Firm-embedded productivity and cross-country income differences*

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Abstract

We measure the contribution of firm-embedded productivity to cross-country income differences. By firm-embedded productivity we refer to the components of productivity that are firm specific, such as blue-prints, management practices, and other intangible capital. Using micro-level data for multinational enterprises (MNEs), we compare market shares of the same MNE in different countries and document that they are systematically larger in less-developed countries. This indicates that MNEs face less competition and that firm-embedded productivity is scarce in these countries. We implement a measure of firm-embedded productivity based on this observation. Differences in firm-embedded productivity account for a third of the cross-country variance in output per-worker in our sample.

Keywords: Development Accounting, TFP, Multinational Enterprises

JEL Codes: O4, O1, F2

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1 Introduction

Differences in Total Factor Productivity (TFP) account for about half of the cross-country differences in income per-capita.[1] Understanding TFP differences is thus at the center of Development Economics. A common view is that aggregate productivity is partly determined by knowledge and expertise that is embedded in individual firms in the form of blue-prints, management practices, and other intangible capital.[2] This view has motivated a wide array of policies that promote firm-embedded productivity around the world, ranging from tax-incentives for R&D to incubator programs for startups.[3] More recently, randomized control trials have shown that micro-level interventions fostering different aspects of firm-embedded productivity can improve firm outcomes.[4] Nonetheless, the Macro Development literature has been mostly silent on the aggregate contribution of firm-embedded productivity to cross-country income differences.[5]

This paper introduces and implements a framework for measuring the contribution of firm-embedded productivity to cross-country income differences. By 'firm-embedded productivity' we refer to the components of productivity that are specific to the firm. We contrast these components with 'country-embedded factors,' which are available to all firms producing in a country, such as natural amenities, infrastructure, and workers' quality. As noted by Burstein and Monge-Naranjo (2009), separating between these two components is challenging, as different combinations of firm-embedded productivity and country-embedded factors can result in the same level of output per-worker.

Our approach overcomes this challenge by bringing to bear firm-level data on the cross-border operations of multinational enterprises (MNEs). We compare the market shares of the exact same MNE in different countries and document that they are roughly four times larger in developing than in high-income countries. We propose and implement a new measure of firm-embedded productivity based on this observation. Our central idea is that the same firm should have larger market shares in countries where aggregate firm-embedded productivity is relatively scarce, as they face less competition in those countries. The observed differences in MNE market shares are indicative of large differences

[1] See Hall and Jones (1999) and Caselli (2016).

[2] See Prescott and Visscher (1980), Klette and Kortum (2004), Atkeson and Kehoe (2005), Bloom and Van Reenen (2007), and McGrattan and Prescott (2009).

[3] See the policy report by Atkin et al. (2019) for a review.

[4] For example, Giné and Yang (2009) and Atkin et al. (2017a) facilitate technology adoption at the firm level; Bloom et al. (2013) and Brooks et al. (2018) improve management practices; Cai and Szeidl (2017) and Atkin et al. (2017b) provide intangible capital in the form of business networks and market access.

[5] Burstein and Monge-Naranjo (2009) is a notable exception that we discuss in detail below.

in the firm-embedded productivity of the competitors that MNEs face in each country.

We develop this logic in a development accounting framework and measure aggregate firm-embedded productivity using data on market shares of the foreign affiliates of MNEs that simultaneously operate in multiple countries. The framework assumes that producers in a country are heterogeneous in their production efficiency and product quality (what we call 'firm-embedded productivity'), but access the same country-embedded factors and set a constant markup over their marginal cost. Thus, the market share of a MNE in a country is determined by the MNE's productivity relative to the aggregate firm-embedded productivity in the country. MNEs can transfer their productivity around the world but face different competitors in each country where they operate. Differences in market shares of the same MNE in different countries pin-down the difference in aggregate firm-embedded productivity between those countries. We attribute the residual differences in income per-capita across countries to differences in country-embedded factors.

Certainly, MNEs may not be able to fully transfer their productivity across countries. We allow for imperfect technology transfers by assuming that MNEs can only use a fraction of their productivity when operating abroad. This is the standard assumption in the Multinational Production literature when modeling imperfect technology transfers, home-bias in preferences, and other costs and policies that imply a differential treatment of MNEs versus domestic firms. Under this assumption, the market share of a MNE can be relatively low in a country either if aggregate firm-embedded productivity in that country is high, or if the MNE faces large transfer costs.

We control for these transfer costs in two straightforward ways. First, we focus on the cross-country variation in the market shares of MNE's *foreign* affiliates (not parent firms), and we control for MNE-specific transfer costs that are common across foreign destinations. Second, we control for the country-pair specific component of the transfer costs using a gravity specification that follows Waugh (2010). This specification assumes that bilateral costs are a function of bilateral distance and other country-pair specific characteristics, such as taxes to MNEs, and includes country dummies to control for source country-specific costs.

We implement our framework using data on MNE revenues from ORBIS, a worldwide dataset maintained by Bureau van Dijk. The main advantage of ORBIS is the scope and accuracy of its ownership information, which allows us to build ownership links between affiliates of the same MNE in different countries. We build these links at the firm-sector level to ensure that the affiliates in our comparisons are producing similar goods and services across countries. We focus on destinations where ORBIS has the most extensive coverage, so that our sample is mainly comprised of Eastern and Western European countries.

We estimate the key structural equation from our model, which states that the log of a MNE market share in a country and sector can be written as the sum of: (i) a MNE-sector component; (ii) a destination-sector component; and (iii) the transfer costs. We fit a two-way fixed-effect specification to measure cross-country differences in firm-embedded productivity from the estimated destination-sector fixed effects.

The OLS estimates of the destination-sector specific components of the market shares are unbiased if the assignment of MNEs to destination-sector pairs is exogenous with respect to the error term. This is the case if selection of MNEs into destinations is driven by firm characteristics (e.g. productivity) and by destination-sector characteristics (e.g. market size), as it is the case in workhorse models of multinational production in the tradition of Helpman et al. (2004). This is also the case if selection is driven by firm-destination characteristics uncorrelated to firm revenues, such as firm-destination specific fixed-costs (e.g. Tintelnot, 2017; Head and Mayer, 2019). Thus, the fact that MNEs are larger and more productive than domestic firms, the fact that MNEs are more likely to enter sectors where domestic firms are relatively unproductive, and the fact that ORBIS may not cover the universe of MNEs, do not bias our estimates of the destination-sector fixed effects. These estimates are identified from variation in market shares *within* MNEs across countries, rather than from variation across MNEs. We evaluate violations of the exogeneity assumption in Section 5.

We find that for the average country in our sample, firm-embedded productivity is 0.20 log points lower than in France, our reference country. The relative importance of the differences in firm-embedded productivity varies considerably across countries. For example, firm-embedded productivity in Italy is 0.28 log-points higher than in Greece, accounting for three quarters of the observed differences in output per-worker between these two countries. In contrast, firm-embedded productivity is similar for Greece and Bulgaria, though output per-worker in Greece is 0.5 log points higher due to the difference in country-embedded factors between these two countries.

We show that there is a strong positive correlation between firm-embedded productivity and output per-worker and that differences in firm-embedded productivity account for about one-third of the cross-country variance in output per-worker. The positive correlation with output per-worker also holds once we control for country size. We also show a positive correlation between firm-embedded productivity and measures of innovation and management practices across countries, and that the foreign output of a country's MNEs is concentrated in sectors where the country's firm-embedded productivity is relatively high.

Finally, we embed our framework in a standard general equilibrium model of MNE location choices and evaluate the gains from eliminating barriers to the mobility of MNEs. We show that the size of these gains depends on whether we calibrate the model assuming that observed differences in output per-worker are due to firm-embedded or country-embedded factors. If we assume that all initial differences in income per-capita are driven by country-embedded factors, we obtain gains that are roughly the same for all countries. In this scenario, by assumption, all countries start with the same firm-embedded productivity, and end up with the same firm-embedded productivity —since with no barriers to MNE mobility the same firms operate in all locations. In contrast, we obtain gains that vary enormously across countries and are much higher on average if we assume that all initial differences in output per-worker are driven by differences in firm-embedded productivity. In this case, the gains are larger for poorer countries that integrate with countries that have more productive firms. Our baseline estimates imply gains that are between these two extremes, with the largest gains accruing to the countries with the lowest firm-embedded productivity.

Related literature: Our paper is closely related to Burstein and Monge-Naranjo (2009), who separate firm-embedded productivity from country-embedded factors using a model of MNE location choices and aggregate data on output per-worker, capital stocks, and corporate tax rates. Their framework is based on the Lucas 'span of control' model and assumes that each firm (or manager) must choose only one country where to produce. Under these assumptions, they can recover the contribution of firm-embedded productivity to cross-country income differences using aggregate data and the model's equilibrium condition that equates after-tax managerial profits across countries, without using any data on the cross-country operations of MNEs.[6] In contrast, our approach recovers firm-embedded productivity from firm-level data on MNE market shares in multiple countries, and hence, it does not rely on specific assumptions on how MNEs make location choices.

[6] The main goal of Burstein and Monge-Naranjo (2009) is to analyze the aggregate consequences of reallocating firm-embedded productivity across countries. To such end, they need to estimate the autarky allocation of firm-embedded productivity, which does require data on Foreign Direct Investment (FDI) stocks in addition to the model's equilibrium.

The idea behind our approach is similar to that in Hendricks and Schoellman (2018), who use worker-level data on wage gains upon migration to separate the contributions of aggregate human capital from country-embedded factors in explaining cross-country income differences. They exploit the idea that workers can take their human capital with them when moving to a foreign country. In the same spirit, we use firm-level data and exploit the idea that MNEs can use their firm-specific productivity in many countries to measure cross-country differences in aggregate firm-embedded productivity.

More broadly, our paper is related to the extensive literature on development accounting, which measures the contribution of factors of production to cross-country income differences directly and computes TFP as a residual (see Caselli 2005 for a survey). This literature has focused on improving measures of factor stocks to better account for differences in productivity embodied in physical and human capital (recent examples are Hendricks and Schoellman, 2018, Lagakos et al., 2018 and Caunedo and Keller, 2020). We contribute to this literature by proposing a measure of the productivity that is embodied in firms. In doing so, we provide a direct (not residual) measure of one of the components of TFP, firm-embedded productivity, using data on MNEs.

Finally, our paper is related to the large literature studying technology transfers through MNEs. One branch of the literature uses parent-affiliate matched data to estimate how productivity and shocks are transmitted within the MNE (e.g. Cravino and Levchenko 2017 and Bilir and Morales 2020). In contrast, our focus is on measuring the contribution of firm-embedded productivity in explaining cross-country income differences. A different branch of the literature parameterizes general equilibrium models of MNE location choices to measure MNEs' contribution to welfare and TFP (see e.g. Burstein and Monge-Naranjo, 2009, McGrattan and Prescott, 2009,Ramondo and Rodriguez-Clare, 2013, Ramondo, 2014, Irarrazabal et al., 2013, Alviarez, 2019, and Arkolakis et al., 2018). Our measurement strategy is based on parent-affiliate matched data rather than on the general equilibrium conditions of a structural model.

The rest of the paper is organized as follows. Section 2 presents the accounting framework. Section 3 describes the data and our empirical strategy. Section 4 presents the quantitative results. Section 5 collects robustness exercises. Section 6 presents the counterfactual exercises. Section 7 concludes.

2 Accounting framework

In this section, we first develop a stylized framework that formalizes our definition of firm-embedded productivity and show how to measure it using firm-level data on the cross-border operations of MNEs. Next, we present a quantitative version of this framework that allows for multiple sectors and factors of production.

2.1 A model economy

Preliminaries: We consider a world economy consisting of N countries indexed by i and n. Each country is populated by a continuum of differentiated intermediate good producers that are owned by firms from different source countries. We refer to a firm that simultaneously operates in multiple countries as a MNE. Factor markets are competitive and integrated within countries, and markups are constant across firms. Intermediate goods cannot be traded internationally. In each country, intermediates are aggregated into a final tradable good by a competitive producer.

Technologies: The production function for the final good in each country n is given by

$$Y_n = \left[\sum_i \int_{\omega \in \Omega_{in}} \left[Q_{in}(\omega) Y_{in}(\omega) \right]^{\frac{\rho-1}{\rho}} d\omega \right]^{\frac{\rho}{\rho-1}}, \tag{1}$$

where $Y_{in}(\omega)$ is the output of firm ω from country i operating in country n, Ω_{in} denotes the set of firms from country i that are active in country n, and $Q_{in}(\omega)$ is a shifter for firm ω, which we interpret as product quality, and can differ across production locations. The parameter $\rho \geq 1$ is the elasticity of substitution across intermediate goods.

The production function for intermediate goods is

$$Y_{in}(\omega) = Z_n X_{in}(\omega) L_{in}(\omega), \tag{2}$$

where $L_{in}(\omega)$ is the number of workers employed by firm ω in country n. The productivity of the firm depends on a country-specific component, Z_n, and a firm-specific component, $X_{in}(\omega)$. Following Burstein and Monge-Naranjo (2009), we refer to Z_n as "country-embedded productivity," as it captures factors that affect all firms in a country, such as infrastructure, institutions, workers' quality, and natural amenities. In contrast, $X_{in}(\omega)$

is idiosyncratic to firm ω, and like product quality, can differ across production locations.

It is useful to define $A_{in}(\omega) \equiv [Q_{in}(\omega) \times X_{in}(\omega)]^{\rho-1}$. In what follows, we will refer to $A_{in}(\omega)$ as "firm-embedded productivity." This variable captures production, managerial, and marketing know-how specific to the firm.

We assume that firm-embedded productivity can be transferred imperfectly across countries, so that the productivity of an MNE from country i when it produces in country n is

$$A_{in}(\omega) = A_i(\omega) \times exp(-\kappa_{in}(\omega)), \tag{3}$$

with $\kappa_{ii}(\omega) = 0$. Here, $A_i(\omega)$ is the productivity embedded in firm ω in its home country i, and $\kappa_{in}(\omega)$ is a technology transfer cost that captures the degree to which firm-embedded productivity can be moved from i to n. If $\kappa_{in}(\omega) = 0$, the MNE can use the same $A_i(\omega)$ in all the countries where it produces.

Aggregate output and TFP: Using Equations (1) and (2), we can write aggregate output as

$$Y_n = Z_n \Phi_n^{\frac{1}{\rho-1}} L_n, \tag{4}$$

where

$$\Phi_n \equiv \sum_i \int_{\omega \in \Omega_{in}} A_{in}(\omega) \, d\omega \tag{5}$$

denotes *aggregate* firm-embedded productivity in country n, which is the sum of the productivity embedded in all the firms that produce in country n.

In what follows, we use lowercase to denote the log of a variable, and use $y_n \equiv ln[Y_n/L_n]$ to denote the log of output per-worker. Using Equation (4), we can thus write

$$y_n = z_n + \frac{1}{\rho-1}\phi_n. \tag{6}$$

Equation (6) states that cross-country differences in output per-worker arise from differences in country-embedded productivity, z_n, and differences in aggregate firm-embedded productivity, ϕ_n. Clearly, the same level of y_n can be achieved with different combinations of z_n and ϕ_n, so that these two terms cannot be separated using only aggregate data. Next, we show how to use micro-level data on the cross-border operations of MNEs to separate ϕ_n from

z_n.

2.2 Decomposing cross-country differences in output per-worker

We now show how cross-country differences in ϕ_n can be computed using firm-level data on market shares. From the demand functions implied by Equation (1), we can write the revenue of firm ω from country i producing in country n, relative to the sum of the revenues of all firms producing in n, as

$$S_{in}(\omega) \equiv \frac{P_{in}(\omega)\, Y_{in}(\omega)}{\sum_i \int_{\omega \in \Omega_{in}} P_{in}(\omega)\, Y_{in}(\omega)\, d\omega} = \frac{A_{in}(\omega)}{\Phi_n}. \tag{7}$$

A MNE market share in a country depends on its productivity, $A_{in}(\omega)$, relative to the productivity embedded in all firms operating in that country, Φ_n. Intuitively, MNEs should have larger market shares in countries where aggregate firm-embedded productivity is relatively low, since they face less competition in those countries.

We build on this intuition to identify cross-country differences in Φ_n. Substituting Equation (3) in (7), the log market share is

$$s_{in}(\omega) = a_i(\omega) - \kappa_{in}(\omega) - \phi_n. \tag{8}$$

Equation (8) shows that if technology transfer costs do not vary across foreign destinations, $\kappa_{in}(\omega) = \kappa_i(\omega)$, cross-country differences in market shares of affiliates of the same MNE pin-down differences in ϕ_n. In this case, one could regress affiliate-level market shares on MNE- and destination-level dummies to recover ϕ_n. The MNE-level dummies would capture differences in $a_i(\omega) - \kappa_i(\omega)$ across MNEs, while the cross-country variation in shares within an MNE would identify the differences in ϕ_n. After obtaining cross-country differences in ϕ_n, differences in z_n can be computed as residuals from Equation (6) (given a value for the elasticity ρ). This two-way fixed-effect approach constitutes the basis of our estimation strategy described in Section 3.2.

In the more general case where technology transfer costs vary across destinations, differences in market shares across affiliates of the same MNE are not enough to identify differences in aggregate firm-embedded productivity. As Equation (8) makes clear, this is because the market share of an affiliate can be relatively low in country n if either firm-embedded productivity is relatively large in country n (high ϕ_n), or if the costs to transfer technology are large (high $\kappa_{in}(\omega)$). Section 3.2 shows how, if we observe market shares for MNEs from multiple source countries and into multiple destinations, we can identify differences in ϕ_n by imposing assumptions on the structure of $\kappa_{in}(\omega)$ that are standard in the International Trade and Multinational Production literature.

Two remarks are in order. First, the firm-level market shares in Equation (7) only vary across destinations due to competition in the destination, captured by ϕ_n, and the technology transfer cost, $\kappa_{in}(\omega)$. In contrast, aggregate market shares, $S_{in} = \int_{\omega \in \Omega_{in}} S_{in}(\omega)\, d\omega$, also vary across destinations if MNEs with different $a_i(\omega)$'s select into different n's. This comparison highlights the importance of including firm-level dummies to recover ϕ_n from destination-level dummies. We show the biases of an estimation based on aggregate market shares in Appendix D.1.

Second, country-embedded productivity, Z_n, does not affect the MNE market share $S_{in}(\omega)$ in Equation (7), since it proportionally affects all the firms producing in n. This result follows from the assumption that Z_n and $X_{in}(\omega)$ enter log-linearly into the production function in Equation (2). Together with the assumption on transfer costs in Equation (3), the assumption also implies that country-embedded factors that have different effects across domestic and foreign firms -such as regulations that apply only to foreign firms- would be captured by $\kappa_{in}(\omega)$.[7] Section 5.2 and Appendix C show that the log-linear functional form provides a good approximation of the data.

2.3 Quantitative model

We now extend our framework to incorporate additional sectors and factors of production. We assume that in each country there are J sectors indexed by j, and that a competitive producer of final goods aggregates sectoral output according to

$$Y_n = \prod_j \left[Y_n^j \right]^{\theta_n^j}, \tag{9}$$

[7]That is, our model is isomorphic to assuming a production function given by $Y_{in}(\omega) = \tilde{Z}_{in}(\omega) X_{ii}(\omega) L_{in}(\omega)$, with $\tilde{Z}_{in}(\omega) \equiv \kappa_{in}(\omega) Z_n$.

where Y_n^j denotes the final output from sector j and $\theta_n^j \in [0,1]$ with $\sum_j \theta_n^j = 1$. Sectoral output is produced by aggregating intermediate goods,

$$Y_n^j = \left[\sum_i \int_{\omega \in \Omega_{in}^j} \left[Q_{in}^j(\omega) Y_{in}^j(\omega) \right]^{\frac{\rho^j - 1}{\rho^j}} d\omega \right]^{\frac{\rho^j}{\rho^j - 1}}, \tag{10}$$

where $Y_{in}^j(\omega)$ is the output of intermediate-good producer firm ω from country i in sector j. $Q_{in}^j(\omega)$ denotes product quality of firm ω from country i in sector j.

Intermediate goods in each sector are produced with a Cobb-Douglas technology,

$$Y_{in}^j(\omega) = Z_n^j X_{in}^j(\omega) H_{in}^j(\omega)^{1-\alpha^j} K_{in}^j(\omega)^{\alpha^j}, \tag{11}$$

where $\alpha^j \in [0,1]$. The variables $H_{in}^j(\omega)$ and $K_{in}^j(\omega)$ denote the effective units of labor and capital employed by firm ω in country n and sector j.[8]

As in the previous section, we define $A_{in}^j(\omega) \equiv \left[Q_{in}^j(\omega) \times X_{in}^j(\omega) \right]^{\rho^j - 1}$ and assume that

$$A_{in}^j(\omega) = A_i^j(\omega) \times exp\left(-\kappa_{in}^j(\omega) \right). \tag{12}$$

Aggregate output in each sector satisfies

$$Y_n^j = Z_n^j \left[\Phi_n^j \right]^{\frac{1}{\rho^j - 1}} \left[\bar{H}_n^j L_n^j \right]^{1-\alpha^j} \left[K_n^j \right]^{\alpha^j},$$

where $\Phi_n^j \equiv \sum_i \int_{\omega \in \Omega_{in}^j} A_{in}^j(\omega) d\omega$ is the aggregate firm-embedded productivity in sector j and country n, L_n^j denotes the number of workers employed in sector j, $\bar{H}_n^j \equiv \left[\sum_i \int_{\omega \in \Omega_{in}^j} H_{in}^j(\omega) d\omega \right] / L$ are the units of effective labor per-worker in sector j, and K_n^j is the physical capital employed in sector j. Output per-worker in sector j can be written as

$$\frac{Y_n^j}{L_n^j} = \tilde{Z}_n^j \tilde{\Phi}_n^j, \tag{13}$$

where $\tilde{Z}_n^j \equiv \left[Z_n^j \right]^{\frac{1}{1-\alpha^j}} \bar{H}_n^j \left[\frac{K_n^j}{Y_n^j} \right]^{\frac{\alpha^j}{1-\alpha^j}}$, $\tilde{\Phi}_n^j \equiv \left[\Phi_n^j \right]^{\beta^j}$, and $\beta^j \equiv \frac{1}{1-\alpha^j} \frac{1}{\rho^j - 1}$. In what follows, we

[8] Appendix G shows that our approach and quantitative results do not change if we incorporate intermediate inputs in production, and recalibrate the model's parameters accordingly.

refer to both $\tilde{\Phi}_n^j$ and Φ_n^j as firm-embedded productivity, and to $\tilde{Z}_n^j$ as country-embedded factors since it includes physical and human capital, in addition to the country-embedded productivity Z_n^j.

