FOREIGN KNOW-HOW, FIRM CONTROL, AND THE INCOME OF DEVELOPING COUNTRIES*

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Management know-how shapes the productivity of firms, and can be reallocated across countries as managers acquire control of factors of production abroad. We construct a quantitative model to investigate the aggregate consequences of the international reallocation of management know-how. Using aggregate data, we infer the relative scarcity of this form of know-how in a sample of developing countries. We find that developing countries gain, on average, 12% in output and 5% in welfare (with wide variation across countries) when they eliminate policy barriers to foreign control of domestic factors of production.

I. Introduction

The diffusion of productive knowledge has a prominent place in the literature on cross-country income differences. Much of the attention has been on flows of

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knowledge that is embedded in patents and internationally traded goods, and on the role of cross-country spillovers in the diffusion of ideas. There has been less focus on the transfer of productive know-how that takes place when firm management crosses borders and directly controls factors of production in a foreign country.[1] These transfers appear to have gained importance with the expanding multinational activity of recent years.[2]

In this paper, we investigate the aggregate consequences of reallocating firm management know-how across countries. In a world economy in which firms can reallocate and produce abroad, it is important to distinguish between the fixed productivity components of a country and those that are internationally mobile. We refer to the immobile components of productivity, which impact all firms operating in a country (such as infrastructure, regulations, and natural amenities), as "country-embedded productivity." In contrast, we refer to the internationally mobile components, which generate productivity differences across firms operating within the same location, as "firm-embedded productivity."

At the aggregate level, separating country- from firm-embedded productivity is not straightforward. For given levels of capital and labor, a combination of high country- and low firm-embedded productivity can lead to the same observed output level as a combination of low country- and high firm-embedded productivity. However, if firm-embedded productivity flows from countries where it is relatively abundant to countries where it is scarce, then country- and firm-embedded productivities can be separated. A high share of capital and labor controlled by foreign firms indicates that the domestic level of firm-embedded productivity is low relative to country-embedded productivity.

1. Barro and Sala-i-Martin (1998), Keller (2004), and Klenow and Rodriguez-Clare (2005) review the literature on technology diffusion and its implications on cross-country income differences.

2. See chapter one of Barba Navaretti and Venables (2004) and references therein for an account of the impressive growth of multinational firms during the last two decades of the 20th century.

We develop this logic in a quantitative model of the world allocation of firm-embedded productivity. We use the model and aggregate data to disentangle country- and firm-embedded productivities in a set of developing countries. Then, we conduct counterfactuals on policies that restrict the control by foreign firms of local factors of production.

Our model follows a long tradition in the literature that links firm-embedded productivity to the management know-how and skills of individuals leading the firm.[3] Management know-how is similar to codified technological knowledge, as it can be reallocated across sectors, regions, and, albeit imperfectly, across countries. But management know-how differs from codified technological knowledge, as it is to a large extent a rival factor requiring the holder's direct involvement when making the critical decisions facing a firm.[4] Since time and attention are limited, the use of know-how in one task or location entails an opportunity cost in another.[5]

The reallocation of firm-embedded productivity across countries in our model, is consistent with the observation that multinational firms in developing countries rely largely on expatriates from the source country for "senior management positions and key technical and engineering jobs to execute sophisticated or specialized production tasks" (UNCTAD 1994, p. 238). Bloom, Sadun and Van Reenen (2007) and Bloom and Van Reenen (2007) show that multinational firms shape their productivity abroad by transplanting their organization structures and management practices.[6]

3. See, for example, Kaldor (1934), Lucas (1978), Rosen (1982), Oi (1983), and Garicano (2000). Firm-embedded productivity is also related to "organization capital" (Prescott and Visscher 1980), which also includes the firm-specific knowledge of non-management workers.

4. Firm-leading skills and management know-how are to a large extent a "tacit knowing", as defined by Polanyi (1967), that lies within the individuals making the critical choices of the firm. This know-how is costly –if not impossible– to describe and teach to others. Kaldor (1934) highlights the limited span of control in the coordinating role of management.

