.195***	-0.217***	-0.278**	-0.336***	-0.275	-0.741
	(0.244)	(0.244)	(0.944)	(1.281)	(0.0277)	(0.0283)	(0.0950)	(0.0526)	(0.0228)	(0.0192)	(0.130)	(0.116)	(0.276)	(0.856)
Observations	4,269	4,269	361	361	10,772	10,772	5,028	5,028	12,666	12,666	753	753	3,400	3,400
R^2	0.630	0.629	0.617	0.621	0.759	0.759	0.385	0.385	0.790	0.785	0.375	0.400	0.664	0.577
Number of Firms	1,452	1,452	183	183	3,813	3,813	2,073	2,073	6,391	6,391	426	426	1,827	1,827
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Export Controls	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Net Effect (Backward + Forward)	-0.887	-0.864	-1.240	-1.210	0.0997	0.0255	-9.563	-0.0672	0.966	0.175	-0.457	-0.454	1.688	-0.632
F-statistic (Net Effect=0)	1.565	1.169	0.785	3.103	7.714	12.06	326.2	1087	11.71	14.47	5.431	7.303	6.444	0.0262

Standard errors clustered at the 5-digit industry level. Three sectors were omitted due to insufficient observations - Utilities, Financial Services, and Petroleum firms. *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Elasticity of Substitution Estimates, Imported and Domestic Inputs

Downstream Industry **3-Digit ISIC**	Log(Share^2)	(s.e.)	Log(Share) X Log(Price)	(s.e.)	γ_{1j}	γ_{2j}	ρ_j	σ_j
Other Agricultural Goods	0.0933***	(0.00600)	-0.412*	(0.0901)	0.093	-0.412	0.086	3.200
Forestry and Wood	0.167*	(0.0412)	-0.472	(0.266)	0.167	-0.472	0.146	2.758
Fishing Goods	0.169***	(0.00594)	-0.526**	(0.0635)	0.169	-0.526	0.147	2.574
Petroleum, Natural Gas, Uranium	0.122**	(0.00163)	-0.422**	(0.000804)	0.122	-0.422	0.110	3.078
Metallic Minerals	0.213***	(0.00573)	-0.718***	(0.0179)	0.213	-0.718	0.180	2.086
Non-Metallic Minerals	0.159***	(0.00183)	-0.440***	(0.0220)	0.159	-0.440	0.140	2.903
Meat and Fish Products	0.106**	(0.0128)	-0.826**	(0.0910)	0.106	-0.826	0.097	2.080
Oils, Animal and Vegetable Grease	0.155***	(0.00819)	-0.592**	(0.0793)	0.155	-0.592	0.136	2.423
Lactose Products	0.117***	(0.00794)	-0.538***	(0.0140)	0.117	-0.538	0.106	2.637
Milled Products and Starches	0.125**	(0.0111)	-0.416	(0.170)	0.125	-0.416	0.113	3.098
Coffee Products	0.218***	(0.0128)	-1.061*	(0.232)	0.218	-1.061	0.184	1.729
Sugar and Cane Products	0.198***	(0.00888)	-0.816***	(0.0703)	0.198	-0.816	0.169	1.975
Cacao, Chocolate, and Jam Products	0.212***	(0.0138)	-0.683***	(0.0356)	0.212	-0.683	0.179	2.144
Food Products	0.132**	(0.0134)	-0.413***	(0.0287)	0.132	-0.413	0.118	3.098
Beverages	0.184**	(0.0181)	-0.495***	(0.0183)	0.184	-0.495	0.159	2.638
Tobacco Products	0.383***	(0.0276)	-1.422*	(0.252)	0.383	-1.422	0.296	1.408
Fabrics and Fiber Textiles	0.171**	(0.0159)	-0.389**	(0.0359)	0.171	-0.389	0.149	3.123
Textile Articles	0.151***	(0.0112)	-0.533***	(0.0309)	0.151	-0.533	0.133	2.588
Clothing Textiles	0.0915*	(0.0171)	-0.409**	(0.0574)	0.092	-0.409	0.084	3.221
Leather Products	0.124***	(0.00766)	-0.478***	(0.00676)	0.124	-0.478	0.111	2.830
Wood Products	0.159***	(0.0118)	-0.413*	(0.108)	0.159	-0.413	0.140	3.029
Paper and Cardboard Products	0.204**	(0.0160)	-0.467***	(0.00788)	0.204	-0.467	0.174	2.690
Printing and Editing Machines	0.143*	(0.0277)	-0.296*	(0.0484)	0.143	-0.296	0.127	3.887
Petroleum, Refining, Nuclear Combustion	0.199**	(0.0266)	-0.836*	(0.227)	0.199	-0.836	0.170	1.951
Non-Metallic Mineral Products	0.122***	(0.00367)	-0.406***	(0.00442)	0.122	-0.406	0.110	3.161
Other Machinery, Electronic Appliances	0.141***	(0.00446)	-0.486***	(0.00542)	0.141	-0.486	0.126	2.764
Transportation Equipment	0.106*	(0.0229)	-0.476***	(0.0323)	0.106	-0.476	0.097	2.874
Furniture	0.132*	(0.0136)	-0.456*	(0.0495)	0.132	-0.456	0.118	2.900
Electric Energy	0.336	(0.0277)	-2.103	(0.207)	0.336	-2.103	0.265	1.304
Water	0.406**	(0.0330)	-1.183*	(0.159)	0.406	-1.183	0.310	1.465
Private Construction	0.0519*	(0.00677)	-0.379**	(0.0206)	0.052	-0.379	0.049	3.501
Public Construction	0.101***	(0.00303)	-0.341	(0.129)	0.101	-0.341	0.092	3.639
Repair Services	0.154	(0.0476)	-0.400*	(0.0704)	0.154	-0.400	0.136	3.107
Tourism, Hotels, Restaurants	0.109***	(0.00304)	-0.620*	(0.0773)	0.109	-0.620	0.099	2.435
Land Transport Services	0.145*	(0.0150)	-0.670	(0.156)	0.145	-0.670	0.128	2.274
Air Transport Services	0.282*	(0.0399)	-1.047*	(0.217)	0.282	-1.047	0.230	1.670
Other Transport Services	-0.124*	(0.0237)	1.969**	(0.223)	-0.124	1.969	-0.145	0.428
Financial Intermediary Services	0.0887**	(0.0115)	-0.143	(0.0751)	0.089	-0.143	0.082	7.363
Rental Services	0.0707*	(0.00895)	-0.176	(0.0716)	0.071	-0.176	0.066	6.292
Social and Health Services	0.0227	(0.114)	0.497	(0.864)	0.023	0.497	0.022	-0.966
Sewage Services	0.258***	(0.0144)	-1.280**	(0.121)	0.258	-1.280	0.213	1.570