Aggregate output per worker can be written as

$$\frac{Y_n}{L_n} \quad = \quad \tilde{Z}_n \tilde{\Phi}_n. \tag{14}$$

Here, $\tilde{\Phi}_n \equiv \prod_j \left[\tilde{\Phi}_n^j\right]^{\theta_n^j \frac{\beta_n}{\beta^j} \frac{\rho_n - 1}{\rho^j - 1}}$, $\beta_n \equiv \frac{1}{1-\alpha_n}\frac{1}{\rho_n - 1}$, $\alpha_n \equiv \sum_j \theta_n^j \alpha^j$, $\rho_n \equiv \sum_j \theta_n^j \rho^j$, and $\tilde{Z}_n \equiv \bar{\theta}_n \bar{H}_n \left[\frac{K_n}{Y_n}\right]^{\frac{\alpha_n}{1-\alpha_n}} \prod_j \left[Z_n^j\right]^{\frac{\theta_n^j}{1-\alpha_n}}$. L_n and K_n are the number of workers and capital stock in country n, and $\bar{H}_n \equiv \left[\sum_j \sum_i \int_{\omega \in \Omega_{in}^j} H_{in}^j(\omega)\, d\omega\right] / L_n$ is the average human capital in country n.[9]

Applying logs to Equation (14), we can thus write

$$y_n \quad = \quad \tilde{z}_n + \tilde{\phi}_n. \tag{15}$$

We can compute the terms in Equation (15) following steps analogous to those described in Section 2.2. In particular, the log market share of MNE ω operating in country n and sector j is

$$s_{in}^j(\omega) = a_i^j(\omega) - \kappa_{in}^j(\omega) - \phi_n^j. \tag{16}$$

A MNE revenue share in a sector depends on its productivity, $a_i^j(\omega)$, relative to the productivity of all firms in the sector, ϕ_n^j. As explained in the previous section, we can use differences in sectoral market shares across affiliates of the same MNE that are located in different country-sector pairs to pin-down differences in ϕ_n^j. These differences can be aggregated to obtain $\tilde{\phi}_n = \sum_j \theta_n^j \frac{\beta_n}{\beta^j} \frac{\rho_n - 1}{\rho^j - 1} \phi_n^j$. Once $\tilde{\phi}_n$ is calculated, $\tilde{z}_n$ can be computed as a residual from Equation (15).

Finally, our development accounting exercise evaluates the contribution of firm-embedded productivity to the cross-country variance in output per-worker. We follow the variance

[9] $\bar{\theta}_n \equiv \prod_j \left[\left[\frac{\theta_n^j[1-\alpha^j][1-1/\rho^j]}{\sum_j\left[\theta_n^j[1-\alpha^j][1-1/\rho^j]\right]}\right]^{1-\alpha^j}\left[\frac{\theta_n^j \alpha^j [1-1/\rho^j]}{\sum_j \left[\theta_n^j \alpha^j [1-1/\rho^j]\right]}\right]^{\alpha^j}\right]^{\frac{\theta_n^j}{1-\alpha_n}}$ is a country-specific constant.

decomposition in Klenow and Rodriguez-Clare (1997) and compute

$$\frac{cov(y_n, \tilde{z}_n)}{var(y_n)} + \frac{cov(y_n, \tilde{\phi}_n)}{var(y_n)} = 1. \tag{17}$$

The next section explains how we implement this variance decomposition in our data.

3 Data and empirical strategy

3.1 Data description

Our firm-level data come from ORBIS, a worldwide dataset maintained by Bureau van Dijk that includes comprehensive information on firm's revenue and employment. The main advantage of ORBIS is the scope and accuracy of its ownership information: it details the full list of direct and indirect subsidiaries and shareholders of each company in the dataset, along with a company's global ultimate owner and other companies in the same corporate family. This information allows us to build links between affiliates of the same MNE, including cases in which the affiliates and the parent are in different countries.

The main variable used in our analysis is the revenue (turnover) of each firm. We use data for the year 2016, which is the year with the largest coverage in ORBIS. We focus on a subset of destination countries for which aggregate revenues of foreign firms in ORBIS account for at least 20 percent of the aggregate revenues of foreign firms reported by OECD/Eurostat. In contrast, every country in the world is a potential source country of MNEs in ORBIS, so that our sample of source countries is much larger than our sample of destination countries.[10]

The original unit of observation in ORBIS is a tax-identification number. Often, affiliates located in different addresses within the same country and belonging to the same corporate

[10] OECD Activity of Multinational Enterprises (AMNE) database and the Eurostat Foreign Affiliate Statistics database. Appendix Figure A.1 shows our sample of destination countries and reports, for each destination, the ratio of the foreign-firm revenues in ORBIS to the foreign-firm revenues as reported by OECD/Eurostat. Our sample of source countries includes the United States, China, and Canada, among others. As destinations, these countries have very low, or inexistent, coverage in ORBIS, and thus they are not included in our sample of destination countries. In addition, we exclude Ireland, Luxembourg, and Switzerland from our sample as MNE revenues in those countries are particularly sensitive to profit-shifting strategies.

group, are registered with different tax-identification numbers. We aggregate revenues of all firms in ORBIS that belong to the same corporate group and that operate in the same country and 2-digit NAICS sector. Our unit of observation is then a corporate group-country-sector triplet. For example, ORBIS shows multiple tax-id's belonging to Renault in Germany in the Transportation and Equipment sector. We aggregate the revenues of those affiliates to obtain Renault's total revenues in this sector in Germany. Our procedure compares affiliates of Renault in the Transportation and Equipment sector located in different countries, and separately compares affiliates of Renault's in, e.g., the Retail sector across countries.

Finally, to compute market shares, we divide the revenues of each corporate group-country-sector by the aggregate revenues in each country-sector. Since ORBIS not always covers the population of firms in each country-sector pair, we use data on aggregate revenues from EU KLEMS and OECD.

We obtain aggregate output per-worker from the Penn World Tables (9.1), and compute output-per-worker in international dollars at the sector level using data on output per-worker from EU KLEMS and the PPP conversion factor from the Penn World Tables (9.1).

We refer the reader to Appendix B for further details on the data construction.

3.2 Empirical strategy

This section describes how we measure cross-country differences in firm-embedded productivity using firm-level data on the activity of MNEs across countries. Our strategy builds on Equation (16) and imposes structure on the technology transfer costs following a long tradition in International Economics that approximates trade and multinational production costs using observable variables.

We assume that technology transfer costs are given by

$$\kappa_{in}^{j}(\omega) = O_i^j + D_n^j + B_{in}^j + \varepsilon_{in}^j(\omega). \tag{18}$$

The assumption states that technology transfer costs in each sector can be additively decomposed into origin- and destination-specific components, O_i^j and D_n^j, a bilateral component, B_{in}^j, and a MNE-destination-sector specific component, $\varepsilon_{in}^j(\omega)$. We proxy for the bilateral component B_{in}^j with a log-linear function of bilateral distance and a dummy for common language, which we obtain from *Centre d'Etudes Prospectives et d'Informations Internationales* (CEPII). Section 5.6 shows that our results are unchanged if we add country-pair specific taxes for MNEs, bilateral tax treaties, and other gravity variables as additional controls for B_{in}^{j}.

Substituting Equation (18) into (16), we obtain our estimating equation:

$$s_{in}^{j}(\omega) = \delta_{i}^{j}(\omega) + \mathbb{A}_{n}^{j} + B_{in}^{j} + \epsilon_{in}^{j}(\omega). \tag{19}$$

Here, $\delta_{i}^{j}(\omega)$ are MNE-sector fixed effects. $\mathbb{A}_{n}^{j}$ denotes a set of dummies that take the value of 1 if the destination country is n and the sector is j. We estimate Equation (19) by Ordinary Least Squared (OLS) using the sample of foreign affiliates of MNEs in the ORBIS data — MNEs in their home country are not included. The regression identifies $\delta_{i}^{j}(\omega)$ from the within-MNE average market share across destinations, in each sector j, controlling for destination characteristics and the bilateral component of the technology transfer costs. Similarly, the destination effects $\mathbb{A}_{n}^{j}$ are identified from the average market shares of the foreign affiliates that operate in each country n and sector j, controlling for within-MNE characteristics and the bilateral component of the technology transfer costs. The residual $\epsilon_{in}^{j}(\omega)$ is (the negative of) $\varepsilon_{in}^{j}(\omega)$ in Equation (19).

The OLS estimates of the destination-sector-specific components of the market shares, $\mathbb{A}_{n}^{j}$, are unbiased if $\mathbb{E}\left[\mathbb{A}_{n}^{j}\epsilon_{in}^{j}(\omega) \mid \delta_{i}^{j}(\omega), B_{in}^{j}\right] = 0$. This requires the assignment of MNEs to destination countries to be exogenous with respect to the error term, $\varepsilon_{in}^{j}(\omega)$. This restriction is satisfied if selection is driven by firm characteristics (e.g. productivity), by destination-country characteristics (e.g. market size), or by firm-destination characteristics uncorrelated with firm revenues (e.g. firm-destination specific fixed-costs). In contrast, the OLS estimates would be biased if the assignment of MNEs to destination countries is driven by $\varepsilon_{in}^{j}(\omega)$. Appendix D formalizes this intuition in the context of a general equilibrium model of MNE location choices.

For the reminder of this section, we assume that MNEs do not select into countries based on $\varepsilon_{in}^{j}(\omega)$. In Section 5.2, we show that our main results are robust to reestimating Equation (19) using subsamples of MNEs that are more likely to satisfy the exogeneity assumption.

3.3 Cross-country differences in MNE market shares

In what follows, we use the notation $\Delta x_n \equiv x_n - x_r$ to express the difference of a variable in country n with respect to France, our reference country. Using data on sectoral expenditure shares in each country, θ_n^j, and our OLS estimates of $\Delta \mathbb{A}_n^j$, we compute the aggregate destination-specific effects as

$$\Delta \mathbb{A}_n \equiv \sum_j \theta_n^j \Delta \mathbb{A}_n^j. \tag{20}$$

The aggregate country effect $\Delta \mathbb{A}_n$ captures the log average MNE market share in each destination relative to France, after controlling for the MNE-sector fixed effects and the bilateral variables.

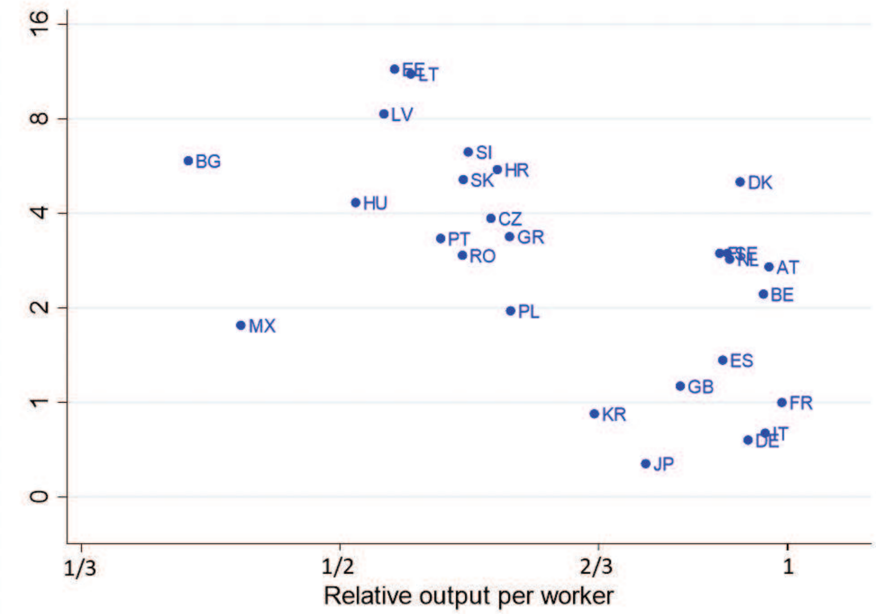
Figure 1 reports $exp(\Delta \mathbb{A}_n)$ against output per-worker.[11] On average, MNE market shares are larger in less developed countries. Differences between developed and developing countries are enormous: MNE market shares are about three and a half times larger in Greece and Portugal, and about twelve times larger in Estonia and Lithuania, compare to their market shares in France. In contrast, MNEs have similar market shares in the United Kingdom, Germany, and France.

In the model, revenue shares, employment shares, and value-added shares coincide, so that in theory any of these shares can be used for our estimation. Appendix Figure A.2 shows that we obtain very similar estimates if we use data on employment shares or data on value-added shares as the dependent variables in Equation (19).[12]

[11]The country-sector dummies $\Delta \mathbb{A}_n^j$ and the MNE-sector dummies $\delta_i^j(\omega)$ account respectively for 0.27 and for 0.45 of the total variance of $s_{in}^j(\omega)$ in Equation (19), while the R-squared of the regression is 0.72. Appendix Table A.1 reports the OLS coefficients on bilateral distance and common language, ψ_d^j and ψ_l^j, for each sector, while Appendix C presents additional statistics on our two-way fixed effect estimator. Appendix Figure A.2 reports standard errors for our estimates of $\Delta \mathbb{A}_n$, and shows that these dummies are tightly estimated and exhibit substantial variation across countries.

[12]We use revenue shares for our baseline estimates since ORBIS has a more complete coverage of revenues than of employment and value-added. Using employment data, however, alleviates concerns about profit-shifting strategies by MNEs.

Figure 1: Market shares of foreign MNE affiliates, relative to France.



Note: The figure shows $exp(\Delta\mathbb{A}_n)$, calculated using Equation (20) and the OLS estimates of Equation (19). The x-axis reports the output per-worker of each country, relative to France, from Penn World Tables (9.1).

3.4 Interpreting differences in MNE market shares

We calculate the differences in $\Delta\phi_n^j$ using our estimated country-sector effects, $\Delta\mathbb{A}_n^j$. Using Equations (16) and (18), these effects correspond to

$$\Delta\mathbb{A}_n^j = -\left[\Delta\phi_n^j + \Delta D_n^j\right], \tag{21}$$

which conflates firm-embedded productivity, $\Delta\phi_n^j$, and the destination-specific component of the technology transfer costs, ΔD_n^j. For our baseline results, the identification strategy follows Waugh (2010), and assumes that costs have an origin-specific, $\Delta O_i^j \neq 0$, but not destination-specific, component, $\Delta D_n^j = 0$. In that case, the country dummies can be interpreted as $\Delta\mathbb{A}_n^j = -\Delta\phi_n^j$, and the MNE-level dummies, $\delta_i^j(\omega)$, would absorb the origin-specific component of the technology transfer cost, ΔO_i^j. But what if this identification assumption is not satisfied and $\Delta D_n^j \neq 0$? If ΔD_n^j is high for low income countries (i.e. it is harder to transfer technology into less developed countries), then $cov(\Delta y_n, \Delta D_n^j) \leq 0$. This inequality implies that our baseline estimates of $\Delta\phi_n^j$ based on Equation (21) would understate the contribution of aggregate firm-embedded productivity to the cross-country variance in output per-worker,

$$cov\left(\Delta y_n, -\Delta \mathbb{A}_n^j\right) = cov\left(\Delta y_n, \Delta \phi_n^j + \Delta D_n^j\right) \leq cov\left(\Delta y_n, \Delta \phi_n^j\right). \tag{22}$$

Section 5 presents a robustness exercise that allows for $\Delta D_n^j > 0$, but assumes that $\Delta O_i^j = 0$. Those results are remarkably similar to our baseline results.

3.4.1 Parameterization

As shown in Section 2.3, to evaluate the contribution of aggregate firm-embedded productivity to cross-country income differences, we need to aggregate our sectoral estimates and assign values to the model parameters. Taking logs in Equation (13) and using our baseline identification assumption on technology transfer costs so that $\Delta \mathbb{A}_n^j = -\Delta \phi_n^j$ yield

$$\Delta y_n^j = -\beta^j \Delta \mathbb{A}_n^j + \Delta \tilde{z}_n^j. \tag{23}$$

The composite elasticity $\beta^j \equiv \left[\left[\rho^j - 1\right]\left[1 - \alpha^j\right]\right]^{-1}$ can be estimated from an OLS regression of Δy_n^j on $\Delta \mathbb{A}_n^j$. Unfortunately, these estimates would not be consistent unless $\Delta \mathbb{A}_n^j$ is orthogonal to $\Delta \tilde{z}_n^j$. A concern would be that policies that encourage accumulation of country-embedded factors, captured by $\Delta \tilde{z}_n^j$, would also improve firm-embedded productivity, $\Delta \phi_n^j$. One way to deal with this concern is to control for factors included in $\Delta \tilde{z}_n^j$ that simultaneously affect the accumulation of firm-embedded productivity, such as human capital and the capital-output ratio, the quality of institutions, and the infrastructure in country n. In particular, we estimate

$$\Delta y_n^j = b_0^j + b_1^j \Delta \mathbb{A}_n^j + b_2^j \Delta C_n + u_n^j, \tag{24}$$

where C_n is a vector of country-specific controls.

Table 1 reports these estimates. Columns (1), (4), and (7), show the results for the pooled sample of sectors, for Manufacturing sectors, and for Service sectors, estimated under the restriction that b_1 is the same in all (sub-)sectors (see Appendix Table A.2 for results on estimating b_1^j for each sub-sector in Manufacturing and Services). The coefficient b_1 is precisely estimated around -0.20 in the three samples. As shown in Columns (2), (5) and (8), we estimate very similar values when we control for the (log of the relative) capital-output ratio and the (log of the relative) average years of schooling, and also in Columns (3), (6) and (9) when controlling for measures of country's governance and infrastructure.[13] Overall, we cannot reject the null hypothesis that $\beta = 0.2$ in any of these samples.

Using $\beta = 0.2$ for all j and the restriction that $\Delta D_n^j = 0$, we get our baseline estimates of aggregate firm-embedded productivity as $\Delta\tilde{\phi}_n = -\beta\Delta\mathbb{A}_n$, where $\Delta\mathbb{A}_n$ is obtained from aggregating the OLS estimates in Equation (19) according to Equation (20).[14] We calculate $\Delta\tilde{z}_n$ as a residual using data on output per-worker.

4 Quantitative results

This section combines the estimates from Equation (20) with our elasticity estimates from Section 3.4.1 to decompose differences in output per-worker across countries into aggregate firm-embedded productivity and country-embedded factors. Figure 2 plots the result of this decomposition (see Appendix Table A.5 for the exact numbers). The x-axis shows the log-difference in output per-worker in each country relative to France, Δy_n. In the y-axis, the red circles show the difference in firm-embedded productivity in each country relative to France, $\Delta\tilde{\phi}_n$, while the blue squares show the differences in country-embedded factors relative to France, $\Delta\tilde{z}_n$.

For the average country, firm-embedded productivity is 0.20 log points lower than in France. There is, however, wide variation across countries. For some of the large developed nations in our sample, such as Germany and Korea, firm-embedded productivity is the same as in France, whereas in Japan it is somewhat larger (0.09 log-difference). In contrast, firm-embedded productivity is quite low in the Baltic Republics of Lithuania, Latvia, and Estonia.

[13] Our measure of infrastructure is the number of mobile cellular subscriptions per-capita, from the World Development Indicators. Our estimates are unchanged if we use alternative measures of infrastructure, such as the number of fixed broadband subscriptions per-capita or the electric power consumption per-capita.

[14] In a one-sector model, estimating Equation (24) without controlling for ΔC_n would yield $\beta = -\frac{cov(\Delta\mathbb{A}_n,\Delta y_n)}{var(\Delta\mathbb{A}_n)}$. Using this expression to calculate $\Delta\tilde{\phi}_n = -\beta\Delta\mathbb{A}_n$, the second term of the variance decomposition in Equation (17) would boil down to $\frac{cov(\Delta y_n,\Delta\tilde{\phi}_n)}{var(\Delta y_n)} = -\beta\frac{cov(\Delta y_n,\Delta\mathbb{A}_n)}{var(\Delta y_n)} = \frac{cov(\Delta\mathbb{A}_n,\Delta y_n)cov(\Delta y_n,\Delta\mathbb{A}_n)}{var(\Delta\mathbb{A}_n)var(\Delta y_n)}$, which corresponds to the R-squared of a regression of Δy_n on $\Delta\mathbb{A}_n$, and does not depend on the model parameters. Rather than focusing exclusively on this R-squared, we parameterize β to evaluate the decomposition for each individual country in our sample.

Table 1: Estimating the composite elasticity β.

	All sectors			**Manufacturing sectors**			**Service sectors**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta\mathbb{A}_n^j$	-0.194***	-0.199***	-0.197***	-0.189***	-0.203***	-0.196***	-0.193***	-0.194***	-0.193***
	[0.0267]	[0.0261]	[0.0282]	[0.0338]	[0.0372]	[0.0340]	[0.0342]	[0.0342]	[0.0386]
$\Delta[k_n - y_n]$		0.381***	0.275*		0.496**	0.297		0.195	0.121
		[0.115]	[0.157]		[0.165]	[0.167]		[0.122]	[0.128]
Δh_n		0.244	-0.168		0.774	0.144		-0.0915	-0.456
		[0.385]	[0.522]		[0.494]	[0.751]		[0.301]	[0.423]
$\Delta Governance_n$			0.479			0.780			0.348
			[0.350]			[0.432]			[0.219]
$\Delta Infrastructure_n$			0.117			0.00421			0.197
			[0.390]			[0.385]			[0.380]
Observations	445	445	445	158	158	158	161	161	161
R-squared	0.334	0.393	0.422	0.397	0.513	0.581	0.420	0.447	0.482

Notes: The table reports the OLS estimates from Equation (24). $\Delta\,[k_n - y_n]$ denotes the capital-output ratio, Δh_n denotes human capital from the Penn World Tables (9.1). $\Delta Governance_n$ is an aggregate indicator of governance averaging the six World Governance Indicators: (1) rule of law, (2) voice and accountability, (3) political stability and absence of violence, (4) government effectiveness, (5) regulatory quality, and (6) control of corruption. $\Delta Infrastructure_n$ is measured by the number of mobile cellular subscriptions per-capita (from World Development Indicators). Sector fixed effects are included and standard errors are clustered by country and sector (in parentheses).