5. The rival nature of firm-embedded productivity is at the core of a large literature on the firm-size distribution (e.g. Lucas [1978], and Atkeson and Kehoe [2005]).

6. Chari, Ouimet, and Tesar (2007) find that firms from developed countries obtain positive returns from acquiring firms in emerging markets only when they acquire a controlling stake.

We extend a standard neoclassical model by introducing management know-how as an additional factor of production. As in Lucas (1978), firms are teams of managers, workers and capital. Each country has domestic supplies of labor and of management skills, both of which can change over time with the occupation choice of individuals. Managers can reallocate their skills and lead firms in foreign countries, where they face country-specific taxes. Capital can be accumulated over time and reallocated across countries.

The worldwide equilibrium allocates management know-how by equalizing its net-of-tax marginal product across countries. A country attracts more foreign management know-how the lower its domestic supply, the higher its country-embedded productivity, and the lower its tax rate on the returns to foreign management know-how. These implications echo the results in Helpman (1984), that inflows of multinational firms are more prevalent in countries that have a relative scarcity of factors intensively used by headquarter services (e.g., management, marketing and R&D), but that are relatively rich in factors used intensively in production activities (e.g., unskilled labor).[7]

With the model, we infer separately the domestic supply of firm-embedded productivity and the level of country-embedded productivity in each country. We measure the aggregate share of inputs controlled by foreign firms in host countries as the ratio of the stock of inward foreign direct investment (FDI) to the stock of physical capital in each country. FDI is connected with the notion of foreign-controlled capital in our model (in contrast to other forms of capital flows such as portfolio equity or debt), since FDI represents foreign investment that exercises a significant influence in the management of the firm. We also construct an alternative measure based on the share of efficiency units of labor controlled by multinational firms (combining data on the wage bill of

7. See also Markusen (2002) and references therein.

U.S. multinational firms and inward stocks of FDI). Despite some important limitations, which we discuss below, both measures can be constructed for a large set of host countries.

The average stocks of FDI for the period 1996-2000 show that most net sources of FDI are developed countries, while most recipients of FDI are developing or recently developed countries (see Table I). In our quantitative analysis we construct a single net source of firm-embedded know-how by aggregating the data for the largest net sources of FDI, and use data for 31 individual net host countries.[8] To account for the flows of FDI in our data, our model implies that developing countries have a low domestic supply of firm-embedded productivity relative to their country-embedded productivity.

Our model provides an organizing framework for quantifying the importance of fixed country productivity components (country-embedded productivity), internationally mobile productivity components (home and foreign firm-embedded productivity), and physical capital stocks in accounting for cross-country differences in per capita output observed in the data. We find that country-embedded productivity is the leading factor in accounting for output differences between source and host countries (roughly 50%), but that differences in firm-embedded productivities also account for a sizeable share (roughly 16%).

Next, we conduct policy counterfactuals. We quantify the aggregate impact in host countries of lowering taxes on payments to foreign management know-how. We assess the contribution of three margins on the gains in aggregate output and welfare: (i) the response in the inflow of firm-embedded productivity, which depends largely on the output share of management know-how; (ii) the response of capital accumulation, which depends on the output share of cap-

8. Most gross flows of FDI worldwide are between net sources of FDI. We abstract from these because our model does not capture trade frictions, which play a key role in North-North multinational activity. See Helpman, Melitz, and Yeaple (2004) for a model of horizontal FDI in which firms establish foreign subsidiaries to serve the local market and avoid international trade costs.

ital; and (iii) the reallocation of individuals across occupations, which depends on the shape of the cross-section distribution of managerial skills. Under our parameterization, for host countries the average output and welfare gains from moving from autarky to undistorted openness to foreign firms are roughly 5% and 2%, respectively, when margins (ii)–(iii) are shut-down, and 12% and 5%, respectively, when margins (ii)-(iii) are incorporated.