Notes. This table displays the results from regression variants of equations (23) and (24) following Feenstra (1994), with log domestic and import prices as the dependent variable in the first two columns. *Coffee Bean*, *Gas*, and *Waste Product* industries were eliminated due to insufficient observations. Only two industries above feature σ estimates less than 1, *Other Transport Services* and *Social and Health Services.* Rather than implementing a grid search for these two industries as in Broda and Weinstein (2004), I omit these industries in subsequent correlation results. All estimates contain year fixed effects and heteroskedatic-robust errors.

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Appendices

Appendix A. Alternative Proof of Omitted Variable Bias Correlation with Elasticity of Substitution

Without loss of generality, assume $k \in \{1, 2\}$. Directly expanding the numerator in 12:

$$Cov[\sum_{k=1}^{2} \alpha_{jk}^{D} H_k, \sum_{k=1}^{2} \alpha_{jk}^{F} H_k] = Cov[\alpha_{j1}^{D} H_1 + \alpha_{j2}^{D} H_2, \alpha_{j1}^{F} H_1 + \alpha_{j2}^{F} H_2]$$

By the additive law of covariance:

$$= Cov[\alpha_{j1}^{D} H_1, \alpha_{j1}^{F} H_1] + Cov[\alpha_{j1}^{D} H_1, \alpha_{j2}^{F} H_2] + Cov[\alpha_{j2}^{D} H_2, \alpha_{j1}^{F} H_1] + Cov[\alpha_{j2}^{D} H_2, \alpha_{j2}^{F} H_2]$$

By the linearity properties of expectations and since H_1 and H_2 are scalars:

$$= H_1^2 Cov[\alpha_{j1}^{D}, \alpha_{j1}^{F}] + H_2^2 Cov[\alpha_{j2}^{D}, \alpha_{j2}^{F}] + H_1 H_2 (Cov[\alpha_{j1}^{D}, \alpha_{j2}^{F}] + Cov[\alpha_{j2}^{D}, \alpha_{j1}^{F}])$$

Since H_1 and H_2 are positive scalars by definition, the sign of 12 is thus driven entirely by the covariance among foreign and domestic inputs.

