Accounting for cross-country productivity differences: New evidence from multinational firms *

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Abstract

We use data on the cross-country operations of multinational enterprises and their foreign affiliates to separate the components of productivity that are internationally mobile from those that are immobile. We show that the productivity factors that are embedded in firms and can be transferred globally account for about 20 percent of the observed differences in TFP across European countries, thought its importance varies widely across countries. This indicates large potential gains form convergence in 'firm-embedded' productivity.

Keywords: growth accounting, TFP, multinational firms
JEL Codes: O4, O1, F41, F23, F62

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1 Introduction

Cross-country differences in income per capita can be partly attributed to differences in total factor productivity (TFP).[1] Identifying the factors behind these TFP differences is crucial for the development of policies that can foster growth in poor countries. In this paper, we shed light on this topic by distinguishing between those components of productivity that are internationally mobile (production knowledge, management know-how, intangible capital, etc) from those that are immobile (regulations, institutions, infrastructure, natural amenities, etc). We label these components of productivity 'firm-embedded' and 'country-embedded' respectively,[2] and develop and apply a framework for disentangling their respective contributions to cross-country income differences.

Our framework is based on detailed firm-level data on the operations of multinational enterprises and their cross-border affiliates. It relies on the notion that all firms producing in any particular country share the productivity embedded in that country. The relative size of each firm is thus determined by its firm-embedded productivity relative to the productivity embedded in the other firms producing in the country. Under the assumption that multinational firms can transfer their firm-embedded productivity across countries, the relative size of the same multinational firm in two countries can be used to back out the differences in total firm-embedded productivity between those countries.

To apply the framework described above we need to specify the extent to which multinational firms are able to transfer their firm-embedded productivity across countries. A large literature in international economics has documented substantial evidence on the importance of multinational production costs: multinational firms tend to be relatively larger in source countries than in host countries. Following this literature, we allow for imperfect technology transfers between a parent firm and its affiliates. We estimate the importance of the multinational production costs using our data under alternative procedures, and take them into account in our calculations.

Our data on multinational firms sales comes from ORBIS, a worldwide dataset maintained by Bureau van Disk. ORBIS documents detailed ownership information for a large set of firms operating in multiple countries. We focus on a set of European countries for which the coverage of the ORBIS dataset is particular good, and compute the 'firm-embedded' productivity of each of those countries relative to Germany.

We show that differences in firm-embedded productivity account for about 20 percent of the global differences in TFP. There is wide variation across countries, some oil-

[1] See Klenow and Rodriguez-Clare (1997) and the long literature that followed.

[2] These labels were first coined by Burstein and Monge-Naranjo (2009).

producing countries such as Norway have high country-embedded but relatively low firm embedded productivity. In contrast, in some developing countries such as Mexico or Portugal, differences in firm-embedded productivity account for about half of the TFP of these countries relative to Germany. This indicates large potential gains form convergence in 'firm-embedded' productivity.

Our paper is closely related to Burstein and Monge-Naranjo (2009), who separate country-embedded from firm-embedded productivity using aggregate data on FDI stocks in a setting where firm-embedded productivity is a rival factor. Their framework is based on the Lucas 'span of control' model and assumes that each firm or manager must choose one country in which to produce. Under those assumptions, firm embedded productivity can be recovered from aggregate data using a non-arbitrage condition that equates after-tax managerial profits across countries. In contrast, our approach builds on the modern literature that treats firm-embedded productivity as a non-rival factor and studies multinationals enterprises that simultaneously manage affiliates in multiple countries. We exploit this feature to estimate firm-embedded productivity using firm level data on multinational firms sales across multiple countries. In that sense, our approach is similar to that in Hendricks and Schoellman (2018), who use wage data for US immigrants before and after migration to separate human capital from country embedded factor affecting wages.