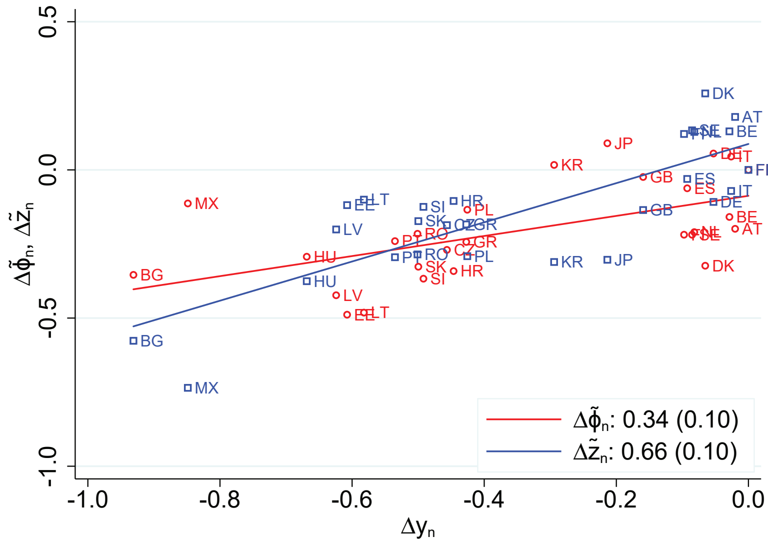
The relative importance of the differences in firm-embedded productivity and country-embedded factors also varies considerably across countries. For example, Italy and Slovenia — both EU members — have similar levels of country-embedded factors. However, Italy has more firm-embedded productivity, which generates significant differences in output per-worker between these two countries. In contrast, firm-embedded productivity is similar for Slovenia and Bulgaria, though output per-worker is much higher in Slovenia due to a large difference in country-embedded factors between these two countries. For countries such as Spain and the Netherlands, with roughly the same level of output per-worker, our decomposition indicates that while for Netherlands firm-embedded productivity is 0.15 log-point lower than for Spain, that negative difference is compensated by an advantage of equal magnitude in country-embedded factors.

Our measure of aggregate firm-embedded productivity is strongly correlated with output per-worker. While the development accounting literature documents a positive correlation between TFP and output per-worker, it computes TFP as a residual using output per-worker data. In contrast, we directly measure one component of TFP (firm-embedded productivity) and show that this component is strongly correlated with independent measures of output per-worker.

For our development accounting exercise, we compute the share of the cross-country variance in output per-worker accounted for aggregate firm-embedded productivity and country-embedded factors, in the spirit of Klenow and Rodriguez-Clare (1997). The contribution of aggregate firm-embedded productivity corresponds to the slope of a bivariate OLS regression of $\Delta\tilde{\phi}_n$ on Δy_n, which is reported in Figure 2. Differences in $\Delta\tilde{\phi}_n$ account for roughly a third of the cross-country variance in output per-worker; differences in country-embedded factors account for the remaining two thirds.

Correlation with country characteristics: Table 2 evaluates how our measures of firm-embedded productivity and country-embedded factors correlate with country characteristics. In particular, we regress output per-worker, firm-embedded productivity, and country-embedded factors on a country's capital-output ratio, human capital, measures of governance and infrastructure, and the number of patent applications per capita. Table 2 shows that differences in firm-embedded productivity are uncorrelated with physical and human capital (Column 3), and with Governance and Infrastructure (Column 4), but strongly correlated with the number of patent applications per capita (Column 4). In contrast, differences in country-embedded factors are significantly correlated with physical and human capital (Column 5), and Governance (Column 6), but they are uncorrelated with

Figure 2: Dev. accounting: firm-embedded productivity vs country-embedded factors.



Notes: Each circle (square) represents a country's firm-embedded productivity (country-embedded factors) relative to France. The figure plots the decomposition in Equation (15), where Δy_n is plotted in the x-axis and $\Delta\tilde{z}_n$ and $\Delta\tilde{\phi}_n$ are plotted in the y-axis. The legend reports the slopes of a bivariate OLS regression of $\Delta\tilde{\phi}_n$ ($\Delta\tilde{z}_n$) on Δy_n.

the number of patent applications per capita (Column 6). These results are reassuring since, as explained in Section 2.3, cross-country differences in factors should be captured by our measure of country-embedded factors, and not by our measure of firm-embedded productivity.[15]

Correlation with country size: A recurring theme in the International Trade and Growth-Development literatures is that aggregate scale or variety effects may be important for TFP (e.g. Krugman 1980, Jones 1995, and Hsieh and Klenow 2009). We next evaluate if differences in firm-embedded productivity are driven by country size. With this in mind, we fit the regression given by $\Delta\tilde{\phi}_n = b \times \Delta pop_n + u_n$, where country size is proxied by population. We evaluate the relation between the residual u_n and output per-worker also residualized by population.[16] Figure 3 shows that the cross-country variation in firm-embedded productivity, after controlling for population accounts for 16 percent of the cross-country variance in output per-worker, almost half of the variation accounted for

[15] Our measure of firm-embedded productivity is also strongly correlated (0.52) with the index of Management Practices from the World Management Survey, while the correlation with our measure of $\Delta\tilde{z}_n$ is not significant (see Figure A.6 in the Appendix). Unfortunately, this index is only available for 12 countries in our sample, and thus we cannot include it in the regressions in Table 2.

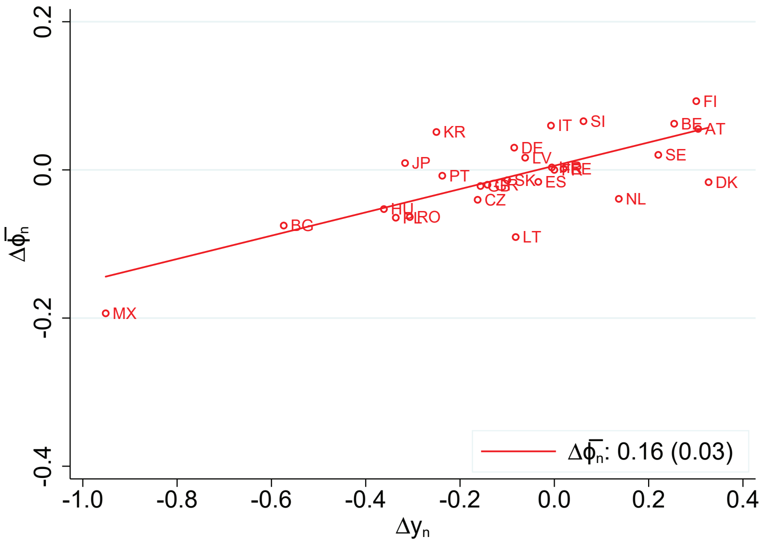
[16] Thus, the slope of this relation corresponds to the slope of a regression of Δy_n on $\Delta\tilde{\phi}_n$ that also controls for Δpop_n.

Table 2: Correlations with country characteristics.

dep. var.	Δy_n		$\Delta \tilde{\phi}_n$		$\Delta \tilde{z}_n$	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta [k_n - y_n]$	0.379**	0.183	-0.045	-0.0496	0.428***	0.232**
	[0.179]	[0.187]	[0.094]	[0.103]	[0.127]	[0.103]
Δh_n	0.772*	-0.157	-0.019	-0.331	0.792**	0.174
	[0.424]	[0.630]	[0.274]	[0.213]	[0.350]	[0.525]
$\Delta Governance_n$		0.689*		-0.134		0.823***
		[0.385]		[0.205]		[0.235]
$\Delta Infrastructure_n$		-0.0643		-0.101		0.0365
		[0.597]		[0.338]		[0.319]
$\Delta patents(pc)_n$		0.0841**		0.110***		-0.0264
		[0.0366]		[0.0211]		[0.0262]
Obs.	27	27	27	27	27	27
R-squared	0.201	0.525	0.007	0.610	0.358	0.637

Notes: The table reports the OLS estimates from Equation (24). $\Delta [k_n - y_n]$ denotes the capital-output ratio, Δh_n denotes human capital from the Penn World Tables (9.1). $\Delta Governance_n$ is an aggregate indicator of governance averaging the six Worldwide Governance Indicators (WGI): (1) rule of law, (2) voice and accountability, (3) political stability and absence of violence, (4) government effectiveness, (5) regulatory quality, and (6) control of corruption. $\Delta Infrastructure_n$ is measured by the number of mobile cellular subscriptions per-capita. $\Delta patents(pc)_n$ denotes the total number of patent applications per capita from the World Development Indicators. Sector fixed effects are included and standard errors are clustered by country and sector (in parentheses).

Figure 3: Dev. accounting: firm-embedded productivity residualized by population.



Notes: Each circle represents a country. The y-axis plots the residual of a regression of firm-embedded productivity, $\Delta\tilde{\phi}_n$, on the log of population. The x-axis plots the residual of a regression of the log of output per-worker, y_n, on the log of population.

our aggregate measure of firm-embedded productivity.

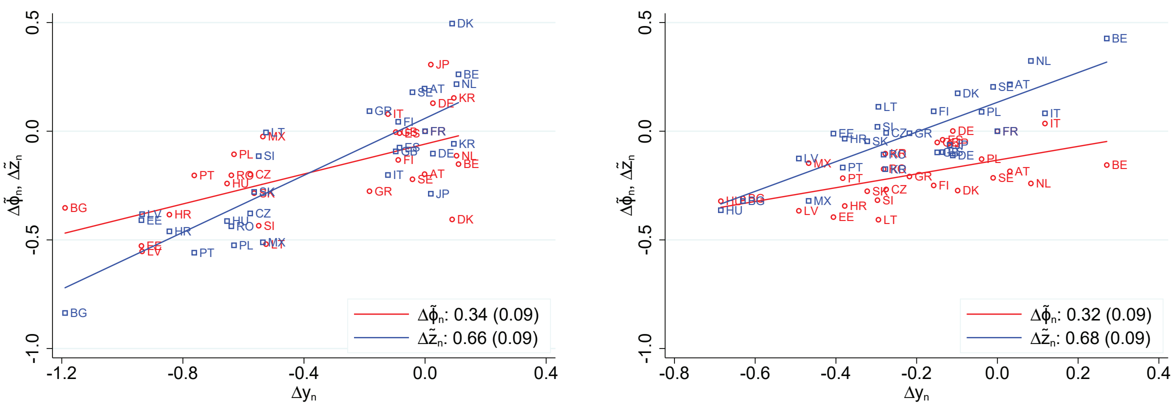
Sector-level decompositions: We now decompose differences in output per-worker in Manufacturing and Services by aggregating our sectoral estimates of the country effects into those two broad sectoral categories. Figure 4 reports the results. Firm-embedded productivity for the average country (relative to France) is similar for Manufacturing and Services (-0.18 vs -0.20 log-points), as well as its contribution to cross-country income differences, which is roughly one third for both sectors. There is substantial variation across countries. For example, Japan, Korea, and Germany have relative high levels of firm-embedded productivity in Manufacturing, but their firm-embedded productivity in Services is similar to that of other developed countries. Firm-embedded productivity is lower than country-embedded factors, relative to France, in Services sectors for all countries, except for Germany, Mexico, and Hungary.[17]

Firm-embedded productivity and comparative advantage: We now evaluate how sectoral

[17] Appendix Figures A.3 and A.4 show that for each sub-sector in Manufacturing and in Services, the correlation between our sectoral measures of firm-embedded productivity and output per-worker at the sector level is very strong. Appendix Figure A.5 further shows that cross-country differences in aggregate firm-embedded productivity are not driven by cross-country differences in sectoral output shares. Within-sector differences in firm-embedded productivity across countries overwhelmingly create the observed aggregate differences.

Figure 4: Dev. accounting: Manufacturing and Services.

Manufacturing | Services



Notes: Each circle (square) represents a country's firm-embedded productivity (country-embedded factors). The figures plot the decomposition in Equation (15) at the sectoral level. Δy_n^j is plotted in the x-axis and $\Delta \tilde{z}_n^j$ and $\Delta \tilde{\phi}_n^j$ are plotted in the y-axis for j =Manufacturing (left panel) and j =services (right panel).

differences in firm-embedded productivity and in country-embedded factors shape the sectoral concentration of the foreign output of a country's MNEs. The notion that MNEs can use their firm-specific productivity around the world while country-embedded factors are immobile suggests that only the former should affect the activities of MNEs when producing abroad.

With this in mind, we correlate sectoral differences in firm-embedded productivity in a country with the sectoral concentration of the foreign output of the MNEs from that country — referred as 'outward MNE sales.' We measure this sectoral concentration using a Revealed Comparative Advantage (RCA) index for outward MNE sales, defined as

$$\Delta rca_n^j \equiv ln\left(\frac{R_{n,row}^j / \sum_{j'} R_{n,row}^{j'}}{R_{r,row}^j / \sum_{j'} R_{r,row}^{j'}}\right), \tag{25}$$

where $R_{n,row}^j$ ($R_{r,row}^j$) denote the total revenues of MNEs from country n (reference country, r) in the rest of the world.[18] When the share of sector j in outward MNE sales is larger for MNEs from country n than for MNEs from France, $\Delta rca_n^j > 0$.[19]

[18]Using the notation from Section 2, $R_{n,row}^j \equiv \sum_{n' \neq n} \int_{\omega \in \Omega_{nn'}^j} P_{nn'}^j(\omega)\, Y_{nn'}^j(\omega)\, d\omega$.

[19]Note that, while $\Delta\tilde{\phi}_n^j$ is measured with data on market shares of foreign MNEs in country n, Δrca_n^j is measured with data on sales of country n's MNEs in foreign countries, so that the two measures do not need to be correlated.

Table 3: Sectoral firm-embedded productivity and comparative advantage.

dep. var. Δrca_n^j	All sectors			Manufacturing sectors			Service sectors		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta\tilde{\phi}_n^j$	2.63***		3.23***	4.14**		5.48***	3.07**		2.84**
	[0.663]		[0.836]	[1.326]		[1.075]	[0.906]		[0.812]
$\Delta\tilde{z}_n^j$		0.17	0.83		1.51	2.49**		-0.76	-0.19
		[0.469]	[0.501]		[0.927]	[0.823]		[0.527]	[0.645]
Observations	313	313	313	121	121	121	132	132	132
R-squared	0.072	0.001	0.094	0.138	0.056	0.274	0.063	0.023	0.064

Notes: Each j corresponds to a NAICS 2-digit sector. 'All sectors' include sectors those in Manufacturing, Services, and others. Dependent variable Δrca_n^j is defined in Equation (25). Standard errors are clustered by country and sector (in parentheses).

Using disaggregated 2-digit sectors, Table 3 shows the results of regressing Δrca_n^j on $\Delta\tilde{\phi}_n^j$ and $\Delta\tilde{z}_n^j$. Columns (1), (4) and (7) show a strong correlation between a country's sectoral firm-embedded productivity and its comparative advantage in outward MNE sales.[20] In contrast, Columns (2), (5), and (8) show no correlation between sector-level country-embedded factors and a country's comparative advantage. Columns (3), (6), and (9) reports similar results when country-embedded factors and firm-embedded productivity are simultaneously included in the regression.[21]

These results are in line with the notion that firm-embedded productivity is a source of advantage for MNEs operating abroad. Country-embedded factors do not appear to shape the sectoral concentration of a country's MNEs.

Contribution of domestic and foreign firms: We now decompose the sources of the cross-country differences in firm-embedded productivity into differences in the productivity embedded in domestic firms versus affiliates of foreign MNEs operating in each country.

The market share of domestic firms in country n and in sector j is

$$S_{nn}^j \equiv \int_{\Omega_{nn}^j} S_{nn}^j(\omega)d\omega = \frac{\Phi_{nn}^j}{\Phi_n^j}, \tag{26}$$

[20]This result is in line with the findings in Alviarez (2019), who uses sectoral-level data to show a positive correlation between the bilateral sales of affiliates of foreign MNEs in a sector and the RCA index for sectoral TFP in the source country of the MNE.

[21]Appendix Figure A.7 complements these results and shows a strong positive correlation between differences in firm-embedded productivity in manufacturing vs. services, $\Delta\tilde{\phi}_n^{man} - \Delta\tilde{\phi}_n^{serv}$, and differences in RCA in those sectors for outward MNE sales, $\Delta rca_n^{man} - \Delta rca_n^{serv}$.

where $\Phi^j_{nn} \equiv \int_{\Omega^j_{nn}} A^j_{nn}(\omega)\, d\omega$ is the productivity embedded in domestic firms in country n. Similarly, the market share of foreign firms in country n is given by

$$S^j_{Fn} \equiv \sum_{i \neq n} \int_{\Omega^j_{in}} S^j_{in}(\omega) d\omega = \frac{\Phi^j_{Fn}}{\Phi^j_n}, \tag{27}$$

where $\Phi^j_{Fn} \equiv \sum_{i \neq n} \int_{\Omega^j_{in}} A^j_{in}(\omega)\, d\omega$ denotes the productivity embedded in foreign firms operating in country n. Log approximating the definition of Φ^j_n and aggregating across sectors, we can calculate the contributions of domestic firms ($\Delta\tilde{\phi}_{nn}$) and foreign firms ($\Delta\tilde{\phi}_{Fn}$) to the observed differences in aggregate firm-embedded productivity ($\Delta\tilde{\phi}_n$),

$$\Delta\tilde{\phi}_n = \underbrace{\sum_j \theta^j_n S^j_{rr} \Delta\tilde{\phi}^j_{nn}}_{\Delta\tilde{\phi}_{nn}} + \underbrace{\sum_j \theta^j_n \left[1 - S^j_{rr}\right] \Delta\tilde{\phi}^j_{Fn}}_{\Delta\tilde{\phi}_{Fn}}. \tag{28}$$

Here, S^j_{rr} refers to the market share of domestic firms in France (and sector j), $\Delta\tilde{\phi}^j_{nn} \equiv \beta^j \Delta\phi^j_{nn}$, and $\Delta\tilde{\phi}^j_{Fn} \equiv \beta^j \Delta\phi^j_{Fn}$.[22]

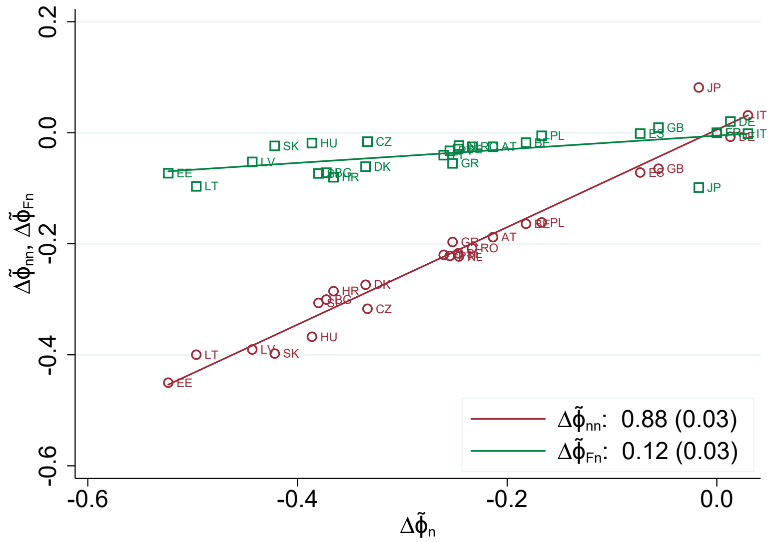
Figure 5 shows the two terms on the right-hand side of Equation (28). The average country has a 0.21 log-point difference relative to France for domestic firm-embedded productivity, while the gap for foreign firms is only 0.04. Differences in firm-embedded productivity for domestic firms account for 88 percent of the cross-country differences in aggregate firm-embedded productivity. Differences in the productivity embedded in the foreign affiliates of MNEs are very small across countries, with some developing countries having better foreign MNE affiliates than developed countries.

5 Sensitivity analysis

This section presents sensitivity analysis for our baseline estimates of country-embedded productivity. First, we show how to estimate firm-embedded productivity under alternative assumptions on the technology transfer costs. Second, we evaluate potential selection concerns. Third, we evaluate the log-linearity assumption on the production function.

[22] To measure these contributions, we use domestic shares S^j_{nn} from the data, our estimates of Φ^j_n, and Equation (26) to compute Φ^j_{nn}. Similarly, we use the revenue share of foreign firms in country n, S^j_{Fn}, together with the estimates of Φ^j_n, and Equation (27), to compute Φ^j_{Fn}. We aggregate across sectors using sectoral shares θ^j_n and the sectoral revenue share for French firms, S^j_{rr}.

Figure 5: Aggregate firm-embedded productivity: domestic vs foreign firms.



Notes: Brown circles and green squares, respectively, report $\Delta\tilde{\phi}_{nn}$ and $\Delta\tilde{\phi}_{Fn}$ defined in Equation (28).

Fourth, we evaluate the potential bias created by abstracting from trade in intermediate goods. Fifth, we show how to interpret our results when there are output distortions, such as markups, that vary across firms. Finally, we repeat our empirical analysis using alternative samples, finer sectoral disaggregations, and other gravity controls.