To put these gains in perspective, we relate them to other experiments on the gains of globalization. On one hand, the welfare gains from the reallocation of physical capital over time (Gourinchas and Jeanne 2006) and across countries (Caselli and Fryer 2007) seem to be smaller, in the order of 1% on average for the countries in their samples. On the other hand, the welfare gains from the transfer of fully non-rival productivity factors via trade of goods (Alvarez and Lucas 2007; Eaton and Kortum 2002) or via multinational activity (McGrattan and Prescott 2007; Ramondo 2006) seem to be larger, in the order of $20 - 50\%$ on average for the countries in their samples.

An extensive literature on the international diffusion of knowledge alludes to the tacit and rival dimensions of knowledge to rationalize cross-country spillovers stemming from FDI (see Keller [2004] and references therein). This has motivated many empirical studies aimed at quantifying the effects of FDI on the productivity of domestic firms (see, for example, Aitken and Harrison [1999] and Haskel, Pereira, and Slaughter [2001]). We show that the international reallocation of rival management know-how can have significant welfare consequences for host countries, even with no spillovers and with source countries appropriating the marginal contribution of their know-how on the host country output. Related work on the cross-country allocation of rival management knowledge includes Markusen, Rutherford and Tarr (2006), focusing on the gains in varieties of production services in host countries, and Antras, Garicano, and

Rossi-Hansberg (2006a, 2006b), on its impact on the assignment of individuals to tasks and the income distribution.

Our quantitative framework abstracts from some interesting issues involving the international mobility of firms. For example, our model does not deal with the endogenous choice of organization, either on the cross-country, within-firm allocation of skills and tasks, or on the choice between outsourcing and integration (e.g., Helpman [1984]; Grossman and Helpman [2003]; Antras and Helpman [2004]; Grossman and Rossi-Hansberg [2006]). Our analysis also abstracts from worker mobility (e.g., Rauch [1991]; Klein and Ventura [2006]), and from interactions between factor mobility and international trade in goods with different factor intensities.[9]

The paper is organized as follows. Section II presents a simple model to illustrate the equilibrium allocation of firm-embedded productivity, and how firm-embedded productivity can be separated from country-embedded productivity using aggregate data. Section III presents the quantitative model with multiple countries, capital accumulation, and occupation choice. Section IV describes the data, parameterization, and inference results, Section V shows the policy counterfactuals, and Section VI concludes. An Appendix discusses details of the model and the data.

II. A Basic Two-Country Model

In this section we use a highly stylized model for two purposes. First, we examine the equilibrium allocation of management know-how across countries. Second, we show how to use aggregate data to infer the relative scarcity of this form of know-how in each country.

9. With differences in country-embedded productivity, international trade in goods does not necessarily imply factor price equalization. Indeed, factor mobility and trade can even be complementary (see e.g. Wong [1986]).

II.A. The Model

Consider a world of two countries, indexed by $i = 1, 2$ and a single, freely traded consumption good. Production is organized in firms, requiring labor services and the know-how and management skills of the individuals leading the firm. With x units of management know-how and n units of labor, output of a firm that operates in country i is

$$y = Z^i x^{1-\nu} n^{\nu}, \tag{1}$$

where $1 - \nu \in (0, 1)$ is the share of management know-how in output.

The term Z^i is common to all firms operating in country i. We refer to it as "country-embedded productivity" because it captures factors that are fixed in the country, such as infrastructure, regulation, quality of workers, natural amenities and any other nontradeable factors of production of the country.

As a counterpart to Z^i, we refer to x as "firm-embedded productivity", encompassing the know-how and skills of the managers that make and implement the critical production and marketing decisions facing the firm. The underlying human aspect of firm-embedded productivity implies that (1) it is a rival factor (i.e. its use in one task or location detracts its use in another) and (2) it is internationally mobile. In Appendix I, we show that our results are unchanged if these two properties hold only partially.

Each country is endowed with an aggregate of N^i units of labor, and an aggregate of $\bar{X}^i$ units of firm-embedded productivity. These endowments are formed, respectively, by the sum of labor units of all workers, and the sum of skills and know-how of all managers in the population. Workers are fixed in each country, but managers can reallocate their know-how across countries. The amount of firm-embedded productivity operating in country i is denoted by X^i.