Our paper is also related to the large literature studying technology transfers through multinationals firms.[3] Bilir and Morales (2016) and Cravino and Levchenko (2017) use parent-affiliate matched data to estimate how productivity and shocks are transmitted across parties of a multinational firm. In contrast, our focus is on splitting differences in aggregate firm-embedded vs. country embedded productivity across countries. The parent-affiliate matched data is what allows us to distinguish between these two components.

Finally, our paper is also related to the international trade literature that estimates country-level productivity shifters using gravity models (see Eaton and Kortum (2002), Waugh (2010), Ramondo and Rodríguez-Clare (2013), Arkolakis et al. (2018) and the long literature that followed). We show that in a context with heterogeneous firms and fixed costs, matched-firm level data is needed to separate cross-country differences in firm-embedded productivity from selection.

The rest of the paper is organized as follows. Section 2 develops our framework

[3] A non-exhaustive list of theoretical contributions includes McGrattan and Prescott (2009); Keller and Yeaple (2013) and Ramondo and Rodríguez-Clare (2013). Javorcik (2004); Guadalupe et al. (2012); Fons-Rosen et al. (2013); and Alviarez (2018) among many others have studied this question empirically.

for disentangling 'firm-embedded' from 'country-embedded' productivity. Section 3 describes our data and quantitative results. Section 4 relates our results to the trade and MP literature that estimates country-level productivity shifters using gravity models, and Section 5 concludes.

2 Accounting framework

This section provides a framework for disentangling 'firm-embedded' from 'country-embedded' productivity.

2.1 Environment

Preliminaries 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 potentially owned by firms from different source countries. The output of the intermediate producers cannot be traded internationally. In each country, intermediates are aggregated into a final good by competitive final goods producers. We assume that the final good is homogeneous across countries and can be freely traded. The final good is the numeraire of the world economy and its price is set to one.

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

$$Y_n = A_n \left[\sum_i \int \left[a_{in}(\varphi) Y_{in}(\varphi) \right]^{\frac{\rho-1}{\rho}} d\varphi \right]^{\frac{\rho}{\rho-1}}, \tag{1}$$

where $Y_{in}(\varphi)$ is the output of intermediate producer φ from source country i that operates in country n, and $a_{in}(\varphi)$ is a demand shifter for producer φ from country i operating in country n. A_n is a country-level shifter that determines the productivity of the producer of final goods in country n. The demand for the output of firm φ is given by

$$Y_{in}(\varphi) = a_{in}(\varphi)^{\rho-1} \left[\frac{P_{in}(\varphi)}{P_n} \right]^{-\rho} Y_n, \tag{2}$$

where $P_{in}(\varphi)$ is the price set by producer φ, and $P_n = 1$ is the price of the final good.

Each intermediate producer operates a Cobb-Douglas technology that uses labor and capital in the destination country as the only factors in production. In particular, the output of producer φ in country n is given by

$$Y_{in}(\varphi) = Z_n z_{in}(\varphi) L_{in}(\varphi)^{1-\alpha_n} K_{in}(\varphi)^{\alpha_n}, \tag{3}$$

where $L_{in}(\varphi)$ and $K_{in}(\varphi)$ denote employment and the capital stock of firm φ in country n. The productivity of the firm depends on a country specific component, Z_n, and an idiosyncratic component, $z_{in}(\varphi)$. The profit maximizing price for firm φ satisfies:

$$P_{in}(\varphi) = \frac{\rho}{\rho-1} \frac{C_n}{Z_n z_{in}(\varphi)}, \tag{4}$$

where C_n is the cost of the input bundle in country n.