5.1 Alternative assumptions on the technology transfer costs

Our baseline estimates for $\Delta\phi_n^j$ were derived under the assumption that technology transfer costs could have an origin-specific but not a destination-specific component. As explained in Section 3.2, if this assumption does not hold, and if it is harder to transfer technology to less developed countries, our baseline estimates would understate the contribution of firm-embedded productivity to the cross-country variance of output per-worker.

We now show how to estimate $\Delta\phi_n^j$ when $\Delta D_n^j \neq 0$. We use data on market shares of both affiliates and parent firms of MNEs, and assume that costs have a destination-specific, $\Delta D_n^j \neq 0$, but no origin-specific component, $\Delta O_n^j = 0$, as in Eaton and Kortum (2002). In particular, we estimate

$$s_{in}^j(\omega) = \delta_i^j(\omega) + \mathbb{A}_n^j + \mathbb{P}_n^j + B_{in}^j + \epsilon_{in}^j(\omega). \tag{29}$$

Here, $\mathbb{A}_n^j$ is a set of dummies that take the value of 1 if the destination country is n and the firm is an affiliate, $i \neq n$, in sector j, while $\mathbb{P}_n^j$ is a set of dummies that take the value of 1 if the destination country is n and the firm is a parent, $i = n$, in sector j. In this specification, the dummies $\mathbb{A}_n^j$ are given by Equation (21), while the dummies $\mathbb{P}_n^j$ are

$$\Delta \mathbb{P}_n^j = -\left[\Delta \phi_n^j - \Delta O_n^j\right]. \tag{30}$$

If $\Delta O_n^j = 0$, $\Delta \mathbb{P}_n^j$ can be interpreted as (the negative of) the firm-embedded productivity in country n relative to France. If the assumption is not satisfied and the origin-specific component of the transfer cost is higher for low-income countries, $cov(\Delta {y^j}_n, \Delta O_n^j) \leq 0$, estimates based on Equation (30) would overstate the contribution of firm-embedded productivity to the cross-country variance of output per-worker,

$$cov\left(\Delta y_n, -\Delta \mathbb{P}_n^j\right) = cov\left(\Delta y_n, \Delta \phi_n^j - \Delta O_n^j\right) \geq cov\left(\Delta y_n, \Delta \phi_n^j\right). \tag{31}$$

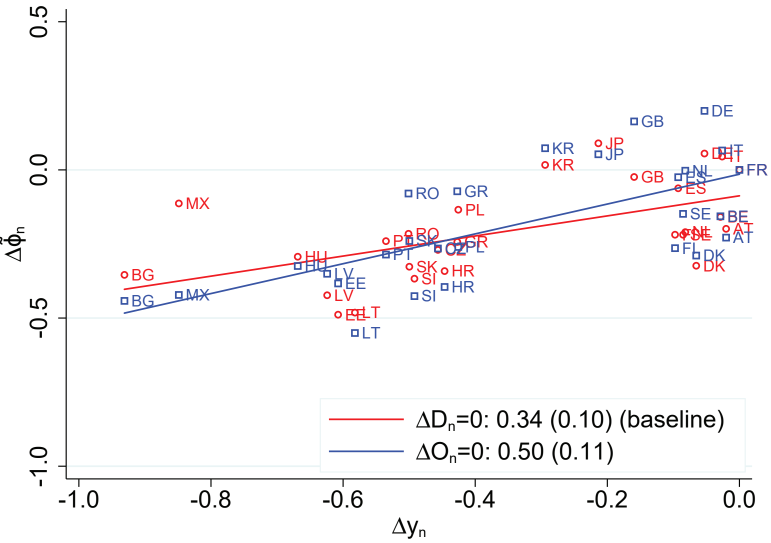
Hence, while our baseline estimates yield a lower bound to the contribution of differences in firm-embedded productivity to cross-country differences in income, this alternative specification yields an upper bound to that contribution.

Figure 6 compares our baseline estimates with those based on Equations (29), (30), and the restriction that $\Delta O_n^j = 0$. The two alternative identification assumptions on transfer costs yield similar estimates for aggregate firm-embedded productivity, relative to France, for each country. Appendix Figure A.8 shows that the OLS estimates from Equation (29) are less precise than our baseline estimates, as the number of MNE parent firms in our data is far lower than the number of MNE foreign affiliates. For the average country, this alternative estimate of $\Delta \phi_n$ is -0.19 log-points, relative to France, while our baseline estimate is -0.20. One of the largest differences is observed for Mexico where aggregate firm-embedded productivity, relative to France, is estimated to be -0.42 when we assume that $\Delta O_n^j = 0$ and -0.11 when we alternately assume that $\Delta D_n^j = 0$.

5.2 Selection based on MNE-destination specific characteristics

The OLS estimates of the destination-sector specific components of the market shares, $\mathbb{A}_n^j$, are unbiased if the assignment of MNEs to destination countries is exogenous with respect to the error term in Equation (19). This is the case if selection is driven by firm characteristics and by destination-country characteristics. In contrast, the estimates are biased if MNE-destination specific transfer costs drive the assignment of MNEs to countries

Figure 6: Alternative assumptions on the technology transfer costs.



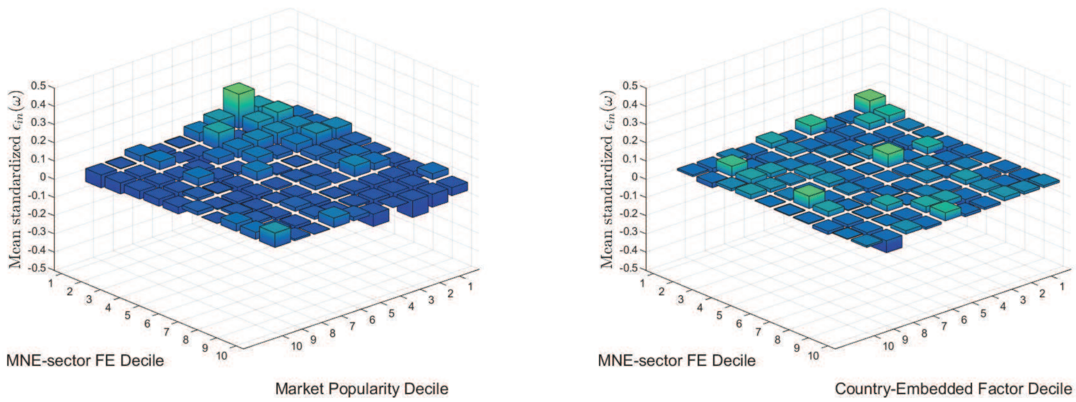
Notes: Each circle (square) represents a country. The figure plots the decomposition in Equation (15), where Δy_n is plotted in the x-axis and $\Delta\tilde{\phi}_n$ is plotted in the y-axis. The legends report the slopes of a bivariate OLS regression of $\Delta\tilde{\phi}_n$ on Δy_n under the assumption that $\Delta D_n^j = 0$ (baseline) and $\Delta O_n^j = 0$. Standard errors are in parenthesis.

-that is, if selection is based on match-specific effects. If the relatively unproductive MNEs enter unattractive locations only when their MNE-destination specific component of the transfer cost $\varepsilon_{in}^j(\omega)$ is low, the average of $\varepsilon_{in}^j(\omega)$ across the MNEs that choose to enter each destination would vary across n, and thus, it would be captured by the country fixed effect $\mathbb{A}_n^j$.

To assess the severity of this potential bias, we follow the literature on two-way matching (Abowd et al., 1999) and analyze the residuals from estimating our baseline specification in Equation (19) by OLS (e.g. Card et al., 2013). If the assignment of MNEs to countries is driven by MNE-destination specific transfer costs, we should expect these costs to be on average lower -low $\varepsilon_{in}^j(\omega)$- for low-productivity MNEs in unattractive markets. In contrast, highly productive MNEs are more likely to enter these markets irrespective of their $\varepsilon_{in}^j(\omega)$. If this is the case, our specification should underestimate market shares for low-productivity MNEs in unattractive markets, as it does not take into account that the $\varepsilon_{in}^j(\omega)$'s can systematically vary with firm productivity among the MNEs that choose to enter any given market (see also Appendix D for a formal argument).

We evaluate this implication in Figure 8a, which plots the mean standardized residuals, $\hat{\varepsilon}_{in}^j(\omega) = \frac{s_{in}^j(\omega) - \hat{s}_{in}^j(\omega)}{\sigma_s}$, against deciles of estimates of the MNE-sector fixed effects, $\delta^j(\omega)$,

Figure 7: OLS Residuals.



(a) By MNE-sector and market popularity.

(b) By MNE-sector and country-embedded factors.

Notes: Deciles are calculated within sectors. Market popularity refers to the number of foreign MNEs in a country-sector pair, from OECD-Eurostat. Country-embedded factor refers to estimates of $\tilde{Z}_n^j$.

and deciles of market popularity. Our measure of market popularity is calculated using data from OECD-Eurostat on the number of foreign MNEs operating in a country-sector pair. Indeed, we tend to see positive residuals for the less productive MNEs (decile 1 of the MNE-sector fixed effect) in less popular markets (decile 1 of market popularity). In contrast, we overestimate the market shares of the most productive MNEs (decile 10 of the MNE-sector fixed effect) in these markets. The residuals are very close to zero in the remaining bins, indicating that technology transfer costs do not vary systematically across MNEs and locations in those bins.

With this concern in mind, we proceed to re-estimate Equation (19) using alternative subsamples, restricted to exclude the MNEs at the extremes of the market-share distribution. Concretely, we restrict the sample to subsets of MNEs that lie within the 2nd to 9th, 3rd to 8th, 4th to 7th deciles, or 5th and 6th deciles, of the MNE-sector fixed effect distribution, for each sector. Alternatively, we also apply our estimation procedure to subsamples of MNEs that operate in at least 3, 5, or 10 countries. These are large MNEs that are unlikely to select into destination markets due to the MNE-destination specific component of the technology transfer costs. Table 4 shows that the contribution of firm-embedded productivity to the cross-country variance in output per-worker is very similar to our baseline in all these subsamples.

Table 4: Contribution of firm-embedded productivity, restricted samples.

	$\frac{cov(\Delta y_n, \Delta\tilde{\phi}_n)}{var(\Delta y_n)}$
Baseline	0.34 (0.10)
I. Keeping MNEs with MNE-sector FE belonging to:	
2nd to 9th Decile	0.32 (0.10)
3rd to 8th Decile	0.31 (0.11)
4th to 7th Decile	0.31 (0.11)
5th to 6th Decile	0.37 (0.12)
II. Keeping MNEs operating in:	
at least 3 countries	0.32 (0.10)
at least 5 countries	0.28 (0.08)
at least 10 countries	0.32 (0.08)

Notes: Slopes of a bivariate OLS regression of $\Delta\tilde{\phi}_n$ on Δy_n. MNE-sector fixed effect, for each sector, estimated using Equation (19) by OLS. Standard errors are in parenthesis.

5.3 Assumptions on the production function

A related concern with our baseline estimation refers to the separability between firm-embedded productivity and country-embedded factors. Our model assumes a production function that is log-linear in firm-embedded productivity and country embedded factors. This separability is inherited by the aggregate production function, which is linear in $\tilde{z}_n$ and $\tilde{\phi}_n$. But if, for instance, high productivity MNEs do relatively better in countries with high country-embedded factors, the assumption would not longer hold, and our procedure would underestimate market shares for high productivity MNEs in those markets.

We evaluate this implication in Figure 8b, which plots the mean standardized residuals, $\hat{\epsilon}^j_{in}(\omega) = \frac{s^j_{in}(\omega) - \hat{s}^j_{in}(\omega)}{\sigma_s}$, against deciles of estimates of the MNE-sector fixed effects, $\delta^j(\omega)$, and deciles of estimates of the country-embedded factors $\tilde{z}^j_n$. We see positive residuals for the less productive MNEs (decile 1 of the MNE-sector fixed effect) in countries with lower $\tilde{z}^j_n$ (decile 1 of country-embedded factors). We actually overestimate the market shares of the most productive MNEs (decile 10 of the MNE-sector fixed effect) in these countries. The residuals are very close to zero in the remaining bins, indicating that the log-linearity assumption is not systematically violated in those bins. Table 4 shows that the contribution of firm-embedded productivity to the cross-country variance in output per-worker is very similar when estimated in subsamples of MNEs that are not at the extremes of the fixed-effect distribution.

An alternative approach to assess the additive separability assumption on the production function is to group destination countries using k-mean clustering based on the distribution of affiliates' market shares (Bonhomme et al., 2019). Based on this approach, Appendix C presents additional tests that support our linearity assumption.

5.4 Trade in intermediate goods and export platforms

An important simplifying assumption of our framework is that there is no trade in intermediate goods. This ensures that MNE affiliates only sell in the markets where they produce, and that their market shares are given by Equation (7). In practice, an MNE market share in a location can be large if the MNE uses that location to serve additional locations through export platforms. In Appendix F, we extend our framework to allow for trade in intermediate goods and export platforms. The Appendix shows how one could still estimate cross-country differences in firm-embedded productivity by focusing on MNE shares on domestic (non-export) revenues. Unfortunately, ORBIS reports export data for a very limited number of firms in the manufacturing sector. Despite this limitation, Appendix Figure F.1 shows that, for the few countries where those data are available, the export-corrected estimates of firm-embedded productivity are close to our baseline estimates.

To understand this result, we note that the difference between an MNE share in total revenues (used for our baseline estimation) and the MNE share in domestic revenues (the appropriate statistic in the model with trade) depends on the MNE export intensity relative to the export intensity of all firms in the economy; if all firms export the same fraction of their revenues, total and domestic revenue shares coincide. The Appendix shows that the bias that arises from using total revenue shares is proportional to the difference between the ratio of exports to revenues for the average MNE affiliate in the destination and the ratio of total export to total revenues in that same destination. Appendix Table F.1 uses data from the OECD to compare aggregate export shares for foreign MNEs to the economy-wide export shares, for seven countries for which these data are available. The table shows that while the affiliates of foreign MNEs do get a larger share of their revenues from exports than other firms, the difference is quantitatively small relative to the observed differences in MNE market shares across countries. For instance, the fact that foreign MNE affiliates export a relatively large part of their output makes the market share of MNE affiliates located in Estonia 12 percent larger than the market share of MNE affiliates located in Italy. The Appendix shows that this difference is two-order of magnitudes too small to account for the fact that foreign MNEs in Estonia have a market share that is 13 times larger than in Italy, as shown in Figure 1.

5.5 Variable markups and other output distortions

Equation (7) relies on the assumption that the allocation of resources across firms is efficient. Appendix E extends our framework to allow for variable markups and other output distortions across firms. In such case, an MNE would have a relatively low market share in a destination if its productivity is low relative to the aggregate firm-embedded productivity in the destination, or if its markup (i.e. the distortion) is high relative to the average markup in the destination. If as documented by Bento and Restuccia (2017) and Fattal Jaef (Forthcoming), size-dependent distortions are more prevalent in less developed countries -for example, when larger firms are taxed more or have higher markups in developing countries- these distortions would push *down* MNE market shares in those countries. The Appendix shows that in this case our procedure would underestimate the contribution of firm-embedded productivity to cross country income differences.

5.6 Additional robustness exercises

This section briefly describes additional robustness exercises, which are collected in Table 5. First, we use additional controls for the bilateral component of MNE costs in Equation (18), B^{j}_{in}. In particular, we add bilateral MNE-specific taxes, which we compute using data from several sources (see Appendix B for details). Alternatively, we include an indicator variable for the existence of a bilateral tax treaty between the source and host country, which allow foreign-owned subsidiaries to avoid or mitigate double taxation. Additionally, we control for the difference between the output per-worker of the source and the host country, and finally we repeat our analysis without any gravity control.

In an additional robustness, we consider sectors at the 4-digit NAICS (336 sectors), rather than the 2-digit NAICS classification. Alternatively, we exclude the Health, Education, and Real Estate sectors from our sample, as the government has a large participation in theses sectors for some countries in our sample. Finally, we repeat our analysis for firms

Table 5: Contribution of firm-embedded productivity, additional robustness.

	$\frac{cov(\Delta y_n, \Delta \tilde{\phi}_n)}{var(\Delta y_n)}$
Baseline	0.34 (0.10)
Controlling for bilateral MNE-specific tax rates	0.34 (0.10)
Controlling for bilateral tax treaties (BTT)	0.35 (0.10)
Controlling for differences in GDP per-worker between source and host country	0.34 (0.10)
Excluding gravity variables	0.29 (0.11)
Aggregation at 4-digit NAICS industries	0.38 (0.11)
Excluding Real Estate, Health, and Education	0.32 (0.10)
Excluding MNEs that do not appear in ORBIS every year between 2010-2016	0.39 (0.09)
Excluding MNE affiliates incorporated after 2006	0.33 (0.09)

Notes: Slopes of a bivariate OLS regression of $\Delta\tilde{\phi}_n$ on Δy_n. Bilateral tax treaties data comes from UNCTAD International Investment Agreements. Standard errors are in parenthesis.

that appear in ORBIS in every year between 2010 and 2016, as these are arguably the years when the ORBIS data are of the highest quality (see Appendix Table A.4 for results by year). We also repeat our analysis restricting our sample to firms incorporated after 2005 —so that they were at least 11 years old by 2016 — to mitigate concerns about MNE affiliates having small market shares right after entry.[23] The results of our decomposition for all these alternative specifications are remarkably close to our baseline result.

6 A general equilibrium model of MNE location decisions

This section closes the model presented in Section 2 by explicitly modeling MNE location choices. We use this model to quantify the output gains from eliminating barriers to the mobility of MNEs, and emphasize how our estimates from Section 4 discipline this quantification. In what follows, we reproduce the main equations of the analysis and relegate details to Appendix D.

[23] Existing evidence shows that such dynamics are not quantitatively important in the data: Garetto et al. (2019) show that affiliate sales relative to parent sales are roughly constant over the affiliate life.

6.1 Modeling MNE location decisions

We close the model by assuming that there is an exogenous measure of firms in each country and sector, M_i^j, and that the productivity embedded in those firms $A(\omega)$ is distributed Pareto with shape $\gamma \geq 1$ and scale $B_i^j \geq 1$.[24] We also assume that all firms must pay a fixed cost of $f^j \theta_n^j H_n$ units of country $n's$ labor to operate in market n and sector j.[25] MNEs operating in a foreign country must also pay a fixed cost of f_{in}^j units of country $n's$ labor, with $f_{nn}^j = 0$. Firms choose to operate in markets where their (gross) profits exceed these fixed costs. This implies a firm-embedded productivity cutoff for operating in country n given by

$$\bar{A}_{in}^j = \frac{W_n}{R_n^j} \tau_{in}^j \left[f^j \theta_n^j H_n + f_{in}^j \right] \rho \Phi_n^j, \tag{32}$$

where W_n and R_n^j denote the wage and aggregate revenues in country n and sector j, and $\tau_{in}^j \equiv exp(\kappa_{in}^j)$.

Let $\Phi_{in}^j \equiv \int_{\omega \in \Omega_{in}} A_{in}^j(\omega)\, d\omega$ denote the aggregate-firm embedded productivity of the firms from country i that operate in country n and sector j. Using the cutoff rule and the distributional assumption for productivity, we can write

$$\Phi_{in}^j = T_i^j \left[\tau_{in}^j \right]^{-\gamma} \left[1 + \frac{f_{in}^j}{\theta_n^j H_n} \right]^{1-\gamma} \left[\Phi_n^j \right]^{1-\gamma}, \tag{33}$$

where $T_i^j \propto B_i^j \times M_i^j$ is a technology parameter for country i that summarizes the quantity and the quality of its local firms. Equation (33) shows that Φ_{in}^j is large if country $i's$ technology is very productive (high T_i^j), or if firms from country i face a low cost of entering country n (low f_{in}^j and τ_{in}^j).

We can then express the equilibrium level of firm-embedded productivity as a function

[24] Given that $A(\omega) = [X(\omega) \times Q(\omega)]^{\rho-1}$, this corresponds to assuming that $X(\omega)$ and $Q(\omega)$ are distributed Pareto with scale parameter $\gamma[\rho - 1]$. Thus, the shape parameter γ determines the firm-size distribution.

[25] The assumption that the fixed cost scales with the employment in the country-sector guarantees that MNEs operate in every country when all barriers to the MNE mobility are eliminated.

of the model's parameters:

$$\tilde{\Phi}_n^j = \left[\sum_i \Phi_{in}^j\right]^\beta = \left[\sum_i T_i^j \left[\tau_{in}^j\right]^{-\gamma} \left[1 + \frac{f_{in}^j}{\theta_n^j H_n}\right]^{1-\gamma}\right]^{\frac{\beta}{\gamma}}. \tag{34}$$

Finally, using Equations (26) and (33), we can relate firm-embedded productivity to the aggregate revenue share of domestic firms in local revenues:

$$\tilde{\Phi}_n^j = \left[\frac{T_n^j}{S_{nn}^j}\right]^{\frac{\beta}{\gamma}}. \tag{35}$$

Equation (35) is standard in the class of models of international trade and MNEs analyzed by Arkolakis et al. (2012). The equation relates aggregate productivity in country n to the primitive technology parameter T_n^j, the observed domestic share, S_{nn}^j, and the elasticity β/γ. Papers in this tradition, however, do not typically distinguish between firm-embedded and country-embedded productivity, and interpret the left-hand side of Equation (35) as a country's TFP. In contrast, it is clear from our setting that the left-hand side of Equation (35) only corresponds to the part of TFP that is firm-embedded. As we shall see below, this distinction has important implications when quantifying the gains from eliminating barriers to the mobility of MNEs.