We consider competitive equilibria in which workers earn w^i per unit of labor and managers earn π^i per unit of management skills (i.e. π^i is the market price of firm-embedded productivity). All firms in country i face the same prices and employ the national ratio of firm-embedded productivity per worker X^i/N^i. Aggregation is straightforward, and leads to the following expression for aggregate output in country i:

$$Y^i = Z^i \left(X^i\right)^{1-\nu} \left(N^i\right)^{\nu}. \tag{2}$$

Equilibrium prices are equal to the marginal product of each factor:

$$w^i = \nu Y^i/N^i \quad \text{and} \quad \pi^i = (1-\nu)\, Y^i/X^i. \tag{3}$$

Our equilibrium formulation is equivalent to the one in Lucas (1978), in which managers hire labor in competitive markets and are the residual claimants of firms.

II.B. Autarky

Suppose first that firm-embedded productivity is internationally immobile, i.e. $X^i = \bar{X}^i$. From expression (2), it is evident that the same Y^i can result from many combinations of Z^i and $\bar{X}^i$. Country- and firm-embedded productivities cannot be separately inferred from aggregate data.

Under autarky, the cross-country ratio of firm-embedded productivity prices is

$$R \equiv \frac{\pi^1}{\pi^2} = \left(\frac{Z^1}{Z^2}\right)\left(\frac{\bar{X}^2/N^2}{\bar{X}^1/N^1}\right)^{\nu}. \tag{4}$$

This ratio provides the precise basis for comparing the relative scarcity of firm-

embedded productivity across countries. If $R < 1$, then firm-embedded productivity is scarce in country 2 because, relative to country 1, it has a high country-embedded productivity or a low supply of firm-embedded productivity. In such case, there are potential gains from reallocating firm-embedded productivity from country 1 to country 2.

II.C. International Mobility of Firm-Embedded Productivity

Suppose now that firm-embedded productivity can be reallocated across countries. Assume also that the government of country i sets a tax rate $\tau_D^i \in [0,1]$ on payments to domestic firm-embedded productivity, and a tax rate $\tau_F^i \in [0,1]$ on payments to foreign firm-embedded productivity (autarky corresponds to $\tau_F^i = 1$). Tax revenues are rebated to national households in a lump-sum fashion.

In an interior equilibrium in which country 1 exports firm-embedded productivity to country 2 (i.e. $X^1 \leq \bar{X}^1$ and $X^2 \geq \bar{X}^2$), net-of-tax prices must be equal in both countries:

$$\left(1-\tau_D^1\right)\pi^1 = \left(1-\tau_F^2\right)\pi^2. \tag{5}$$

In addition, if taxes are such that $\left(1-\tau_F^2\right)/\left(1-\tau_D^1\right) < \left(1-\tau_D^2\right)/\left(1-\tau_F^1\right)$, then $\left(1-\tau_F^1\right)\pi^1 < \left(1-\tau_D^2\right)\pi^2$ and no firm-embedded productivity flows from country 2 to country 1. In what follows we assume that this inequality holds.[10] The equilibrium levels of X^1 and X^2 are pinned-down by the expressions (3), (5), and the world adding-up constraint $X^1 + X^2 = \bar{X}^1 + \bar{X}^2$.

For our quantitative exercises, it is useful to define the share of firm-embedded

10. If this condition holds with equality, then only net flows are determined in equilibrium, and gross flows are indeterminate.

productivity in country 2 that is supplied by country 1:

$$s \equiv \left(X^2 - \bar{X}^2\right)/X^2. \tag{6}$$

With $\bar{X}^2$ remaining in country 2, a higher s reduces X^1 and Y^1, and increases X^2 and Y^2. Note also that, since firm-embedded productivity is a proportional shift to the production function, s is also equal to the share of labor in country 2 controlled by managers from country 1.