Appendix B. Time-Series Variation in Foreign Market Shares

Table 8. Foreign Revenue Shares (*Horizontal*) by 1-Digit Industry in Colombia

Industry	**1995**	**1997**	**1999**	**2001**	**2003**	**2005**	**2007**	**2009**	**2011**
Agriculture, Fishing, and Forestry	0.000	0.000	0.000	0.000	0.012	0.013	0.005	0.004	0.003
Mining	0.365	0.456	0.470	0.520	0.735	0.745	0.003	0.006	0.000
Petroleum	0.854	0.812	0.838	0.868	0.901	0.897	0.878	0.945	0.945
Manufacturing	0.019	0.022	0.023	0.021	0.023	0.022	0.008	0.012	0.004
Construction	0.070	0.188	0.171	0.134	0.034	0.019	0.027	0.119	0.011
Electricity, Gas, and Water	0.000	0.019	0.178	0.535	0.168	0.068	0.044	0.349	0.005
Commerce, Tourism, and Services	0.044	0.049	0.065	0.074	0.069	0.053	0.051	0.090	0.004
Transportation-Communications	0.069	0.069	0.068	0.046	0.019	0.015	0.059	0.192	0.008
Financial Intermediation	0.000	0.002	0.001	0.001	0.000	0.000	0.001	0.066	0.001
Public Services	0.016	0.059	0.064	0.051	0.047	0.037	0.040	0.168	0.008

Appendix C. Main Results with Export Controls

Table 9. Effects of Foreign Direct Investment on Domestic Firm TFP - with Export Controls

Panel A. In Logs and Levels

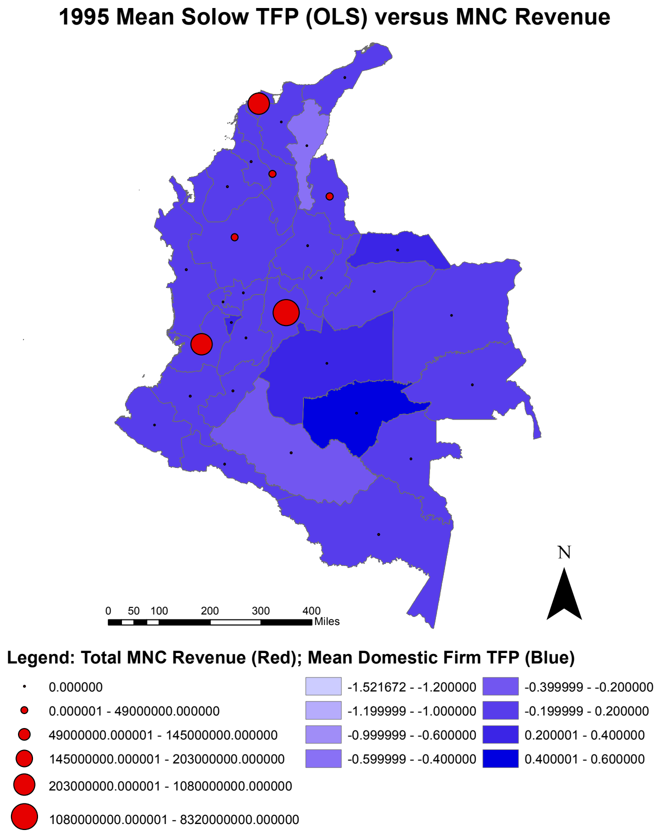
VARIABLES	(1) Log Output	(2) Log Output	(3) TFP (OLS)	(4) TFP (OLS)	(5) TFP (OP)	(6) TFP (OP)	(7) TFP (LP)	(8) TFP (LP)	(9) TFP (ACF)	(10) TFP (ACF)
Horizontal	-1.852***	-1.582***	-2.326**	-1.879*	-2.513*	-1.981	-1.193	0.727	-0.00136	0.00371
	(0.588)	(0.520)	(1.162)	(1.108)	(1.301)	(1.230)	(6.738)	(6.238)	(0.0916)	(0.104)
Backward	6.798***		10.67***		11.78***		20.35		-0.216	
	(1.388)		(1.792)		(1.969)		(16.29)		(0.133)	
Backward - Adjusted		1.590***		2.475***		2.662***		2.760		-0.0760
		(0.390)		(0.579)		(0.653)		(4.383)		(0.0682)
Forward	-5.485**	-4.973*	-8.668**	-8.204*	-9.962**	-9.446*	-35.50**	-34.50*	-0.0418	-0.0498
	(2.374)	(2.658)	(3.752)	(4.322)	(4.255)	(4.890)	(16.21)	(17.72)	(0.0553)	(0.0638)
Observations	6,916	6,916	6,916	6,916	6,916	6,916	6,916	6,916	6,923	6,923
R^2	0.556	0.538	0.373	0.326	0.349	0.295	0.007	0.007	0.044	0.044
Number of Firms	3,040	3,040	3,040	3,040	3,040	3,040	3,040	3,040	3,043	3,043
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Export Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effect (Backward + Forward)	1.313	-3.383	2.001	-5.730	1.820	-6.783	-15.15	-31.74	-0.258	-0.126
F-statistic (Net Effect=0)	15.83	0.000338	20.08	0.386	20.02	0.406	3.104	1.248	2.877	0.697