6.2 Gains from eliminating barriers to MNE mobility

We now evaluate the output gains from eliminating all barriers to MNE mobility across countries. We compare steady state equilibria in a world economy where human capital and capital-output ratios are independent of productivity.[26] Formally, using the superscript F to denotes values in the new equilibrium, we set $\tau_{in}^{jF} = 1$ and $f_{in}^{jF} = 0$ for all n and j. Under these assumptions, we can write the change in output per-worker between the two equilibria as

$$\hat{Y}_n \equiv \frac{Y_n^F}{Y_n} = \frac{\tilde{\Phi}_n^F}{\tilde{\Phi}_n} = \prod_j \left[\frac{\left(\sum_i T_i^j\right)^{\frac{\beta}{\gamma}}}{\tilde{\Phi}_n^j}\right]^{\theta_n^j}, \tag{36}$$

[26] These assumptions are common properties of neoclassical growth models and imply that country-embedded factors are constant across steady states.

where the last equality follows from evaluating Equation (33) at the new equilibrium, the definition of $\tilde{\Phi}_n$, and Equation (14). The equation shows that the gains from eliminating barriers to MNE mobility are determined by the technology parameter's T_i^j. Using Equation (35), we can write these parameters in terms of observables and obtain:

$$\hat{Y}_n = \prod_j \left[\sum_i \left[\frac{\tilde{\Phi}_i^j}{\tilde{\Phi}_n^j} \right]^{\frac{\gamma}{\beta}} S_{ii}^j \right]^{\theta_n^j \frac{\beta}{\gamma}}. \tag{37}$$

Equation (37) highlights how the gains from eliminating barriers to MNE mobility depend on the inferred differences in firm-embedded productivities, $\tilde{\Phi}_i^j / \tilde{\Phi}_n^j$. If we assume that all differences in output per-worker are driven by differences in firm-embedded productivities, then $\left[Y_i^j / L_i^j \right] / \left[Y_n^j / L_n^j \right] = \tilde{\Phi}_i^j / \tilde{\Phi}_n^j$ and the counterfactual change in output per-worker is given by:

$$\hat{Y}_n^{FEP} = \prod_j \left[\sum_i \left[\frac{Y_i^j / L_i^j}{Y_n^j / L_n^j} \right]^{\frac{\gamma}{\beta}} S_{ii}^j \right]^{\theta_n^j \frac{\beta}{\gamma}}. \tag{38}$$

In contrast, if we assume that there are no cross-country differences in firm-embedded productivities, $\tilde{\Phi}_i^j = \tilde{\Phi}_n^j$, and we obtain:

$$\hat{Y}_n^{CEF} = \prod_j \left[\sum_i S_{ii}^j \right]^{\theta_n^j \frac{\beta}{\gamma}}. \tag{39}$$

Next, we quantify and compare the gains from eliminating barriers to MNE mobility implied by Equations (37), (38), and (39).

6.3 Calibration and results

This section evaluates Equations (37), (38), and (39) by considering a world economy comprising of the countries in our sample from Section 3. Our data sources for sectoral output per-worker y_i^j, sectoral domestic revenue shares S_{ii}^j, and sectoral shares θ_n^j, are described in Section 3. We use our estimates of $\Delta\tilde{\phi}_n^j$ and β from Section 4 to evaluate Equation (37). Finally, we set $\gamma = 1.2$ to match the right-tail coefficient of the firm-size distribution, following Atkeson and Burstein (2010).

Figure 8 shows the results. The figure shows that the size of the gains from eliminating barriers to MNE mobility depend on whether we calibrate the model assuming that observed differences in output per-worker are due to firm-embedded or country embedded factors. If we assume that all initial differences in output per-worker are driven by country embedded factors and use Equation (39), gains are roughly the same across all countries (0.92, green squares). Intuitively, in this scenario, all countries start and also end up with the same firm-embedded productivity — since with no barriers to MNE mobility the same firms operate in all locations.[27] In contrast, the gains vary enormously across countries and are on average much higher (1.65, red triangles) if we use Equation (38) and assume that all initial differences in output per-worker are driven by differences in firm-embedded productivity. In this case, the gains are larger for poorer countries that integrate with countries that have better firms.[28] Finally, our baseline estimates imply gains that are between these two extremes, with the average country more than doubling output per-worker (blue dots), and with the largest gains going to the countries with the lowest firm-embedded productivity.

7 Conclusion

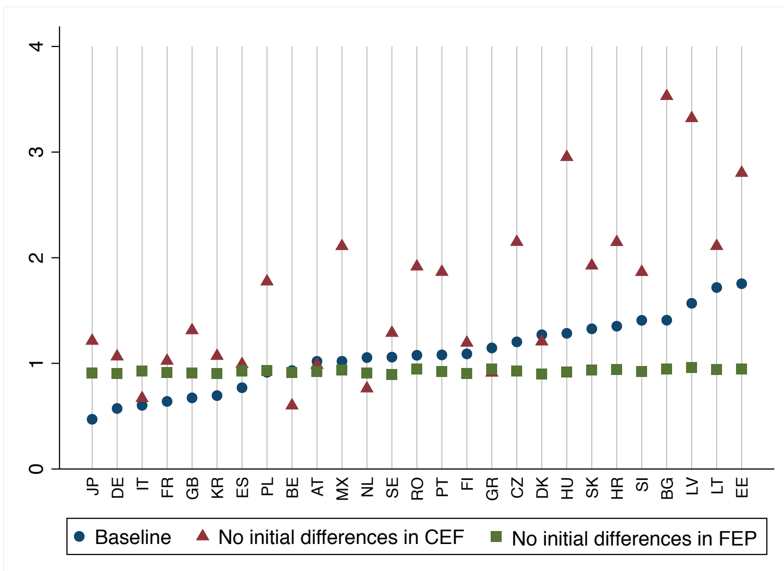
This paper measures cross-country differences in firm-embedded productivity and their contribution to cross-country income differences. Our key insight is that, if MNEs can use their idiosyncratic productivity around the world, but they must use the factors from the countries where they produce, differences in the market shares of the same MNE across countries can be used to measure cross-country differences in firm-embedded productivity. We implement this idea in a development accounting framework and measure firm-embedded productivity using firm-level revenue data on MNEs that produce in multiple countries.

Our results indicate that cross-country differences in firm-embedded productivity are large, accounting for roughly one-third of the observed differences in output per-worker across the countries in our sample. This suggests that policies that help poor countries catch up in terms of firm-embedded productivity, such as eliminating barriers to firm mobility across countries, can play an important role in eliminating cross-country income

[27] The gains are not exactly the same for all countries since Equation (39) weights sectors using country-specific weights, θ_n^j.

[28] The gains are also larger on average since the additional term in Equation (38), $\left[Y_i^j / L_i^j\right]^{\frac{\gamma}{\beta}}$, is convex.

Figure 8: Output gains from eliminating barriers to MNE mobility.



Notes: The figure reports the output gains from eliminating barriers to MNE mobility. 'Baseline' is calculated from Equation (37), and refers to a counterfactual that uses our baseline estimates for cross-country differences in firm- embedded productivity. 'No initial differences in CEF' is calculated from Equation (38), and refers to a counterfactual that assumes that there are no cross-country differences in country-embedded factors, and that all differences in output per-worker in the initial equilibrium are due to differences in firm-embedded productivity. 'No initial differences in FEP' is calculated from Equation (39), and refers to a counterfactual that assumes that there are no cross-country differences in firm-embedded productivity, and that all differences in output per-worker in the initial equilibrium are due to differences in country-embedded factors.

differences.

While our sample of developing countries is limited, our new procedure can be easily applied to more countries as new affiliate-parent matched data become available. In addition, if affiliate-parent matched data could be linked to firm-level measures of physical productivity, the logic of our procedure can be applied under more general assumptions on the firm's revenue function. The key insight of our procedure is that by observing the same firm operating in many countries, it is possible to disentangle the firm- from the country-embedded components of productivity.

References

Abowd, John M, Francis Kramarz, and David N Margolis, "High Wage Workers and High Wage Firms," *Econometrica*, March 1999, *67* (2), 251–333.

Alviarez, Vanessa, "Multinational production and comparative advantage," *Journal of International Economics*, 2019, *119* (C), 1–54.

Andrews, M. J., L. Gill, T. Schank, and R. Upward, "High wage workers and low wage firms: negative assortative matching or limited mobility bias?," *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 2008.

Antras, Pol and Stephen R. Yeaple, "Multinational Firms and the Structure of International Trade," in G. Gopinath, . Helpman, and K. Rogoff, eds., *Handbook of International Economics*, Vol. 4 of *Handbook of International Economics*, Elsevier, 2014, chapter 0, pp. 55–130.

Arkolakis, Costas, Arnaud Costinot, and Andres Rodriguez-Clare, "New Trade Models, Same Old Gains?," *American Economic Review*, February 2012, *102* (1), 94–130.

_ , Natalia Ramondo, Andrés Rodríguez-Clare, and Stephen Yeaple, "Innovation and Production in the Global Economy," *American Economic Review*, August 2018, *108* (8), 2128–2173.

Atkeson, Andrew and Ariel Tomas Burstein, "Innovation, Firm Dynamics, and International Trade," *Journal of Political Economy*, 06 2010, *118* (3), 433–484.

_ and Patrick J. Kehoe, "Modeling and Measuring Organization Capital," *Journal of Political Economy*, October 2005, *113* (5), 1026–1053.

Atkin, D., A. Chaudhry, S. Chaudry, A. K. Khandelwal, and E. Verhoogen, "Organizational barriers to technology adoption: Evidence from soccer-ball producers in Pakistan," *The Quarterly Journal of Economics*, 2017, *132* (3), 1101–1164.

Atkin, David, Amit K. Khandelwal, and Adam Osman, "Exporting and Firm Performance: Evidence from a Randomized Experiment*," *The Quarterly Journal of Economics*, 02 2017, *132* (2), 551–615.

_, Dave Donaldson, Imran Rasul, Matthieu Teachout, Eric Verhoogen, and Christopher Woodruff, "Firms, trade, and productivity," *International Growth Center*, 2019.

Autor, David, David Dorn, Lawrence F Katz, Christina Patterson, and John Van Reenen, "The Fall of the Labor Share and the Rise of Superstar Firms," *The Quarterly Journal of Economics*, 2020, *135* (2), 645–709.

Bento, Pedro and Diego Restuccia, "Misallocation, Establishment Size, and Productivity," *American Economic Journal: Macroeconomics*, July 2017, *9* (3), 267–303.

Bernard, Andrew B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum, "Plants and Productivity in International Trade," *American Economic Review*, September 2003, *93* (4), 1268–1290.

Bilir, L. Kamran and Eduardo Morales, "Innovation in the Global Firm," *Journal of Political Economy*, 2020, *128* (4), 1566–1625.

Bloom, N., B. Eifert, A. Mahajan, D. McKenzie, and J. Roberts, "Does management matter? Evidence from India," *The Quarterly Journal of Economics*, 2013, *128* (1), 1–51.

Bloom, Nicholas and John Van Reenen, "Measuring and explaining management practices across firms and countries," *Quarterly Journal of Economics*, 2007, *122* (4), 1351–1408.

Bonhomme, Stephane, Thibaut Lamadon, and Elena Manresa, "A Distributional Framework for Matched Employer Employee Data," *Econometrica*, 2019, *87* (3), p. 699–739.

Brooks, W., K. Donovan, and T. R. Johnson, "Mentors or teachers? Microenterprise training in Kenya," *American Economic Journal: Applied Economics*, 2018, *10* (4), 196–221.

Burstein, A., V. M. Carvalho, and B. Grassi, "Bottom-up Markup Fluctuations," Cambridge Working Papers in Economics 2096 2020.

Burstein, Ariel T. and Alexander Monge-Naranjo, "Foreign Know-How, Firm Control, and the Income of Developing Countries," *Quarterly Journal of Economics*, February 2009, *124* (1), 149–195.

Cai, Jing and Adam Szeidl, "Interfirm Relationships and Business Performance*," *The Quarterly Journal of Economics*, 12 2017, *133* (3), 1229–1282.

Card, David, JÃ¶rg Heining, and Patrick Kline, "Workplace Heterogeneity and the Rise of West German Wage Inequality," *The Quarterly Journal of Economics*, 05 2013, *128* (3), 967–1015.

Caselli, Francesco, "Accounting for Cross-Country Income Differences," in Philippe Aghion and Steven Durlauf, eds., *Handbook of Economic Growth*, Vol. 1 of *Handbook of Economic Growth*, Elsevier, July 2005, chapter 9, pp. 679–741.

_ , *Technology Differences over Space and Time*, Princeton University Press, 2016.

Caunedo, Julieta and Elisa Keller, "Capital Obsolescence and Agricultural Productivity," *The Quarterly Journal of Economics*, 12 2020, *136* (1), 505–561.

Costinot, Arnaud and Andrés Rodríguez-Clare, "Chapter 4 - Trade Theory with Numbers: Quantifying the Consequences of Globalization," in Gita Gopinath, Elhanan Helpman, and Kenneth Rogoff, eds., *Handbook of International Economics*, Vol. 4 of *Handbook of International Economics*, Elsevier, 2014, pp. 197–261.

Cravino, Javier and Andrei A. Levchenko, "Multinational Firms and International Business Cycle Transmission," *The Quarterly Journal of Economics*, 2017, *132* (2), 921–962.

Eaton, Jonathan and Samuel Kortum, "Technology, Geography, and Trade," *Econometrica*, September 2002, *70* (5), 1741–1779.

Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu, "How Costly Are Markups?," March 2018. NBER Working Paper No. 24800.

Garetto, Stefania, Lindsay Oldenski, and Natalia Ramondo, "Multinational Expansion in Time and Space," NBER Working Papers 25804 2019.

Giné, X. and D. Yang, "Insurance, credit, and technology adoption: Field experimental evidence from Malawi," *Journal of Development Economics*, 2009, *89* (1), 1–11.

Hall, Robert E. and Charles I. Jones, "Why Do Some Countries Produce So Much More Output perWorker Than Others?," *Quarterly Journal of Economics*, 1999, *114* (1), 83–116.

Head, Keith and Thierry Mayer, "Brands in Motion: How Frictions Shape Multinational Production," *American Economic Review*, 2019, *109* (9), 3073–3124.

Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple, "Export versus FDI with Heterogeneous Firms," *American Economic Review*, March 2004, *94* (1), 300–316.

Hendricks, Lutz and Todd Schoellman, "Human Capital and Development Accounting: New Evidence from Wage Gains at Migration," *The Quarterly Journal of Economics*, 2018, *133* (2), 665–700.

Hsieh, Chang-Tai and Peter J. Klenow, "Misallocation and Manufacturing TFP in China and India," *The Quarterly Journal of Economics*, November 2009, *124* (4), 1403–1448.

Irarrazabal, Alfonso, Andreas Moxnes, and Luca David Opromolla, "The Margins of Multinational Production and the Role of Intrafirm Trade," *Journal of Political Economy*, February 2013, *121* (1), 74–126.

Jaef, Roberto Fattal, "Entry Barriers, Idiosyncratic Distortions, and the Firm-Size Distribution," *American Economic Journal: Macroeconomics*, Forthcoming.

Jones, Charles I., "R&D-Based Models of Economic Growth," *Journal of Political Economy*, 1995, *103*, 759–784.

Klenow, Peter and Andres Rodriguez-Clare, "The Neoclassical Revival in Growth Economics: Has It Gone Too Far?," in "NBER Macroeconomics Annual 1997, Volume 12" NBER Chapters, National Bureau of Economic Research, Inc, 03-2018 1997, pp. 73–114.

Klette, Tor Jakob and Samuel Kortum, "Innovating Firms and Aggregate Innovation," *Journal of Political Economy*, October 2004, *112* (5), 986–1018.

Kline, P., R. Saggio, and M. Solvsten, "Leave-out estimation of variance components," *Econometrica*, 2020.

Krugman, Paul, "Scale Economies, Product Differentiation, and the Pattern of Trade," *American Economic Review*, December 1980, *70* (5), 950–59.

Lagakos, David, Benjamin Moll, Tommaso Porzio, Nancy Qian, , and Todd Schoellman, "Life Cycle Wage Growth across Countries," *Journal of Political Economy*, 2018, *126* (2), 797–849.

McGrattan, Ellen R. and Edward C. Prescott, "Openness, technology capital, and development," *Journal of Economic Theory*, November 2009, *144* (6), 2454–2476.

Prescott, Edward C and Michael Visscher, "Organization Capital," *Journal of Political Economy*, June 1980, *88* (3), 446–461.

Ramondo, Natalia, "A quantitative approach to multinational production," *Journal of International Economics*, May 2014, *93* (1), 108 – 122.

_ **and Andres Rodriguez-Clare**, "Trade, Multinational Production, and the Gains from Openness," *Journal of Political Economy*, 2013, *121* (2), 273 – 322.

Tintelnot, Felix, "Global Production with Export Platforms," *Quarterly Journal of Economics*, 2017, *132* (1), 157–209.

Waugh, Michael E., "International Trade and Income Differences," *American Economic Review*, December 2010, *100* (5), 2093–2124.

APPENDIX

A Additional tables and figures

Table A.1: Estimates of gravity coefficients.

	Distance		Common Language	
	Coef.	S.E.	Coef.	S.E.
Other goods				
Agriculture and Mining	-0.702	0.215	-0.078	0.327
Electricity	-0.754	0.138	0.069	0.481
Construction	-0.491	0.222	0.740	0.277
Manufacturing				
Food and Beverage	-0.214	0.165	0.597	0.090
Textiles, Apparel and Wood	-0.285	0.125	-0.144	0.277
Chemicals, Petroleum and Plastic	-0.191	0.075	0.161	0.085
Basic Metals	-0.202	0.097	0.261	0.089
Electrical Equipment and Machinery	-0.030	0.074	0.272	0.112
Transport Equipment and Other Manufacturing	-0.278	0.114	0.004	0.211
Services				
Wholesale Trade and Retail Trade	-0.278	0.064	0.212	0.103
Transportation and Storage	-0.123	0.088	0.233	0.201
Information	-0.340	0.116	0.559	0.114
Financial and Insurance Services	-0.423	0.101	1.013	0.178
Support Services	-0.276	0.058	0.335	0.149
Accommodation and Recreation	-0.075	0.147	0.245	0.218
Other Sectors				
Education	0.081	0.511	0.678	0.592
Health	0.099	0.569	0.240	0.511
Real Estate	-0.296	0.129	0.279	0.176

Notes: This table reports OLS coefficients on distance, and common language, MNE taxes from estimating Equation (19).

Table A.2: Estimates of sectoral elasticities β^j.

	no controls		$+k_n/y_n + h_n$	
	Coef.	S.E	Coef.	S.E
Other goods				
Agriculture and Mining	-0.08	0.04	-0.09	0.04
Construction	-0.21	0.04	-0.21	0.04
Electricity	-0.12	0.02	-0.13	0.02
Manufacturing				
Food and Beverage	-0.18	0.03	-0.19	0.03
Textiles, Apparel and Wood	-0.26	0.05	-0.29	0.05
Chemicals, Petroleum and Plastic	-0.22	0.04	-0.23	0.04
Basic Metals	-0.12	0.02	-0.12	0.03
Electrical Equipment and Machinery	-0.21	0.03	-0.21	0.03
Transport Equipment and Other Manufacturing	-0.31	0.03	-0.32	0.03
Services				
Wholesale Trade and Retail Trade	-0.18	0.05	-0.20	0.04
Transportation and Storage	-0.06	0.05	-0.07	0.05
Information	-0.28	0.05	-0.29	0.05
Financial and Insurance Services	0.05	0.03	0.04	0.02
Support Services	-0.15	0.03	-0.15	0.02
Accommodation and Recreation	-0.20	0.05	-0.22	0.04
Other Sectors				
Real Estate	-0.18	0.04	-0.19	0.04
Health	-0.16	0.04	-0.15	0.04
Education	-0.04	0.05	-0.05	0.06

Notes: OLS estimates from Equation (24) by 2-digit sector. Standard errors in parentheses.

Table A.3: Number of observations, R-squared, and mean squared errors.

	N	R^2	MSE
Baseline	49,811	0.70	1.43
I. Other outcome variables			
Employment	41,697	0.76	1.31
Value Added	27,271	0.75	1.30
II. Alternative assumption on technology transfer costs	70,353	0.72	1.46
III. Keeping MNEs with firm-sector FE belonging to:			
2nd to 9th Decile	38,652	0.74	1.06
3rd to 8th Decile	27,275	0.81	0.80
4th to 7th Decile	16,218	0.89	0.55
5th to 6th Decile	6,120	0.97	0.28
IV. Keeping MNEs operating in:			
at least 3 countries	38,709	0.66	1.43
at least 5 countries	26,298	0.62	1.42
at least 10 countries	11,682	0.58	1.34
V. Other Robustness:			
Aggregation at 4-digit NAICS industries	59,088	0.63	1.54
Excluding Real Estate, Health, and Education	47,584	0.70	1.43
Excluding MNEs that do not appear in ORBIS every year between 2010-2016	32,396	0.72	1.34
Excluding MNE affiliates incorporated after 2006	37,390	0.71	1.38
Controlling for differences in GDP per-worker between source and host country	48,955	0.70	1.43
Controlling for bilateral tax treaties (BTT) between source and host country	49,811	0.70	1.43
Excluding gravity controls	50,649	0.70	1.44

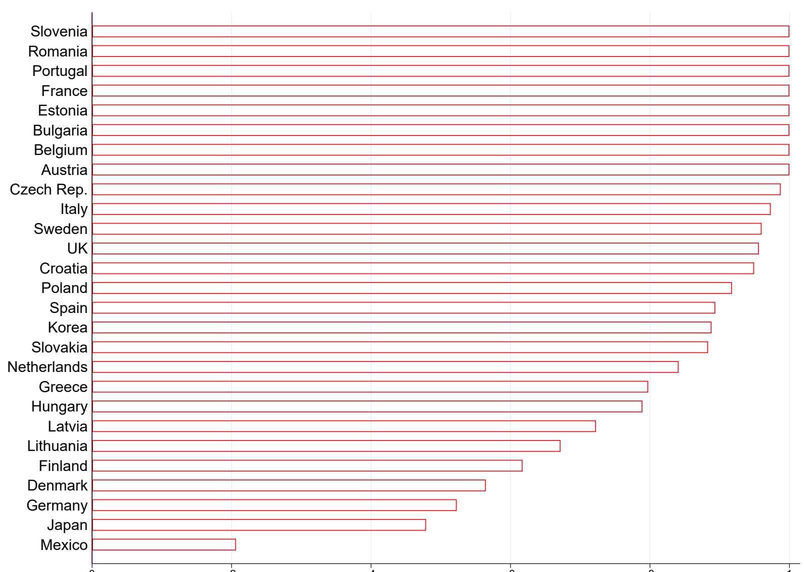
Notes: Number of observations, R^2, and mean squared errors for the regressions presented in the paper. I. refers to alternative firm's outcome variables. II. refers to our alternative specification in Equation (29), which includes data from parent firms. III. refers to keeping firms in the specified deciles of the distribution of the MNE-sector fixed effects. IV. refers to keeping firms that have affiliates in at least as many countries as reflected by the threshold. V. refers to the additional robustness in Section 5.6.