Allocations and income per capita Combining equations (2), (3) and (4) we can write the share of revenues, employment and of the capital stock in firm φ as:

$$\frac{r_{in}(\varphi)}{R_n} = \frac{L_{in}(\varphi)}{L_n} = \frac{K_{in}(\varphi)}{K_n} = \left[\frac{\varphi_{in}}{\Phi_n}\right]^{\rho-1}. \tag{5}$$

Here $\varphi_{in} \equiv a_{in}(\varphi) z_{in}(\varphi)$ denotes the 'efficiency' of firm φ from country i in country n, $r_{in}(\varphi) = P_{in}(\varphi) Q_{in}(\varphi)$ are firm's revenues, $R_n = \sum_i \int r_{in}(\varphi) dG_n(\varphi)$, $L_n = \sum_i \int L_{in}(\varphi) dG_n(\varphi)$, $K_n = \sum_i \int K_{in}(\varphi) dG_n(\varphi)$ are aggregate revenues, employment, and the capital stock, and $G_n(\varphi)$ is the distribution of firms in country n. We refer to $\Phi_n \equiv \left[\sum_i \int \varphi^{\rho-1} dG_n(\varphi)\right]^{\frac{1}{\rho-1}}$ as the total firm-embedded productivity in country i.

Substituting equations (3) and (5) into equation (1) we obtain the aggregate production function

$$Y_n = B_n \Phi_n L_n^{1-\alpha} K_n^{\alpha} \tag{6}$$

where $B_n \equiv A_n Z_n$. In this economy TFP is given by, $\frac{Y_n}{L_n^{1-\alpha_n} K_n^{\alpha_n}} = B_n \Phi_n$. We can write the log difference in tfp across two countries as:

$$tfp_n - tfp_{n'} = [b_n - b_{n'}] + [\phi_n - \phi_{n'}], \tag{7}$$

where $tfp_n \equiv logTFP_n$, $b_n \equiv logB_n$, and $\phi_n \equiv log\Phi_n$. TFP differences across countries are driven by differences in country-embedded productivity, b_n, and in firm-embedded productivity, ϕ_n.

We are also interested in the contribution of each of these two terms to differences in income per capita. Note that aggregate the production function in 6 can be written in per capita terms as:

$$\frac{Y_n}{L_n} = [B_n \Phi_n]^{\frac{1}{1-\alpha}} \left[\frac{K_n}{Y_n}\right]^{\frac{\alpha}{1-\alpha}},$$

letting $y_n \equiv ln\left[\frac{Y_n}{L_n}\right]$ denote the log of income per capita, we can write cross-country difference in income per capita as:

$$y_n - y_{n'} = \left[\tilde{b}_n - \tilde{b}_{n'}\right] + \frac{1}{1-\alpha}\left[\phi_n - \phi_{n'}\right], \tag{8}$$

where $\tilde{b}_n \equiv \frac{1}{1-\alpha} b_n + \frac{\alpha}{1-\alpha} ln\left[\frac{K_n}{Y_n}\right]$ captures both the country embedded productivity and the capital output-ration in country n.

In Section 3, we will follow Klenow and Rodriguez-Clare (1997) and compute the contribution of each of these two terms to the cross-country variance in TFP as:[4]

$$1 = \frac{cov\left[b_n - b_{n'}, tfp_n - tfp_{n'}\right]}{var\left[tfp_n - tfp_{n'}\right]} + \frac{cov\left[\phi_n - \phi_{n'}, tfp_n - tfp_{n'}\right]}{var\left[tfp_n - tfp_{n'}\right]}. \tag{9}$$

We can also compute the contribution of firm embedded productivity to the dispersion of income per capita as:

$$1 = \frac{cov\left[\tilde{b}_n - \tilde{b}_{n'}, y_n - y_{n'}\right]}{var\left[y_n - y_{n'}\right]} + \frac{cov\left[\frac{1}{1-\alpha}\left[\phi_n - \phi_{n'}\right], y_n - y_{n'}\right]}{var\left[y_n - y_{n'}\right]}. \tag{10}$$

The following section shows how the contribution of each of these terms can be measured in the data. To do so, we need to take a stance on how firm-level efficiency is transmitted across countries. We assume that the efficiency satisfies:

$$\varphi_{in} = \varphi / \kappa_{in}, \tag{11}$$

with $\kappa_{in} \geq 1$ and $\kappa_{ii} = 1$. Equation (11) states that the idiosyncratic efficiency of an affiliate is a fraction of the idiosyncratic efficiency of the parent.