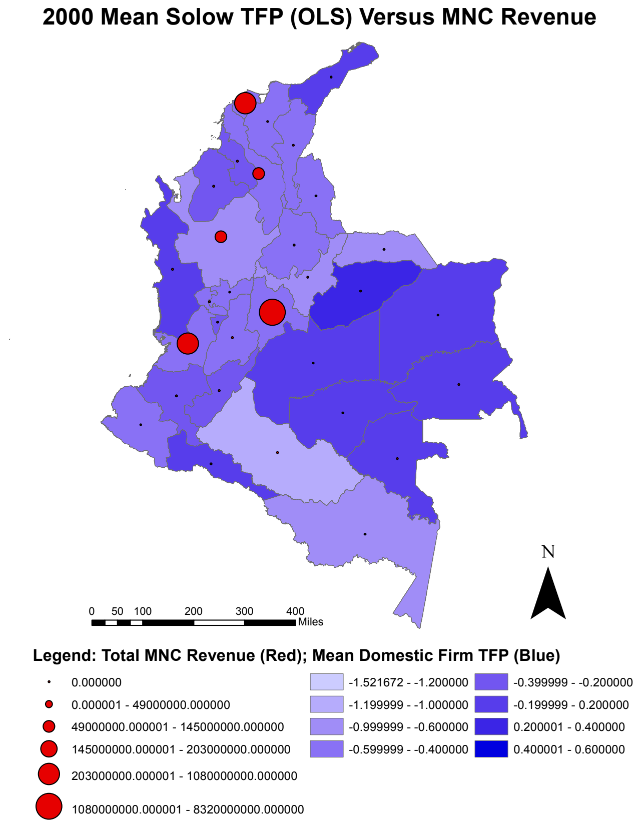
Panel B. In Standardized Variables

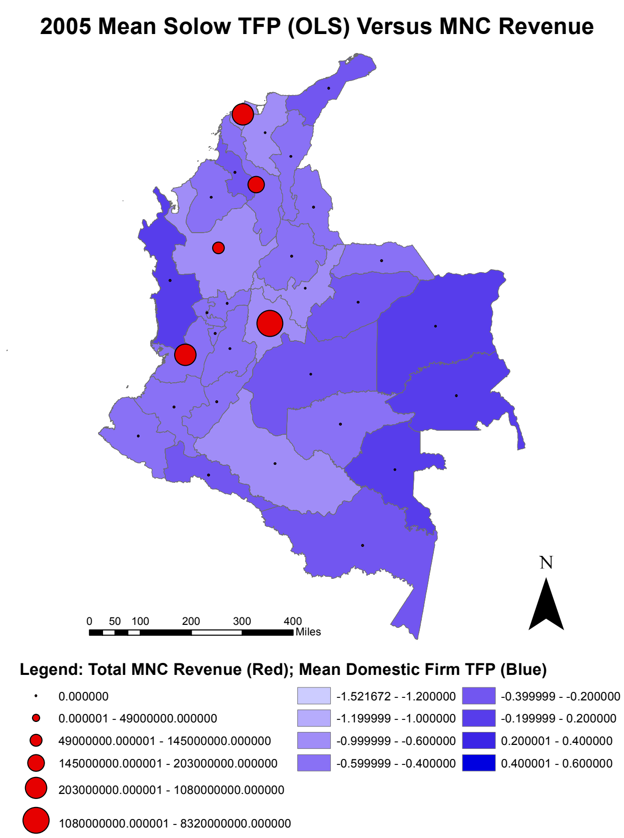
VARIABLES	(1) Log Output	(2) Log Output	(3) TFP (OLS)	(4) TFP (OLS)	(5) TFP (OP)	(6) TFP (OP)	(7) TFP (LP)	(8) TFP (LP)	(9) TFP (ACF)	(10) TFP (ACF)
Horizontal	-0.106***	-0.0904***	-0.427**	-0.345*	-0.595*	-0.469	-0.0370	0.0225	-0.000490	0.00134
	(0.0336)	(0.0297)	(0.213)	(0.204)	(0.308)	(0.291)	(0.209)	(0.193)	(0.0331)	(0.0376)
Backward	0.164***		0.825***		1.175***		0.265		-0.0329	
	(0.0334)		(0.139)		(0.196)		(0.212)		(0.0203)	
Backward - Adjusted		0.0291***		0.145***		0.202***		0.0273		-0.00878
		(0.00713)		(0.0340)		(0.0495)		(0.0434)		(0.00788)
Forward	-0.0435**	-0.0395*	-0.221**	-0.209*	-0.328**	-0.311*	-0.153**	-0.148*	-0.00210	-0.00250
	(0.0188)	(0.0211)	(0.0957)	(0.110)	(0.140)	(0.161)	(0.0698)	(0.0762)	(0.00277)	(0.00320)