Table A.4: Contribution of aggregate firm-embedded productivity, by year.

	All firms	Countries (#)	Constant Sample	Countries (#)
	$\frac{cov(\Delta y_n, \Delta\tilde{\phi}_n)}{var(\Delta y_n)}$		$\frac{cov(\Delta y_n, \Delta\tilde{\phi}_n)}{var(\Delta y_n)}$	
2006	0.28 (0.15)	15		
2007	0.35 (0.10)	24	0.20 (0.11)	15
2008	0.32 (0.09)	25	0.24 (0.08)	24
2009	0.34(0.08)	25	0.26 (0.08)	24
2010	0.36 (0.10)	25	0.31 (0.09)	24
2011	0.35 (0.10)	25	0.29 (0.09)	24
2012	0.38 (0.11)	25	0.31 (0.10)	24
2013	0.28 (0.11)	27	0.33 (0.09)	24
2014	0.32 (0.10)	27	0.34 (0.09)	24
2015	0.33 (0.10)	27	0.37 (0.09)	24
2016	0.34 (0.10)	27	0.39 (0.09)	24
2017	0.34 (0.10)	27	0.41 (0.09)	24

Notes: Slopes of a bivariate OLS regression of $\Delta\tilde{\phi}_n$ on Δy_n. A country is required to have estimates of firm-embedded productivity in at least 10 sectors to construct $\Delta\tilde{\phi}_n$. Each sector is required to have observations of three or more foreign affiliates. The last two columns use only firms (BVDIDs) that are available in ORBIS in every year from 2010 to 2016.

Figure A.1: Data coverage: foreign-MNE revenues.



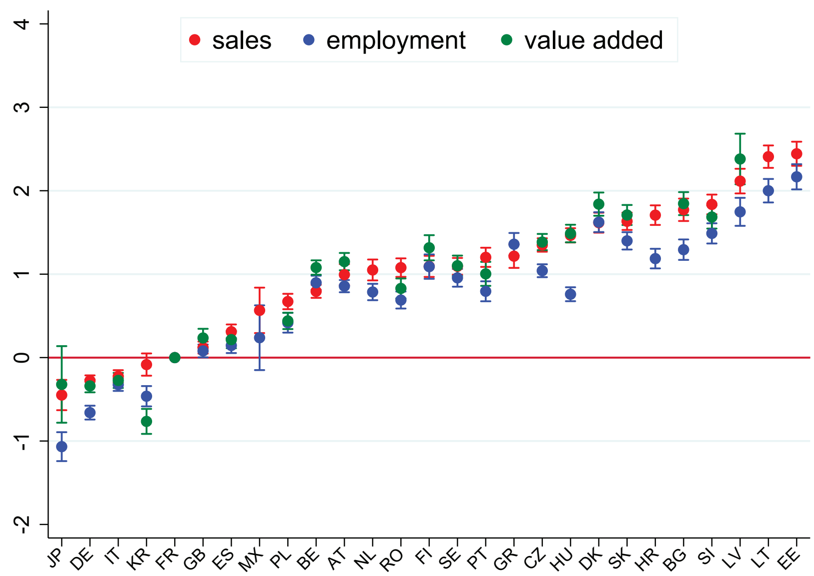
Notes: Ratio of total foreign-affiliate revenues in ORBIS to total foreign-affiliate revenues reported by OECD/Eurostat, for each country in our sample.

Table A.5: Output per-worker and firm-embedded productivity, by country.

Country	ISO	Δy_n	$\Delta\tilde{\phi}_n$	$\Delta\tilde{\phi}_n^{manuf}$	$\Delta\tilde{\phi}_n^{serv}$
Austria	AT	-0.02	-0.20	-0.20	-0.18
Belgium	BE	-0.03	-0.16	-0.15	-0.16
Bulgaria	BG	-0.93	-0.35	-0.35	-0.31
Czech Rep.	CZ	-0.46	-0.27	-0.20	-0.27
Germany	DE	-0.05	0.06	0.13	0.00
Denmark	DK	-0.07	-0.32	-0.41	-0.27
Estonia	EE	-0.61	-0.49	-0.53	-0.40
Spain	ES	-0.09	-0.06	-0.01	-0.04
Finland	FI	-0.10	-0.22	-0.13	-0.25
France (ref)	FR	0.00	0.00	0.00	0.00
UK	GB	-0.16	-0.02	0.00	-0.05
Greece	GR	-0.43	-0.24	-0.28	-0.21
Croatia	HR	-0.45	-0.34	-0.38	-0.34
Hungary	HU	-0.67	-0.29	-0.24	-0.32
Italy	IT	-0.03	0.04	0.08	0.04
Japan	JP	-0.21	0.09	0.31	-0.05
Korea	KR	-0.29	0.02	0.15	-0.10
Lithuania	LT	-0.58	-0.48	-0.52	-0.41
Latvia	LV	-0.62	-0.42	-0.55	-0.37
Mexico	MX	-0.85	-0.11	-0.02	-0.15
Netherlands	NL	-0.08	-0.21	-0.11	-0.24
Poland	PL	-0.43	-0.13	-0.11	-0.13
Portugal	PT	-0.54	-0.24	-0.20	-0.22
Romania	RO	-0.50	-0.22	-0.20	-0.17
Sweden	SE	-0.09	-0.22	-0.22	-0.21
Slovenia	SI	-0.49	-0.37	-0.43	-0.32
Slovakia	SK	-0.50	-0.33	-0.29	-0.28

Notes: Numbers underling Figures 2 and 4. Column 3 shows the country's output per-worker relative to France, Δy_n, Column 4 shows the country's aggregate firm-embedded productivity, $\Delta\tilde{\phi}$, and Columns 5 and 6 show the country's firm-embedded productivity for the Manufacturing and the Service sector, respectively.

Figure A.2: Country effects: Alternative dependent variables.



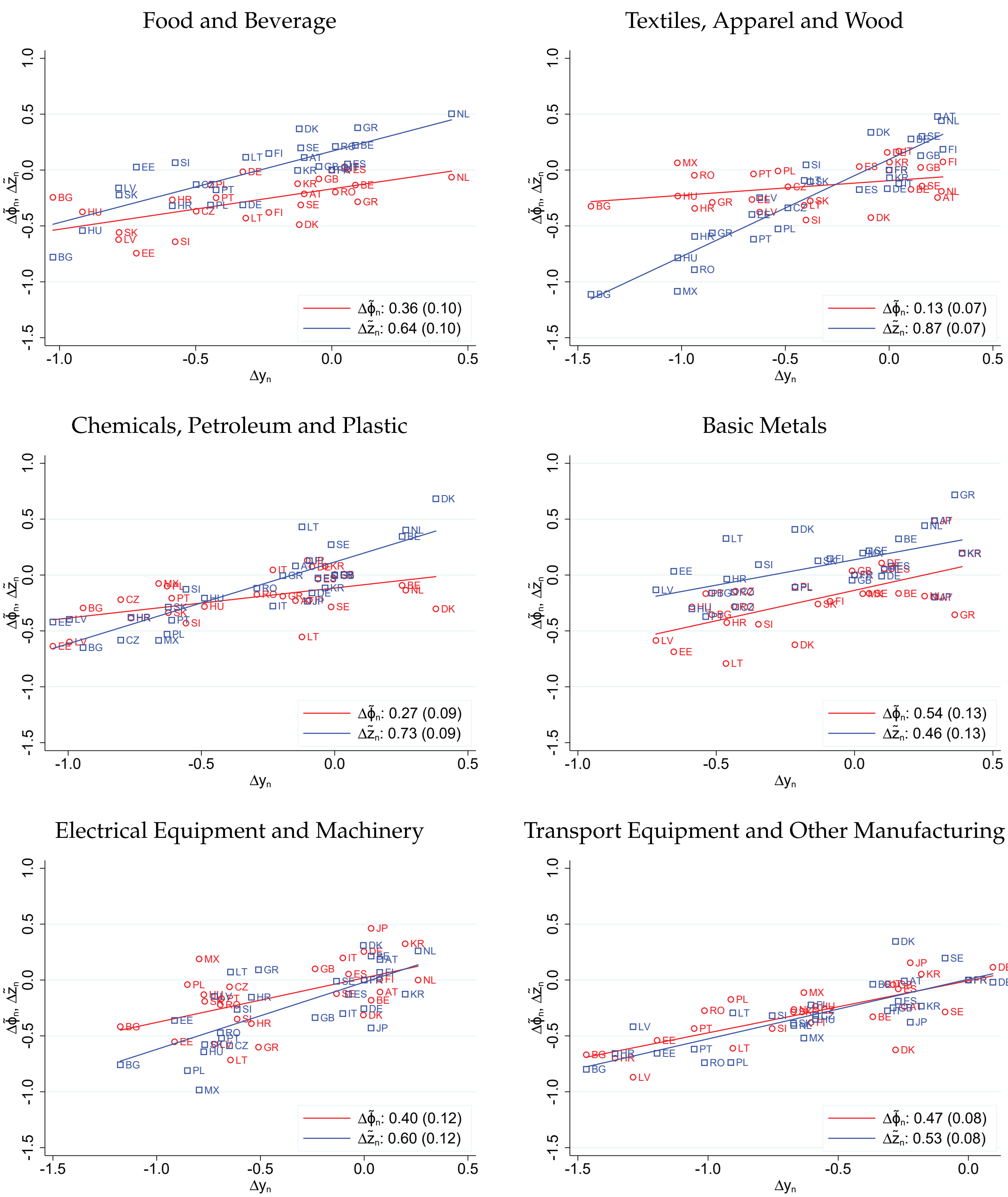
Note: Red dots are OLS estimates of $\Delta\mathbb{A}_n$ from Equation (19) using data on revenue shares. Blue and Green dots are OLS estimates of $\Delta\mathbb{A}_n$ using employment and value added shares, respectively. Bars reflect 95-percent confidence intervals, clustered at the country level.

B Data Appendix

Firm level data: In this section we describe the construction of our sample using ORBIS. We start by dropping those firms with revenues below 100,000 USD. We also drop firms that only report information from consolidated accounts, as well as firms with only "limited financials" (LF) information. From the remaining sample, we exclude firms operating in "Public Administration", "Extraterritorial Organizations", and "Activity of Households"sectors. The time span of our dataset is 2006-2017, but our baseline analysis uses information for 2016 since it is the latest year with the largest number of firms in ORBIS historical.

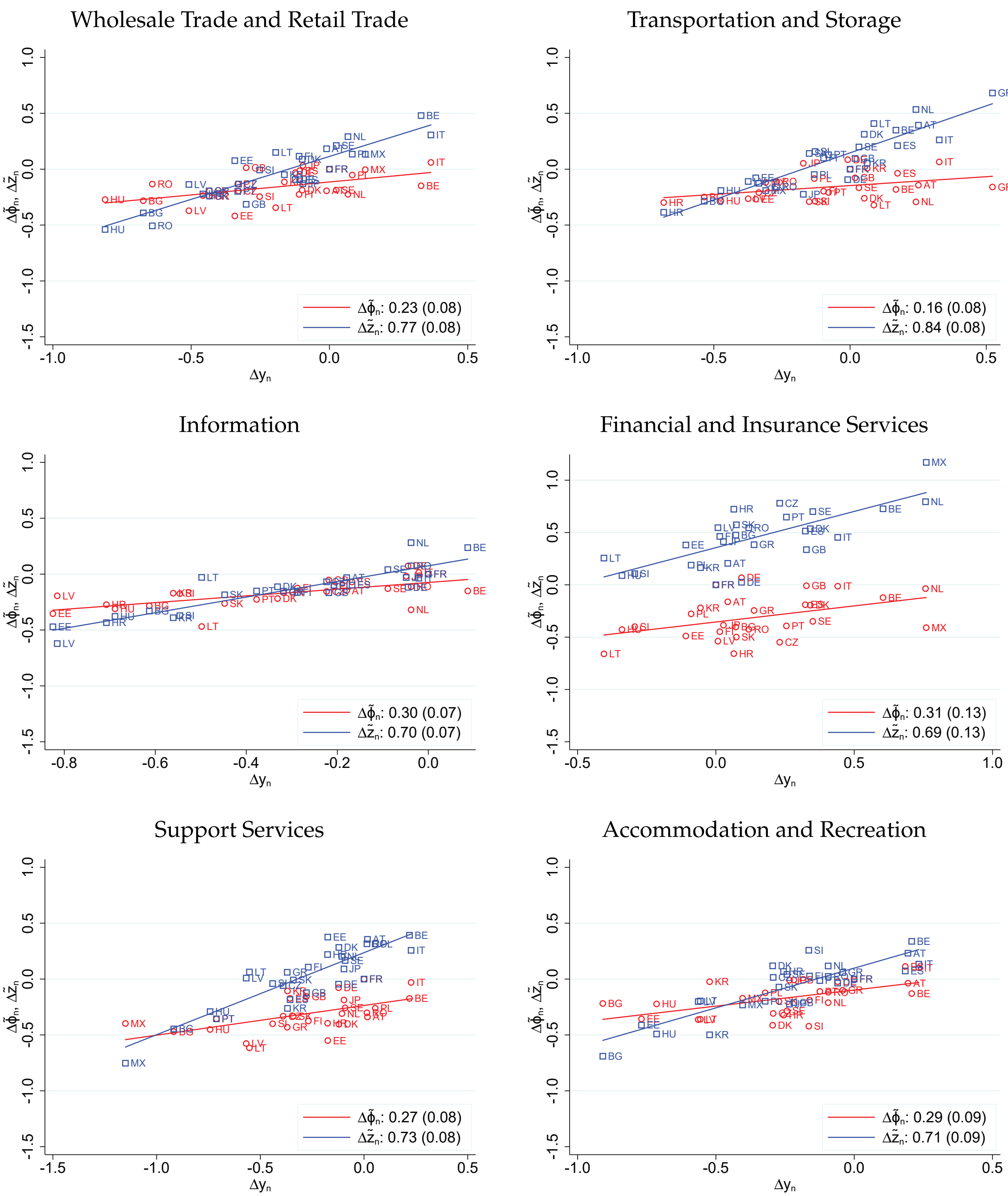
A multinational enterprise (MNE) is defined as a company exerting above 50 percent of the control rights on affiliates located in more than one country. Crucially for our analysis, a MNE is defined within a given sector. In order to define a company as a MNE, we use the NAICS sector classification at three different levels of disaggregation, NAICS2 (18 industries), NAICS3 (99 industries) and NAICS4 (336 industries). Information on revenues, employment, and value-added are aggregated for all tax identification numbers in ORBIS belonging to the same corporate group and operating in the same country and sector. Therefore, in our analysis an affiliate is defined as a corporate group-country-sector triplet in which the country of location differs from the country where the headquarter is located, whereas a parent is defined as a triplet located at the headquarter's country. Moreover, a MNE owning affiliates in multiple countries, but each operating in a different sector, will ultimately be excluded from our sample.

Figure A.3: Dev. accounting: Manufacturing sectors.



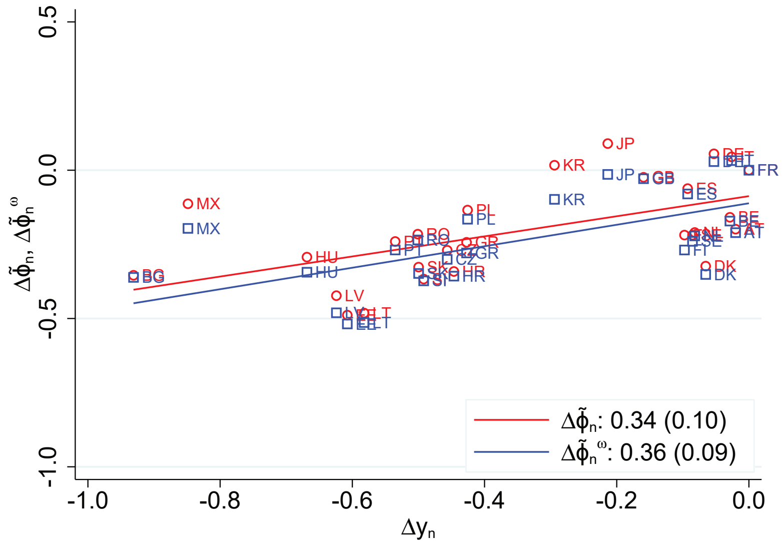
Notes: Each circle (square) represents a country. The figures plot the decomposition in Equation (15) at the sectoral level. Δy_n^j is plotted in the x-axis and $\Delta \tilde{z}_n^j$ and $\Delta \tilde{\phi}_n^j$ are plotted in the y-axis for j = two-digit manufacturing sectors.

Figure A.4: Dev. accounting: Service sectors.



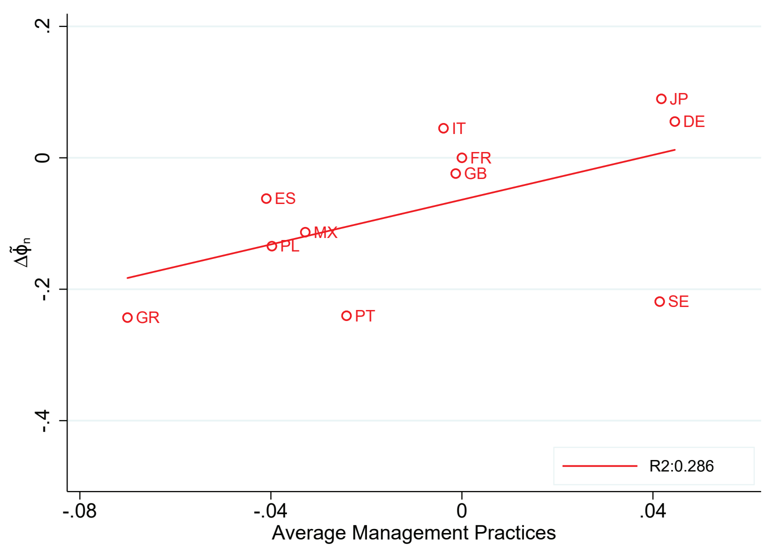
Notes: Each circle (square) represents a country. The figures plot the decomposition in Equation (15) at the sectoral level. Δy_n^j is plotted in the x-axis and $\Delta\tilde{z}_n^j$ and $\Delta\tilde{\phi}_n^j$ are plotted in the y-axis for $j =$ two-digit service sectors.

Figure A.5: Differences in firm-embedded productivity within and between sectors.



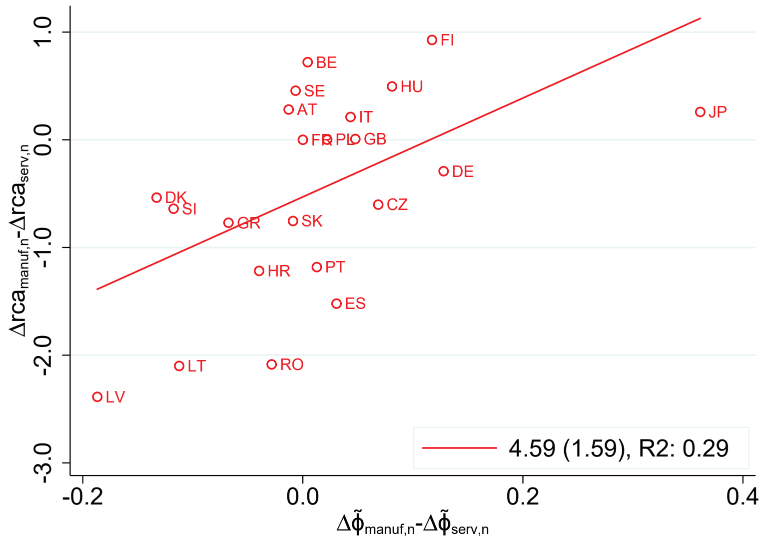
Notes: The figure plots the decomposition in Equation (15), where Δy_n is plotted in the x-axis and $\Delta\tilde{\phi}_n^w \equiv \sum_j \theta_r^j \Delta\tilde{\phi}_n^j$ and $\Delta\tilde{\phi}_n \equiv \sum_j \theta_n^j \Delta\tilde{\phi}_n^j$ are plotted in the y-axis. The legend reports the slopes of a bivariate OLS regression of $\Delta\tilde{\phi}_n$ (rest. $\Delta\tilde{\phi}_n^w$) on Δy_n. Each circle (square) represents a country.

Figure A.6: Firm-embedded productivity and management practices.



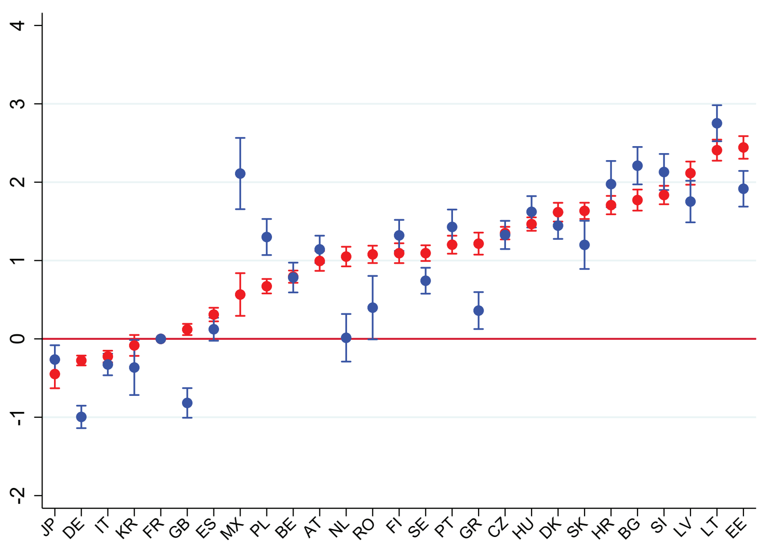
Notes: Each circle represents a country's firm-embedded productivity relative to France. The figure plots the average management practices score from the World Management Survey in the x-axis and $\Delta\tilde{\phi}_n$ in the y-axis. The legend reports the R-squared of a bivariate OLS regression of $\Delta\tilde{\phi}_n$ and country's management practices score.