[4]This variance decomposition follows from noting that, if $x_1 = x_2 + x_3$, then $var\left(x_1\right) = cov\left(x_1, x_1\right) = cov\left(x_1, x_2\right) + cox(x_1, x_3)$.

2.2 Measuring firm-embedded productivity using multinational sales

From equation (5), we can compute the share of sales in country n that goes to firms from country i:

$$\frac{R_{in}}{R_n} = \frac{\int \varphi_{in}^{\rho-1} dG_{in}(\varphi)}{\sum_i \int \varphi_{in}^{\rho-1} dG_{in}(\varphi)} = \frac{1}{\kappa_{in}} \left[\frac{\Phi_{in}^h}{\Phi_n}\right]^{\rho-1}, \tag{12}$$

where $G_{in}(\varphi)$ is the distribution of firms from country i that operate in country n, and $\Phi_{in}^h \equiv \left[\int \varphi^{\rho-1} dG_{in}(\varphi)\right]^{\frac{1}{\rho-1}}$ is the average efficiency that those firms have in their home country. Similarly, we can compute the share of sales that this set of firms has in their home country:

$$\frac{R_{in}^h}{R_i} = \frac{\int \varphi_{ii}^{\rho-1} dG_{in}(\varphi)}{\sum_{i'} \int \varphi_{i'i}^{\rho-1} dG_{i'i}(\varphi)} = \left[\frac{\Phi_{in}^h}{\Phi_i}\right]^{\rho-1}.$$

For the subset of firms from country i that operate in country n, we can write the log-difference in sales shares that these firms have in these two countries as:

$$s_{in} - s_{in}^h = [\rho-1][\phi_i - \phi_n] - [\rho-1] log\kappa_{in}, \tag{13}$$

where $s_{in} \equiv ln\frac{R_{in}}{R_n}$, and $s_{in}^h \equiv ln\frac{R_{in}^h}{R_i}$. Equation (13) states that the difference in sales shares of a set of firms operating simultaneously in two countries is a function if the firm-embedded productivities in these two countries and the MP costs, κ_{in}.

Disentangling productivity from multinational production costs: In what follows, we identify differences in firm-embedded productivity by assuming that MP costs are symmetric, as in Head and Ries (2001). Note that we write the analog of equation (13) as:

$$s_{ni} - s_{ni}^h = [\rho-1][\phi_n - \phi_i] - [\rho-1] log\kappa_{ni}.$$

Subtracting this last equation from (13) yields:

$$\phi_i - \phi_n - \frac{1}{2}[log\kappa_{in} - log\kappa_{ni}] = \frac{[s_{in} - s_{in}^h] - [s_{ni} - s_{ni}^h]}{2[\rho-1]}. \tag{14}$$

Under the assumption that MP costs are symmetric, $log\kappa_{in} = log\kappa_{ni}$, we can use equation (14) and data on sales shares by multinational firms to quantify cross country differences in firm-embedded productivity, $\phi_i - \phi_n$.

3 Quantification

3.1 Data

Our firm level data comes from ORBIS, a worldwide dataset maintained by Bureau van Disk that includes comprehensive information on firm's revenue, employment and assets. ORBIS includes information on both listed and unlisted firms collected from various country-specific sources, such as national registries and annual reports. The main advantage of ORBIS is the scope and accuracy of its ownership information: it details the full lists of direct and indirect subsidiaries and shareholders of each company in the dataset, along with a company's degree of independence, its global ultimate owner and other companies in the same corporate family. This information allows us to build links between affiliates of the same firm, including cases in which the affiliates and the parent are in different countries. We specify that a parent should own at least 50% of an affiliate to identify an ownership link between the two firms.