Observations	6,916	6,916	6,916	6,916	6,916	6,916	6,916	6,916	6,923	6,923
R^2	0.556	0.538	0.373	0.326	0.349	0.295	0.007	0.007	0.044	0.044
Number of Firms	3,040	3,040	3,040	3,040	3,040	3,040	3,040	3,040	3,043	3,043
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Export Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effect (Backward + Forward)	0.120	-0.0104	0.604	-0.0639	0.847	-0.109	0.113	-0.121	-0.0350	-0.0113
F-statistic (Net Effect=0)	2.672	5.416	3.218	1.119	3.250	0.980	4.785	0.102	1.146	0.0485

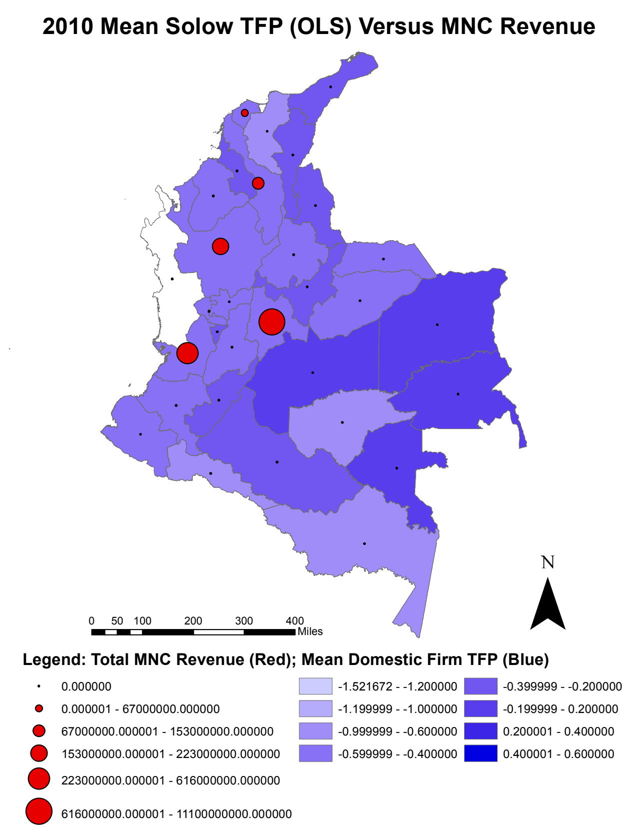
Standard errors clustered at the 5-digit industry level. *** p<0.01, ** p<0.05, * p<0.1. When Log(Output) is the dependent variable, production factors are included as controls.

Appendix D. Geographic Variation in FDI and TFP









Appendix E. Domestic and MNC Export Propensities (2007-11)