Figure A.7: Sectoral firm-embedded productivity and outward MNE sales.



Notes: The x-axis reports the difference in our measure of firm-embedded productivity in manufacturing vs. services, relative to France. The y-axis reports the difference in the Δrca_n^j index defined in Equation (25), between $j =$ Manufacturing and $j =$ Services.

Figure A.8: Country effects: Alternative specification of the technology transfer costs.



Note: Red dots are our baseline OLS estimates of $\Delta\mathbb{A}_n$. Blue dots are the OLS estimates of $\Delta\mathbb{P}_n$ from Equation (29). Bars reflect 95-percent confidence intervals, clustered at the country level.

Table B.1: Number of affiliates and parents, by NAICS2.

	Foreign Affiliates			Parents		
	Sales	Emp.	VA	Sales	Emp.	VA
Other goods						
Agriculture and Mining	407	354	246	43	37	30
Construction	1,041	843	583	125	113	92
Electricity	557	344	273	73	65	57
Manufacturing						
Food and Beverages	1,061	964	794	118	116	99
Textiles, Apparel and Wood	965	886	699	127	126	109
Chemicals, Petroleum and Plastic	3,104	2,861	2,375	307	301	260
Basic Metals	1,550	1,401	1,178	160	158	124
Electrical Equipment and Machinery	3,019	2,828	2,195	327	321	270
Transport Equipment and Other Manufacturing	1,445	1,309	1,082	139	136	105
Services						
Wholesale Trade and Retail Trade	18,513	16,434	11,429	1,245	1,184	868
Transportation and Storage	2,265	2,004	1,417	237	231	192
Information	1,499	1,298	882	115	111	86
Financial and Insurance Services	1,402	1,104	555	147	138	80
Support Services	10,329	9,015	5,817	959	894	702
Accommodation and Recreation	1,218	1,098	774	105	99	75
Other Sectors						
Real Estate	1,969	1,132	910	192	145	112
Health	204	187	151	21	21	19
Education	96	84	49	5	4	4

Notes: A foreign affiliate is a majority-owned firm by a company with operations in multiple countries within a given sector. Sectors roughly correspond to the 2-digit NAICS classification.

Table B.1 shows the number of affiliates and the number of parent firms in each NAICS2 sectors in our sample, including affiliates in "Other Goods" as well as in other sectors. Each column of Table B.1 shows the number of affiliates and parents according to the availability of information on firm's revenues, employment and value-added.

Table B.2 and Table B.3 report the number of affiliates and the number of parents in each country in our sample, according to the available information from sales, employment and value added. The numbers are shown for manufacturing, services, and for all sectors.

Aggregate firm-embedded productivity at the country level is constructed by calculating the weighted average of the sector level firm-embedded productivity, using country-sector level expenditure shares as weights. If a country has less than three foreign MNE affiliates in a particular sector, we exclude the country from that sector, and reweigh the remaining sectors accordingly to compute the aggregate $\Delta\tilde{\phi}_n$ for that country. Table B.4 reports the country-sector pairs for which we cannot compute an estimate of $\Delta\phi_n^j$ for our

Table B.2: Number of foreign affiliates, by country and sector.

Country	Sales			Employment			Value Added		
	All	Mfg.	Services	All	Mfg.	Services	All	Mfg.	Services
Austria	1,510	293	1,141	1,219	271	895	956	242	661
Belgium	2,743	536	1,973	2,555	526	1,866	1,863	434	1,304
Bulgaria	737	119	536	711	119	522	596	108	437
Czech Rep.	2,507	656	1,602	2,389	652	1,555	1,492	499	866
Germany	3,680	1,046	2,378	3,620	1,040	2,337	2,795	921	1,673
Denmark	819	151	581	703	151	502	635	138	454
Estonia	659	99	502	612	94	476	-	-	-
Spain	4,099	819	2,933	3,909	817	2,825	3,995	809	2,855
Finland	1,417	258	1,045	1,143	219	848	655	139	471
France	4,659	1,075	3,267	3,638	950	2,528	3,469	969	2,337
UK	5,072	1,259	3,402	4,690	1,231	3,144	2,744	881	1,689
Greece	512	74	398	502	74	393	-	-	-
Croatia	829	102	634	776	99	609	-	-	-
Hungary	1,272	306	827	1,172	302	774	568	196	310
Italy	4,545	1,176	2,997	4,279	1,166	2,883	3,654	1,098	2,359
Japan	192	48	141	180	47	130	12	4	8
Korea	899	291	592	694	256	426	384	171	208
Lithuania	445	69	324	439	69	318	-	-	-
Latvia	679	60	543	658	60	533	28	2	24
Mexico	137	51	72	52	24	20	-	-	-
Netherlands	1,130	260	805	1,003	249	710	-	-	-
Poland	3,399	833	2,238	992	293	617	1,871	541	1,189
Portugal	1,759	278	1,304	1,651	275	1,249	1,712	275	1,268
Romania	2,040	424	1,365	1,934	416	1,329	1,266	348	788
Sweden	2,694	419	2,064	2,526	411	1,967	1,378	205	1,091
Slovenia	612	108	460	567	106	427	345	64	261
Slovakia	1,603	334	1,102	1,537	332	1,070	996	279	621

Notes: A foreign affiliate is defined as a corporate group-country-sector triplet where the country of operation differs from the country where the headquarter is located.

Table B.3: Number of parents, by country and sector.

Country	Sales			Employment			Value Added		
	All	Mfg.	Services	All	Mfg.	Services	All	Mfg.	Services
Austria	246	55	149	226	54	135	212	53	125
Belgium	218	67	125	204	66	118	185	62	104
Bulgaria	2	-	2	2	-	2	2	-	2
Czech Rep.	54	5	45	53	5	45	44	4	37
Germany	629	192	379	627	192	378	508	174	288
Denmark	156	42	101	143	42	92	136	40	87
Estonia	50	5	36	45	5	33	-	-	-
Spain	248	54	156	246	54	156	243	53	154
Finland	161	45	99	145	44	89	119	34	74
France	715	170	446	639	163	398	647	167	401
UK	459	91	328	425	89	304	308	68	220
Greece	18	3	12	18	3	12	-	-	-
Croatia	8	3	4	8	3	4	-	-	-
Hungary	34	2	28	33	2	27	23	1	20
Italy	387	118	241	376	118	234	361	116	223
Japan	418	180	225	418	180	225	208	137	65
Korea	32	13	18	29	12	17	23	9	14
Lithuania	18	1	15	18	1	15	-	-	-
Latvia	10	2	5	10	2	5	2	-	-
Mexico	8	5	1	6	4	1	-	-	-
Netherlands	109	10	87	92	9	76	-	-	-
Poland	40	7	29	30	6	20	21	1	17
Portugal	36	7	20	36	7	20	35	7	19
Romania	2	-	2	2	-	2	2	-	2
Sweden	365	99	237	348	95	232	188	39	138
Slovenia	13	-	11	13	-	11	10	-	8
Slovakia	10	2	7	9	2	6	8	2	5

Notes: A parent is defined as a corporate group-country-sector triplet located in the source country of the MNE.

Table B.4: Countries with less than 3 affiliates, by NAICS2.

Sector	Country
Other goods	
Agriculture and Mining	KR, MX
Construction	JP
Electricity	KR, MX
Manufacturing	
Food and Beverages	JP, MX
Textiles, Apparel and Wood	JP
Transport Equipment and Other Manufacturing	GR
Services	
Information	MX
Others	
Real Estate	JP
Health	DK, EE, GR, JP, LV, SI
Education	AT, CZ, DK, HU, KR, NL, PT, RO, SI, SK

Notes: A foreign affiliate is a majority-owned firm by a company with operations in multiple countries within a given sector. Sectors roughly correspond to the 2-digit NAICS classification.

baseline regression.

Aggregate data: In addition to the ORBIS data, to construct sales, employment, and value-added shares, we use information from KLEMS and OECD on gross output, gross value-added, and the number of employees at the country-sector level, in million of current dollars and thousands of employees, respectively. The KLEMS dataset corresponds to the statistical national accounts from their latest release in 2019. The OECD statistics come from the Dataset for Structural Analysis (STAN) and we convert the sectoral ISIC revision 4 to the sectoral classification used in KLEMS. To maximize the number of country-sector pairs in our sample, we combine some ISIC sectors into the following categories: Agriculture and Mining; Textiles, Apparel and Woods; Chemicals, Petroleum and Plastic; Electrical Equipment and Machinery; Transport Equipment and Other Manufacturing; and Accommodation and Recreation.

We use the real GDP at chained PPPs in 2016 US dollars over total employment to measure output per-worker in each country from Penn World Tables (PWT, 9.1). To construct measures of output per-worker at the sectoral level we use gross value added per-worker from the KLEMS-OECD dataset that we convert to international dollars using the PPP conversion factor for GDP, measured in units of local currency per international dollars. We obtain the GDP PPP conversion factor and the share of employees compensation in value added from PWT (9.1).

Finally, we obtain aggregate information for the activity of foreign affiliates for each country-sector pair in our sample from the OECD Activity of Multinational Enterprises (AMNE) dataset and the Eurostat Foreign Affiliates Statistics (FATS), for which we harmonize the sectoral classification into the 18 sectors used in our dataset.

Bilateral MNE-specific taxes: Domestic firms and foreign affiliates are often subject to different tax rates. In addition to the corporate tax rate paid in the destination country, foreign affiliates are also subject to withholding taxes, the magnitude of which depends on whether the source and destination countries have signed a bilateral tax-treaty (BTT).[1] In the robustness exercises in Section 5.6 we control for tax differentials between foreign and domestic firms in two alternative ways: (1) by including a BTT dummy, and (2) by including for the ratio of tax rates paid by foreign MNEs to tax rates paid by domestic firms. To compute tax rates paid by foreign MNEs we assume their income subject both to the corporate tax rate and to the withholding tax rate that corresponds to the BTT agreement in place.[2] Data on BTTs comes from UNCTAD International Investment Agreements dataset; corporate tax rates are from the OECD Effective Tax Rates Statistics; and withholding taxes by BTT status are from Deloitte's Withholding Tax Rates dataset.

C Additional statistics: two-way fixed-effect estimation

Connectivity: To identify the country-sector fixed effects in Equation (19), we should perform our estimation on the largest connected set (LCS), which corresponds to the largest sample where destination countries are connected by the MNE foreign affiliates. In our case, the LCS is comprised of all 27 countries in our sample, whether using sales or employment, NAICS2 or NAICS4 sector classification.[3] Nonetheless, it is still possible that countries are poorly connected, even within the LCS, if only few MNEs link them together. When only a handful of MNEs connect countries in the sample, the variance of the fixed effects will be over-estimated and spurious negative correlations can appear between country and MNE fixed effects (Andrews et al. 2008). The literature has proposed three ways in which connectivity can be improved. The first method consists in performing the estimation on the "leave-one-out" set, which is defined as the set of countries that remain connected even after any individual MNE is removed from the sample (Kline et al. 2020). We note that all countries in our sample stay connected regardless of which MNE is dropped from the set. The second method (Andrews et al., 2008) consists of restricting the sample to countries hosting MNEs that also operate elsewhere. Since we only work with MNEs, this restriction is always satisfied in our sample. The third method (Bonhomme et al., 2019) groups destination countries using k-mean clustering based on the distribution of affiliates' market shares. This method enhances connectivity by reducing the number

[1]The withholding tax operates as a retention tax. It is an income tax to be paid to the government by the payer of the income rather than by the recipient of the income. Withholding taxes act as proxy for the income taxes shareholders would pay if they were residents of the destination country.

[2]This calculation assumes that the income earned by majority-owned affiliates is classified as "active,"and therefore the dividends repatriated to the source country are tax exempt.

[3]By definition, all MNEs contribute to connecting the countries where they keep operations, overcoming the usual problem of "limited mobility bias" that plagues most two-way fixed effect exercises in the labor literature. In that literature, identification is achieved by workers who switch employers over their careers (Abowd et al., 1999).

Table C.1: Contribution to $Var\left[s^j_{in}(\omega)\right]$.

Variance Decomp.	Baseline	k-means (linear)	Interaction
	(1)	(2)	(3)
$\Delta\mathbb{A}^j_k$	0.27	0.26	
$\delta^j(\omega)$	0.45	0.45	
R^2	0.72	0.70	0.76

Notes: Column 1 corresponds to the additive model using individual country-sector fixed effects (baseline). Columns 2 and 3 use country-sector-group fixed effect, with k=5. The MNE-sector and the country-sector-group enter additively in the second column, and multiplicatively in the third column.

of country fixed effect that must be estimated. Unfortunately, its application would defeat our purpose of estimating firm-embedded productivity for each country-sector pair.

Log-linearity assumption: In Section 5.3, we show that the standardized residuals are mostly flat across the MNE-sector fixed effects and country-embedded factors decile-bins. A different approach to assess the additive separability assumption comes from Bonhomme et al. (2019), where each pairing of firm and country-sector is allowed to have a differential effect. This new specification replaces the additive country and MNE-sector fixed effects with an interaction between country-group and MNE-sector fixed effect. If country-MNE "match effects" are relevant in determining the assignment of MNEs to countries, then there is a potential for bias since the error term could be correlated with the country fixed effects. Table C.1 shows the share of the variance explained by the country-sector fixed effects. Our results indicate that an additive model provides a very good approximation to our data: allowing interactions between MNE and country-group yields a small increase in the R-squared (Column 3) compared to an additive model that uses individual countries (Column 1) or country groups (Column 2). Also notice that the individual contributions of MNE and country effects to the variance of MNEs market shares remain almost unchanged in the additive model that uses k-country groups relative to the additive model that uses individual countries.

D General equilibrium model: derivations

This section derives all the equations in Section 6 and provides additional details for the model. The productivity cutoff for participating in market n satisfies:

$$\Pi^j\left(\bar{A}^j_{in}\right) = \frac{1}{\rho}R^j_{in}\left(\bar{A}^j_{in}\right) = W_n\left[f^j\theta^j_n H_n + f^j_{in}\right],$$

where $\Pi\left(\bar{A}_{in}\right)$ and $R_{in}\left(\bar{A}_{in}\right)$ denote the revenues and profits of a firm from country i in country n that has productivity $\bar{A}^j_{in}$. Using Equation (7) and solving for $\bar{A}^j_{in}$ yields

Equation (32). Under Pareto, solving Φ_{in}^{j} yields

$$\Phi_{in}^{j} = \frac{\gamma}{\gamma-1}\left[B_i^j M_i^j / \tau_{in}^j\right]\left[\bar{A}_{in}^j\right]^{1-\gamma}. \tag{D.1}$$

Spending in fixed cost labor in country n is given by:

$$\begin{aligned}\sum_j \sum_i \left[1 - G\left(\bar{A}_{in}^j\right)\right] M_i W_n \left[f^j \theta_n^j H_n + f_{in}^j\right] &= \sum_j \sum_i B_i^j / \bar{A}_{in}^{\gamma} M_i \frac{\bar{A}_{in}^j}{\rho \Phi_n^j} \frac{R_n^j}{\tau_{in}^j} \\ &= \frac{\gamma - 1}{\rho\gamma} R_n,\end{aligned}$$

and is proportional to revenues. Here, the first equality follows from the Pareto assumption and Equation (32), and the second equality uses Equation (D.1) and $\Phi_n^j \equiv \sum \Phi_{in}^j$. Total spending in variable labor is also proportional to revenues and given by $\frac{\rho-1}{\rho[1-\alpha]} R_n$. This implies that the ratio of production to fixed labor is constant. It also implies that payments to labor are then proportional to revenues:

$$W_n H_n = c R_n,$$

with $c \equiv \frac{\rho-1}{\rho[1-\alpha]} + \frac{\gamma-1}{\rho\gamma}$. Plugging Equation (32) into (D.1) and noting that $R_n^j = \theta_n R_n$ yields Equation (33), with $T_i^j = \frac{\gamma[\rho c]^{1-\gamma}}{\gamma-1} B_i^j \times M_i^j$. Equation (34) follows directly from Equation (33). Finally, noting from Equation (7) that $S_{nn}^j = \Phi_{nn}^j / \Phi_n^j$ and using $\beta \equiv [[\rho-1][1-\alpha]]^{-1}$, we obtain Equation (35).

D.1 Selection on firm characteristics and estimation with aggregate data

This section discusses the importance of the firm-level data for measuring aggregate firm-embedded productivity using our framework. Let $S_{in}^j \equiv \int_{\omega \in \Omega_{in}} S_{in}^j(\omega)\, d\omega$ denote the combined revenue share of all the MNEs from country i that operate in country n sector j. We can express this revenue share in logs as:

$$s_{in}^j = \phi_{in}^j - \phi_n^j. \tag{D.2}$$

Equation (D.2) differs from Equation (8) because it refers to aggregate rather than firm-level revenue shares. Lacking firm level data, one may be tempted to use Equation (D.2) and implement an aggregate-level analog to our procedure by regressing aggregate market shares on source and destination-dummy variables. Note, however, that even after controlling for the technology transfer cost, ϕ_{in}^j varies across n's if not all firms from country i enter the same destination markets (i.e. if the set $\omega \in \Omega_{in}$ differs across $n's$). For example, in the context of our general equilibrium model where selection is based on firm productivity or on destination-market characteristics (so that only the most productive MNEs enter the least accessible markets), we have that Φ_{in}^{j} is given by Equation (33). Thus, the destination fixed effects from that regression would provide biased estimates of ϕ_{n}^{j}, as they would also capture the destination-specific terms in Φ_{in}^{j}. Intuitively, aggregate market shares of firms from country i in country n can be relatively large if firm-embedded productivity is low in country n (low ϕ_{n}^{j} relative to $\phi_{n'}^{j}$), or if there are many firms from country i that choose to enter market n (ϕ_{in}^{j} high relative to $\phi_{in'}^{j}$). In that case, backing up Φ_{n}^{j} would require assumptions on the general equilibrium structure of the model.

With firm-level data, this challenge can be circumvented by including firm-level fixed effects in Equation (8). In that case, the destination fixed effects do not depend on the productivity of the set of firms that choose to enter the destination, even if selection is based on firm productivity. By including firm-level fixed effects, the destination fixed effects in Equation (8) are identified from within MNE differences in market shares across destinations.

D.2 Selection on firm-destination characteristics

This section discusses how the selection concerns in Section 3.2 affect our estimates in the context of the general equilibrium model of MNE location decisions. To that end, we allow for firm-destination-specific technology transfer cost, $\kappa_{in}^{j}(\omega) = \kappa_{in}^{j} + \varepsilon_{in}^{j}(\omega)$, as in Equation (18). How firms select into destination markets depend on when the firm-specific component $\varepsilon_{in}^{j}(\omega)$ is observed.

Case 1: $\varepsilon_{in}^{j}(\omega)$ is observed after location decisions are made. In this case, the productivity cutoff for entering destination n from market i is (in logs):

$$\bar{a}_{in}^{j} = \log \frac{\rho W_n}{R_n^j} + \log \left[f^j \theta_n^j H_n + f_{in}^j \right] + \phi_n^j + \kappa_{in}^j + \mathbb{E}\left[\varepsilon_{in}^j(\omega) \right], \tag{D.3}$$

where $\mathbb{E}\left[\varepsilon_{in}^{j}(\omega)\right]$ is the unconditional mean across $\omega's$. Equation (D.3) is the analog of Equation (32) in Section 6. It states that firm ω enters market n sector j when $a(\omega) \geq \bar{a_{in}}^{j}$—and hence we observe positive revenues for that firm in the location. In this case, there is no selection based on firm-destination specific characteristics, and the exclusion restriction needed for estimating of Equation (19) is satisfied.

To build intuition for this result, note that, under our assumptions on transfer costs in Section 3.2, the mean difference in market shares of the same MNE in two different destinations is:

$$\mathbb{E}\left[s_{in}^j(\omega) - s_{in'}^j(\omega) \right] = \left[\phi_{n'}^j - \phi_n^j \right] + \left[B_{in}^j - B_{in'}^j \right] + \mathbb{E}\left[\varepsilon_{in}^j(\omega) - \varepsilon_{in'}^j(\omega) \right]. \tag{D.4}$$

After controlling for country-pair characteristics, $\left[B^j_{in} - B^j_{in'}\right]$, this difference equals $\left[\phi^j_{n'} - \phi^j_n\right]$ if $\mathbb{E}\left[\varepsilon^j_{in}(\omega)\right]$ does not vary across destinations (i.e. no selection on firm-destination characteristics), which is the assumption made in Section 3.2 and is satisfied in this case.

Case 2: $\varepsilon^j_{in}(\omega)$ is observed before location decisions are made. In this case, firm ω from country i enters destination n sector j iff (in logs):

$$\varepsilon^j_{in}(\omega) \leq \log \frac{R^j_n}{W_n \rho} - \log\left[f^j \theta^j_n H_n + f^j_{in}\right] + a(\omega) - \kappa^j_{in} - \phi^j_n. \tag{D.5}$$

Equation (D.5) indicates that selection is based on firm-destination specific characteristics: firms with low A may enter market n because their ε is low. In turn, markets with high entry cost, high competition, and small size, may host firms with low ε. Clearly, this type of selection violates the exogeneity conditions imposed in our estimating equation, creating a positive correlation between the error term and each of the regressors. In this case, our specification would underestimate market shares for low-productivity MNEs in unattractive markets, as these would be associated with high ε's. Equation (D.5) indicates that this bias would be less severe for highly productive firms or in highly attractive markets. This observation motivates the robustness exercises in Section 5.2.