The main variable used in the analysis is the total sales (turnover) of each firm. In what follows we focus on a subset of European countries for which ORBIS has good coverage. We refer the reader to Alviarez et al. (2018) for a detailed description of the ORBIS and the procedure used to select our sample of countries.[5] Our data on TFP, income per worker, and the labor share $1 - \alpha$ comes from the PWT 9.0. In what follows, we present results for the year 2011, which is the baseline year in the PWT. Since our framework assumes that the output of multinational firms is not exported, we exclude firms opperating in the mining and agriculture sectors from our analysis.

3.2 Results

Equation (14) gives multiple alternatives for computing the difference in firm-embedded productivity between two countries. To see this, suppose we want to compute the difference in firm-embedded productivity between Germany and Turkey. The most direct alternative would be to use Equation (14) setting countries i and n to be Germany and Turkey. But one can also use the equation to compute the difference between Germany and the UK, then to compute the difference between the UK and Turkey, and then sub-

[5]Other studies that have previously used the ORBIS data to study multinational firms are Fons-Rosen et al. (2013), Cravino and Levchenko (2017) and Alfaro and Chen (2018).

tract these two numbers. The first alternative uses data on the German multinationals operating in Turkey and on the Turkish multinationals operating in Germany. In contrast, the second alternative uses data on the UK multinationals that operate in Germany and Turkey, and on the Turkish and German multinationals that operate in the UK. Under the assumptions of the framework developed in Section 2, all these alternatives should yield identical numbers. In practice, the different alternatives may yield different results if either or some of our assumptions are violated or if there is measurement error in the ORBIS data.

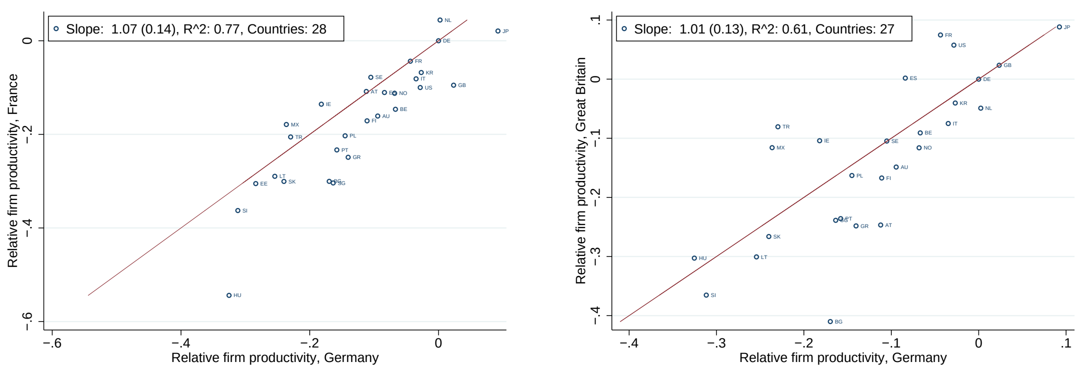
With this in mind, we proceed in the following way. We first compute equation (14) for all the country pairs in our data that involve either Germany, France, or the UK. We thus obtain estimates of the firm embedded productivity of each country first relative to Germany, then relative to France, and then to the UK, respectively. We normalize these differences to always express them as firm-embedded productivity relative to Germany. In the example given above, this implies writing the firm embedded productivity of Turkey relative to Germany, even when we compute it using the data on the French multinationals.

Figure 1 reports our results for $\rho = 10$. The first panel compares our estimates of the cross-country differences in firm embedded productivity using data on the German vs. the French multinationals. The Figure shows that for all countries with the exception of Hungary, our estimates do not vary much across these two data sources: the differences in productivity are close to the 45 degree line and the R-squared of a regression is 0.77. The discrepancy in Hungary arises from the fact that there are very few Hungarian multinationals in these two countries, so that these results are sensible to the size of a few firms. The second panel in figure 9shows that the results are also quite similar when computed using data from UK multinationals. All three data sources indicate that there are large differences in firm-embedded productivity across countries: for the average country in our sample, firm embedded productivity is about 12 percent lower than in Germany. In what follows, we focus on the results from the German data, since it is the largest economy in Europe and has the most multinationals.

Figure 2 decomposes cross-differences in TFP and income per-capita into 'firm-embedded' and 'country-embedded'. The first panel reports the TFP decomposition in equation (9), and the second panel show the decomposition in income per capita in equation (10). The red circles show the differences in firm embedded productivity. In the median country, firm embedded productivity is 0.11 log point lower than in Germany, compared to a median difference in TFP of 0.18 log points. There is wide variation across countries, for example, Norway has relatively low firm embedded productivity (0.07 log points lower

Figure 1: Cross-country differences in 'Firm-Embedded' productivity

(a) German vs. French data (b) German vs. UK data



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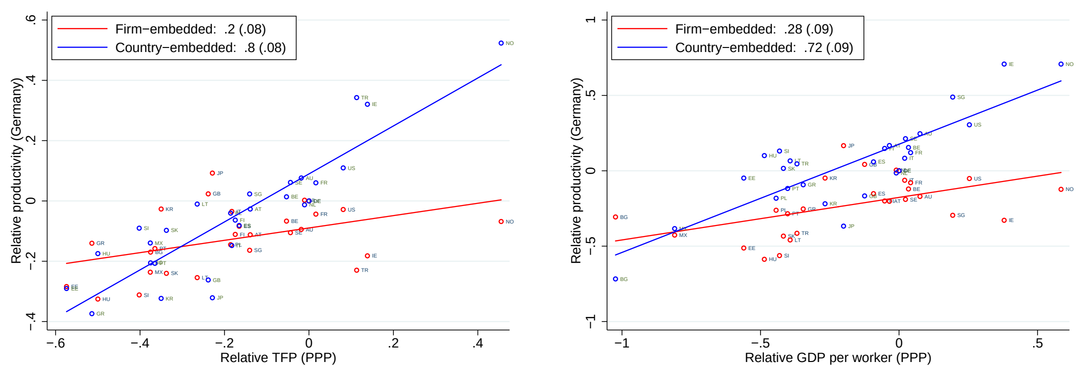
than Germany), but very high TFP (0.57 log points larger than Germany). This is unsurprising given the importance of country embedded factors -oil in particular- for the Norwegian economy. In contrast, differences firm embedded productivity account for about half of the difference TFP in developing countries such as Mexico or Portugal. Finally, the figure shows that the U.S. has about the same firm embedded productivity than Germany, so that the observed differences in aggregate TFP and income per capita between those countries must be country embedded. Notice the relative flatness of firm-embedded compared with country-embedded productivity across different levels of TFP and income per capita. This is consistent with firm capabilities being more transferable across countries, for example, through the activity of multinational corporations. Figure2 also shows that country-embedded productivity is slightly flater with income per capita than with TFP. This could be explained by the fact that income per capita includes physical and human capital, both of which are relatively mobile.

Finally, the figures report the results of the variance decompositions in equations (7) and (8). Note that the contributions of firm-embedded and country-embedded factors to the cross-country variance in TFP (income per capita) correspond to the slope coefficients of a bivariate regression between each of these factors and TFP (income per capita). The figure shows that cross-country differences in firm embedded productivity account for about 20 percent of the variance in TFP, and about 30 percent of the variance in income per capita.

Figure 2: Development accounting

(a) TFP

(b) Income per capita



4 The role of multinational firm-level data

A large literature in international trade uses gravity models to estimates country-level productivity shifters from aggregate trade or multinational production data. This section describes how our procedure relates to this literature and underscores the importance of the firm level data for measuring 'firm-embedded' productivity.