E Variable markups and other output distortions

This section discusses how to interpret our results when there is systematic variation in markups and other output distortions across firms. We consider an extension of the model in Section 2.3 that features the same production functions, but where firm prices are given by

$$P^j_{in}(\omega) = \frac{\mu^j_{in}(\omega)\, C^j_n}{Z^j_n X^j_{in}(\omega)}. \tag{E.1}$$

Here, C^j_n denotes the cost of the input bundle in sector j and country n, and $\mu^j_{in}(\omega)$ is a firm-specific exogenous markup or another output distortion that increases the marginal products of capital and labor by the same proportion.[4] Note that while this formulation allows for factors to be misallocated across producers, it assumes that the composition of the input bundle is undistorted.

Let $\mathcal{M}^j_n \equiv \frac{P^j_n Y^j_n}{W_n H^j_n + R_n K^j_n} = \sum_i \int_{\omega \in \Omega_{in}} \mu^j_{in}(\omega) \frac{H^j_{in}(\omega)}{H^j_n} d\omega$ denote the employment (or cost) weighted average markup (or distortion) in country n and sector j. Following Edmond et

[4] An example would be a firm-specific revenue tax that makes firms' profits equal to $\Pi^j_{in}(\omega) = \left[P^j_{in}(\omega) / \mu^j_{in}(\omega) - C^j_{in}(\omega)\right] Y^j_{in}(\omega)$.

al. (2018) and Burstein et al. (2020), the average markup can be written as

$$\mathcal{M}_n^j = \frac{\sum_i \int_{\omega \in \Omega_{in}} \mu_{in}^j (\omega)^{1-\rho^j} A_{in}^j (\omega)}{\sum_i \int_{\omega \in \Omega_{in}} \mu_{in}^j (\omega)^{-\rho^j} A_{in}^j (\omega) \, d\omega} d\omega.$$

Equation (E.1) and the demand function associated with Equation (10) imply that total output in sector j can be written as

$$Y_n^j = Z_n^j \left[\Phi_n^{m,j}\right]^{\frac{1}{\rho^j - 1}} H_n^{j\,1-\alpha^j} K_n^{j\,\alpha^j},$$

where

$$\Phi_n^{m,j} = \left[\sum_i \int_{\omega \in \Omega_{in}} \mu_{in}^j (\omega)^{1-\rho^j} A_{in}^j (\omega) \, d\omega\right] \left[\mathcal{M}_n^j\right]^{\rho^j - 1} \tag{E.2}$$

is the aggregate firm-embedded productivity in sector j. Equation (E.2) boils down to Equation (9) when μ_{in}^j is constant across firms, and corresponds to the well-known formula for TFP in Hsieh and Klenow (2009) when there are only output distortions and to the formula in Edmond et al. (2018).

Finally, the market share of an affiliate ω is given by

$$S_{in}^j (\omega) = \frac{\mu_{in}^j (\omega)^{1-\rho} A_{in}^j (\omega)}{\sum_i \int_{\omega \in \Omega_{in}} \mu_{in}^j (\omega)^{1-\rho^j} A_{in}^j (\omega) \, d\omega} = \left[\frac{\mu_{in}^j (\omega)}{\mathcal{M}_n^j}\right]^{1-\rho^j} \frac{A_{in}^j (\omega)}{\Phi_n^{m,j}},$$

which can be written in logs as

$$s_{in}^j (\omega) = \left[1 - \rho^j\right] \left[ln \left(\mu_{in}^j (\omega) / \mathcal{M}_n^j\right)\right] + a (\omega) + \kappa_{in} (\omega) - \phi_n^{m,j}. \tag{E.3}$$

Equation (E.3) states that the firm's market shares will be relatively low if either the affiliate's productivity is low relative to the total firm embedded productivity in the country (low $A_{in}^j (\omega) / \Phi_n^{m,j}$), or if the affiliate's markup is high relatively to the average markup in country n (high $\mu_{in}^j (\omega) / \mathcal{M}_n^j$). In this version of the model, the destination-specific fixed effects estimated from Equation (19) should be interpreted as

$$\mathbb{A}_n^j = \left[1 - \rho^j\right] \overline{\Delta ln \left(\mu_n^j / \mathcal{M}_n^j\right)} - \Delta \phi_n^{m,j},$$

where $\overline{\Delta ln \left(\mu_n^j / \mathcal{M}_n^j\right)}$ denotes the average of the log markup of MNE affiliates in country n sector j, relative to the economy-wide average markup in country n sector j. Our baseline measure for firm-embedded productivity differences would be equal to

$$-\beta^j \mathbb{A}_n^j = \frac{1}{1-\alpha_j} \Delta \overline{ln\left(\mu_n^j / \mathcal{M}_n^j\right)} + \beta^j \Delta \phi_n^{m,j}, \tag{E.4}$$

which in addition to the differences in firm-embedded productivity, captures differences in the relative markups/distortions $\Delta \overline{ln\left(\mu_n^j / \mathcal{M}_n^j\right)}$.

Bento and Restuccia (2017) and Fattal Jaef (Forthcoming) document that firm-level distortions are size-dependent and more prevalent in less developed countries (e.g. larger firms are taxed more in developing countries), while Autor et al. (2020) document that large firms set higher markups –a correlation implied by models of variable markups (e.g. Bernard et al., 2003). It is also well documented that MNEs and their affiliates are relatively large firms (e.g. Antras and Yeaple, 2014).

According to Equation (E.4), if MNE affiliates set higher markups/face larger distortions in developing countries, this would *push up* $-\beta^j \mathbb{A}_n^j$, making our estimates less negative in developing countries. Intuitively, our procedure interprets the observed large market shares of MNEs in less developing countries as evidence that these firms face less competition (firm-embedded productivity is relatively scarce) in those countries. According to Equation (E.3), under the assumptions above, firm-specific distortions and markups would make the market shares of MNEs artificially small in developing countries. In this case, our procedure would provide a lower bound for the contribution of firm-embedded productivity to cross-country income differences.

F Trade in intermediate goods and export-platforms

This section extends the model in Section 2 to allow for trade in intermediate goods and export platforms. We focus on the one sector version of the model to facilitate the exposition, though our results can be easily generalized to incorporate multiple sectors.

Preliminaries and technologies: We assume that firms from country i can sell in country n either by exporting from country i, by setting up an affiliate in country n, or by exporting from an affiliate in a different country $l \neq n$ (export-platform). In contrast, we assume that the final good Y_n is non tradeable, and is produced by aggregating intermediate goods from multiple countries,

$$Y_n = \left[\sum_l \sum_i \int_{\omega \in \Omega_{iln}} \left[Q_{il}(\omega) Y_{iln}(\omega)\right]^{\frac{\rho-1}{\rho}} d\omega\right]^{\frac{\rho}{\rho-1}}. \tag{F.1}$$

Here, $Y_{iln}(\omega)$ denotes the output of a firm ω from source country i, located in country l, selling into country n, and Ω_{iln} is the set of firms from country i serving country n from location l.

Trade in intermediate goods is subject to an iceberg-type trade cost $d_{ln} \geq 1$, with $d^j_{nn} = 1$. Under these assumptions and the production function in Equation (11), we can write revenues for a firm from country i serving country n from location l as

$$R_{iln}(\omega) = \left[\frac{\rho}{\rho-1}\right]^{1-\rho} A_{il}(\omega) \left[\frac{d_{ln}C_l}{Z_l}\right]^{1-\rho} P_n^{\rho} Y_n, \tag{F.2}$$

where C_l denotes the cost of the input bundle in country l. The ratio of firm ω's domestic revenues to total domestic revenues is

$$S_{inn}(\omega) \equiv \frac{R_{inn}(\omega)}{\sum_i \int_{\omega\in\Omega_{inn}} R_{inn}(\omega)\, d\omega} = \frac{A_{in}(\omega)}{\Phi_n^x}, \tag{F.3}$$

where $\Phi_n^x \equiv \sum_i \int_{\omega\in\Omega_{inn}} A_{in}(\omega)\, d\omega$.

Aggregate output and TFP: GDP from the expenditure side is the sum of absorption and net exports: $GDP_n \equiv P_n Y_n + \sum_{l\neq n}\sum_i \int_{\omega\in\Omega_{inl}} R_{inl}(\omega)\, d\omega - \sum_{l\neq n}\sum_i \int_{\omega\in\Omega_{iln}} R_{iln}(\omega)\, d\omega$. GDP in units of country n's consumption good (i.e. GDP at PPP prices) can be expressed as

$$GDP_n^{ppp} \equiv \frac{GDP_n}{P_n} = Y_n \left[\frac{1-\lambda_n^m}{1-\lambda_n^x}\right], \tag{F.4}$$

where $\lambda_n^x \equiv \sum_{l\neq n}\sum_i \int_{\omega\in\Omega_{inl}} \frac{R_{inl}(\omega)}{GDP_n} d\omega$ and $\lambda_n^m \equiv \sum_{l\neq n}\sum_i \int_{\omega\in\Omega_{iln}} \frac{R_{iln}(\omega)}{P_n Y_n} d\omega$ denote, respectively, the share of exports in GDP and the share of imports in absorption. Note that we can express Equation (F.1) as

$$Y_n = Y_{nn}\left[1-\lambda_n^m\right]^{\frac{\rho}{1-\rho}}, \tag{F.5}$$

where

$$Y_{nn} \equiv \left[\sum_i \int_{\omega\in\Omega_{inn}} \left[Q_{in}(\omega)\, Y_{inn}(\omega)\right]^{\frac{\rho-1}{\rho}} d\omega\right]^{\frac{\rho}{\rho-1}} \tag{F.6}$$

is an aggregate of intermediate goods produced and sold domestically. Using Equations (11), (F.3), and that the share of factors used for exports coincides with the share of exports in GDP ($\frac{H_{nn}}{H_n} = \frac{K_{nn}}{K_n} = 1-\lambda_n^x$), we obtain:

$$Y_{inn}(\omega) = Z_n X_{in}(\omega) \frac{A_{in}(\omega)}{\Phi_n^x}\left[1-\lambda_n^x\right] H_n^{1-\alpha} K_n^{\alpha}.$$

Substituting in Equations (F.5), (F.6), and (F.4) yields

$$\frac{GDP_n^{ppp}}{L_n} = \tilde{Z}_n \tilde{\Phi}_n^x \left[1 - \lambda_n^m\right]^{-\beta}, \tag{F.7}$$

with $\tilde{Z}_n \equiv [Z_n]^{\frac{1}{1-\alpha}} \bar{H}_n \left[\frac{K_n}{GDP_n^{ppp}}\right]^{\frac{\alpha}{1-\alpha}}$ and $\tilde{\Phi}_n^x = \left[\sum_i \int_{\omega \in \Omega_{inn}} A_{in}(\omega)\, d\omega\right]^{\beta}$.

Equation (F.7) states that differences in GDP per-capita can be decomposed into three terms: $\tilde{Z}_n$, capturing differences in country embedded productivities and factors of production; $\tilde{\Phi}_n^x$ capturing differences in the productivities embedded in the country's firms; and a new term capturing the gains from trade, $[1 - \lambda_n^m]^{-\beta}$, which is a common term in the class of trade models analyzed by Arkolakis et al. (2012). Clearly, the import share λ_n^m is an endogenous object, which depends on firm-level productivities, country-embedded factors, and the trade balance of the country, among other things. Rather than decomposing λ_n^m into exogenous objects, we consider it as an additional term in Equation (F.7), and refer to $\tilde{\Phi}_n^x$ and $\tilde{Z}_n$ as the aggregate firm-embedded productivity and country-embedded factors in n.[5]

Decomposing cross-country differences in output per-worker: We now show how cross-country differences in ϕ_n^x can be computed using firm-level data on market shares in the model with trade and export platforms. Equation (F.3) in logs implies that

$$s_{inn}(\omega) = a_i(\omega) - \kappa_{in}(\omega) - \phi_n^x. \tag{F.8}$$

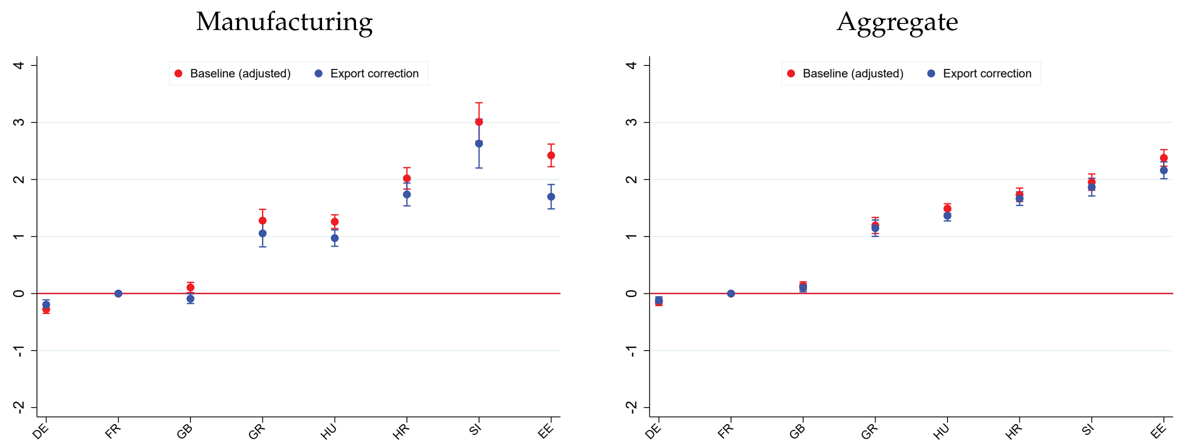
Thus, if one could observe $s_{inn}(\omega)$ in the data, ϕ_n^x could be estimated following the same procedure used in Section (3.2). Note that computing $s_{inn}(\omega)$ requires breaking down MNE revenues into local and export sales. This break-down is only available in ORBIS for a very limited number of firms and countries in the manufacturing sector. Unfortunately, there is almost no data on exports for service-sector firms in ORBIS. For the countries where these data are available, we reestimate differences in firm-embedded productivity using Equation (F.8).

Figure F.1 compares the destination dummies obtained from estimating Equation (19) with the ones from Equation (F.8).[6] The left panel shows that the estimated destination-country dummies for the Manufacturing sectors are similar, although they are slightly smaller using Equation (F.8). The right panel of the figure computes the dummies for the

[5] In practice, the current consensus in the quantitative trade literature is that the gains from trade are small relative to cross-country income differences (see e.g. Costinot and Rodríguez-Clare 2014).

[6] That is, we follow the exact same two-way fixed-effect procedure as in Section 3, with shares calculated at the sectoral level and aggregated using observed sectoral shares θ_n^j. For the countries shown in the figure and for the Manufacturing sector, we restrict the sample to MNE affiliates with data on exports. For the remaining countries –for which we do not have any export data-, we use the same sample of firms as in our baseline, and assume that the ratio of exports to revenues is the same for all firms in a country, which implies that $s_{inn}(\omega) = s_{in}(\omega)$. These countries are included in the estimation to obtain more precise estimates of the country dummies.

Figure F.1: Firm-embedded productivity and export corrections.



Notes: Blue dots are OLS estimates of $\Delta\mathbb{A}_n$ from Equation (F.8) as described in Footnote 6. Red dots are OLS estimates of $\Delta\mathbb{A}_n$ from Equation (19) using the same sample of firms. Bars reflect 95-percent confidence intervals, clustered at the country level.

aggregate economy under the assumption that there is trade in manufacturing, but no trade in service sectors (i.e. $s_{inn}(\omega) = s_{in}(\omega)$ in those sectors). Perhaps unsurprisingly, as Services account for the bulk of the economy, the results line up with our baseline estimation. This result suggests that the bias from ignoring trade is relatively small.

To better understand why correcting for trade barely affects the results, note that, with trade, the share of firm ω in aggregate revenues is given by

$$S_{in}(\omega) \equiv \frac{\sum_l R_{inl}(\omega)}{\sum_l \sum_i \int_{\omega\in\Omega_{inl}} R_{inl}(\omega)\, d\omega} = \frac{A_{in}(\omega)}{\Phi_n} \frac{1-\lambda_n^x}{1-\lambda_{in}^x(\omega)}, \tag{F.9}$$

where $\lambda_{in}^x(\omega) \equiv 1 - \frac{R_{inn}(\omega)}{\sum_l R_{inl}(\omega)}$ is the share of exports in total revenues for firm ω in country n. Taking logs, we obtain:

$$s_{in}(\omega) = a_i(\omega) - \kappa_{in}(\omega) - \phi_n^x + ln\left[\frac{1-\lambda_n^x}{1-\lambda_{in}^x(\omega)}\right]. \tag{F.10}$$

Equation (F.10) states that, in the model with trade in intermediate goods, the share of a MNE in a country's revenues depends not only on the productivity of the firm vs. the productivity of the other firms in the country, $a_{in}(\omega)$ vs. ϕ_n^x, but also on how much the MNE exports relative to the aggregate export share in the country, $\frac{1-\lambda_{in}^x(\omega)}{1-\lambda_n^x}$. Intuitively, a firm's share in revenues will be larger if it exports relatively more than the economy as a whole (large $\frac{1-\lambda_n^x}{1-\lambda_{in}^x(\omega)}$). Thus, our baseline estimates of ϕ_n^x based on data on the shares $s_{in}(\omega)$ will be biased if the export share of foreign MNE affiliates are systematically different from the aggregate export shares, and if these differences vary across destinations.

Table F.1: Share of domestic sales in total revenues: foreign MNE affiliates vs. all firms.

	Manufacturing			Services		
	(1) All	(2) Foreign MNEs	(1)/(2)	(3) All	(4) Foreign MNEs	(3)/(4)
Estonia	0.24	0.19	1.31	0.77	0.60	1.29
Sweden	0.45	0.34	1.31	0.79	0.73	1.09
Italy	0.59	0.51	1.16	0.94	0.90	1.04
Spain	0.62	0.52	1.18	0.90	0.63	1.43
Japan	0.74	0.69	1.07	0.95	0.92	1.04
United States	0.83	0.86	0.97	0.94	0.85	1.11

Notes: The table reports the ratio of domestic sales to total sales for different groups of firms. 'All' refers to all firms, computed using data from OECD STAN dataset. 'Foreign MNEs' refers to sales by the affiliates of foreign MNEs, computed using data from OECD AMNE dataset. 'Manufacturing' and 'Services' refer to firms in the manufacturing and service sectors.

As mentioned above, data on $[1 - \lambda^x_{in}(\omega)]$ are hard to come by. However, the OECD (Activity of Multinational Enterprises AMNE database) reports aggregate data on domestic and export revenues by the affiliates of foreign MNEs. The data are only available for seven countries in our sample, as well as for the United States. We can use these data to get a sense of the magnitude of the ratio $\frac{1-\lambda^x_n}{1-\lambda^x_{in}(\omega)}$, which we report in Table F.1. The table reveals that, while the affiliates of foreign MNEs do get a larger share of their revenues from exports than other firms, these differences are not quantitatively important. For example, the ratio $\frac{1-\lambda^x_n}{1-\lambda^x_{in}(\omega)}$ is roughly 1.3 for Estonia, the most open country in our sample, and 1.16 for Italy. Equation (F.9) indicates that the fact that MNE affiliates export a large share of their output from Estonia makes the market share of MNE affiliates located in Estonia $1.12 \simeq 1.3/1.16$ larger than the market share of MNE affiliates located in Italy. In contrast, our baseline estimates indicate that MNE affiliates in Estonia have market shares that are roughly 13 times larger than the market shares of the same MNEs in Italy (Figure 1), which is two orders of magnitude larger than what can be accounted for by the differences in export shares.

G Intermediate inputs

This section shows how to extend our framework to allow for intermediate inputs in production. We again focus on the one-sector case to facilitate the exposition. We assume that the final good can be used as an input, and that the production function for intermediate goods is

$$Y_{in}(\omega) = Z_{in} X_{in}(\omega) \left[H_{in}(\omega)^{1-\alpha} K_{in}(\omega)^{\alpha} \right]^{\gamma} M_{in}(\omega)^{1-\gamma}.$$

Here, the parameter γ is the value-added share and $M_{in}(\omega)$ represents the intermediate inputs used by producer ω in country n. The aggregate production function is

$$\mathcal{Y}_n = \gamma^{\frac{1}{\gamma}} Z_n^{\frac{1}{\gamma}} \Phi_n^{\frac{1}{\gamma}\frac{1}{\rho-1}} \left[\bar{H}_n L_n \right]^{1-\alpha} \left[K_n \right]^{\alpha}.$$

We can write cross-country differences in the log of value added per-worker as

$$\Delta y_n = \frac{1}{\gamma} \Delta \tilde{z}_n + \frac{1}{\gamma} \Delta \tilde{\phi}_n. \tag{G.1}$$

We show next how to obtain the contribution of aggregate firm-embedded productivity to cross country differences in value added per-worker, $\frac{1}{\gamma}\Delta\tilde{\phi}_n$. Note that in this economy, the revenue, employment, and the value-added shares coincide and are given by Equation (16). We can thus use Equation (19) and the procedure described in Section 3.2 to estimate $\Delta\mathbb{A}_n$, which under our baseline assumption on technology transfer costs corresponds to $\Delta\mathbb{A}_n = -\Delta\phi_n$.

The last step is to reestimate $\beta \equiv [1-\alpha][\rho-1]$ in a way that is consistent with Equation (G.1). With intermediate inputs, Equation (24) becomes

$$\Delta y_n = b_0 + \frac{b_1^{inp}}{\gamma} \Delta \mathbb{A}_n + b_2 C_n + u_n,$$

so that the coefficients in Table 1 should be interpreted as $b_1 = \frac{b_1^{inp}}{\gamma}$. The contribution of firm-embedded productivity to cross-country income differences is $\frac{1}{\gamma}\Delta\tilde{\phi}_n = \frac{b_1^{inp}}{\gamma}\Delta\mathbb{A}_n = b_1 \Delta\mathbb{A}_n$, which coincides with the estimate used in our baseline analysis.