Gravity in models with multinational production: We can close the model in Section 2 by assuming that firms are heterogeneous and there are fixed costs of producing abroad. Let X_{in} denote country $i's$ share in total sales in country n. This share is given by:

$$X_{in} \equiv \frac{R_{in}}{R_n} = \frac{\int \varphi_{in}^{\rho-1} dG_{in}(\varphi)}{\sum_i \int \varphi_{in}^{\rho-1} dG_{in}(\varphi)} = \kappa_{in}^{1-\rho} \left[\frac{\Phi_{in}}{\Phi_n}\right]^{\rho-1}. \tag{15}$$

The share of country $i's$ firms in their home market is:

$$X_{ii} \equiv \frac{R_{ii}}{R_i} = \left[\frac{\Phi_{ii}}{\Phi_i}\right]^{\rho-1}. \tag{16}$$

Taking logs and subtracting yields:

$$s_{in} - s_{ii} = [\rho - 1][\phi_i - \phi_n] - [\rho - 1] \, log\kappa_{in} + [\rho - 1][\phi_{ii} - \phi_{in}],$$

where $\phi_{in} \equiv ln[\Phi_{in}]$. Note that his equation differs from our main equation (14) in that $s_{ii} \neq s_{in}^h$: s_{ii} is the (log) domestic share all the firms from country i, while s_{in}^h is the domestic share of only those firms from country $i$that are also active in country n. These shares will differ in the empirically relevant case where not all the firms from country i are active in country n. This implies that it is not possible to recover cross-country differences in firm embedded productivity using equation (14) and aggregate data without modeling selection explicitly.

Even if the researcher takes a stance on the nature of selection, further assumptions are needed to recover firm-embedded productivity from aggregate data. Suppose we assume, as is common in the literature, that firm productivities are Pareto distributed and that there are fixed costs of operating an affiliate in a foreign country. In that case, on can write the ratio of equations (15) and (16) as:

$$\frac{X_{in}}{X_{ii}} = \kappa_{in}^{1-\rho} \left[\frac{\Phi_i}{\Phi_n}\right]^{\rho-1} \left[\frac{\bar{\varphi}_{in}}{\bar{\varphi}_{ii}}\right]^{\rho-1-\theta}.$$

Here $\bar{\varphi}_{in}$ is the productivity cutoff above which it is profitable for firms in country i to operate in country n, and θ is the Pareto shape parameter.[6] The productivity cutoffs are in turn a function of demand, factor costs, and fixed costs in the host country:

$$\bar{\varphi}_{in} = \left[\frac{\kappa_{in}^{\rho-1} f_{in}}{\frac{C_n^{-\rho}}{P_n^{-\rho}} Q_n}\right]^{\frac{1}{\rho-1}}.$$

Taking logs and substituting this yields:

$$s_{in} - s_{ii} = \delta_i - \delta_n - \left[\frac{\theta}{\rho-1}\right] log\kappa_{in} + \frac{1}{\rho-1} log f_{in},$$

where $\delta_i \equiv [\rho-1]\,\phi_i + [\rho-1-\theta]\,[c_i - p_i] + \frac{\rho-1-\theta}{\rho-1}\,[p_i + c_i]$, so further assumptions and data are required to identify firm embedded productivity ϕ_i from other demand and costs factors in country i.The framework in Section 2 bypasses these issues and requires fewer assumptions by comparing the sales of the same set of firms in two separate countries.

5 Conclusion

This paper provides a decomposition of cross-country TFP differences into components that are 'firm-embedded' vs. 'country-embedded'. About 20 percent of the global dif-

[6] See the Online Appendix for a derivation.

ferences in TFP are 'firm-embedded', which leaves room for large potential gains form convergence in 'firm-embedded' productivity. In future work, we will compute this decomposition in multiple years, and use its evolution across time to evaluate the growth experiences of some developing countries that have experienced fast convergence in TFP in recent years. In addition, we will use the decomposition to evaluate the effectiveness of policies aimed to facilitate technology transfers across-countries, in particular those that attempt to promote inflows of foreign direct investment.

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