Using the equilibrium level of X^2, the share s is given by

$$s = \frac{1 - \left(\frac{\bar{X}^2/N^2}{\bar{X}^1/N^1}\right)\left(\frac{1-\tau_D^1}{1-\tau_F^2}\frac{Z^1}{Z^2}\right)^{1/\nu}}{1 + \bar{X}^2/\bar{X}^1}. \tag{7}$$

The share s is high either because the host country 2 is a relatively productive location (high Z^2/Z^1), or because it has a relatively scarce domestic endowment of firm-embedded productivity (low $[\bar{X}^2/N^2]/[\bar{X}^1/N^1]$). Notice also that country 2 can promote the presence of foreign firm-embedded productivity by lowering the tax rate τ_F^2. The elasticity of s with respect to taxes τ_D^1 and τ_F^2 is directly related to $1-\nu$, the output share of management know-how.

Aggregate consumption in each country equals aggregate output minus the net payments to foreign management know-how. Using equilibrium prices w^i and π^i, aggregate consumptions are

$$C^1 = Y^1 + \left(1-\tau_F^2\right)(1-\nu)\,sY^2, \text{ and } C^2 = \left[1 - \left(1-\tau_F^2\right)(1-\nu)\,s\right]Y^2. \tag{8}$$

It can be shown that a rise in s always leads to an increase in consumption of country 2, since foreign firms earn only a portion of the output increase in country 2. On the other hand, an increase in s can result either in an increase or decrease in consumption of country 1, as domestic output falls but payments

from abroad rise.

To get a first sense of magnitudes, imagine a country that starts in autarky ($s = 0, \tau_F = 100\%$) and lowers taxes to $\tau_F = 24\%$. Assume that this change leads to an increase in s to 25% (as discussed below, these values of τ_F and s correspond roughly to the observed levels in Chile over the period 1996-2000). Setting $\nu = .85$, output and consumption increase by 4.2% and 1.2%, respectively. This back-of-the-envelope calculation abstracts from important factors such as the response in capital accumulation, the reallocation of individuals across occupations, and the presence of competing host countries. Note also that since the value of s was simply assumed, this calculation did not require assumptions on the values for $\bar{X}^i$ and Z^i. To study the aggregate implications of policy changes, we need to determine the equilibrium behavior of s, and this requires separate values for $\bar{X}^i$ and Z^i.

II.D. Using Aggregate Data to Infer Z^i and $\bar{X}^i$

Under autarky, country- and firm-embedded productivities cannot be disentangled since the same aggregate output Y^i can result from different combinations of Z^i and $\bar{X}^i$ (see (2)). With mobility, we can use the equilibrium determination of s to infer Z^i and $\bar{X}^i$ based on aggregate data.

First, using equations (2), (3), and (5), output-per-worker in country 2 relative to country 1 in an interior equilibrium is

$$\frac{Y^2/N^2}{Y^1/N^1} = \left(\frac{Z^2}{Z^1}\right)^{1/v} \left(\frac{1-\tau_F^2}{1-\tau_D^1}\right)^{\frac{1-\nu}{\nu}}. \tag{9}$$

Relative output levels are determined only by taxes and immobile factors (labor and country-embedded productivities) because firm-embedded productivity is reallocated to equalize its after-tax return across countries. From equation (9),

the ratio of country-embedded productivities is

$$\frac{Z^2}{Z^1} = \left(\frac{Y^2/N^2}{Y^1/N^1}\right)^{\nu} \left(\frac{1-\tau_D^1}{1-\tau_F^2}\right)^{1-\nu}. \tag{10}$$

Second, plugging (10) into the equilibrium expression for s, (7), the ratio of country endowments of firm-embedded productivity is

$$\frac{\bar{X}^2}{\bar{X}^1} = \frac{1-s}{\left(\frac{Y^1}{Y^2}\right)\left(\frac{1-\tau_D^1}{1-\tau_F^2}\right)+s}. \tag{11}$$

The expression indicates that, other things equal, the higher the share of foreign-controlled inputs in a country, the lower its domestic supply of firm-embedded productivity must be. Also, a high tax rate τ_F^2 relative to τ_D^1 can only be consistent with the same value of s if firm-embedded productivity is in short supply in the host country. Finally, a lower output in the host country indicates a lower level of country-embedded productivity, hence a lower domestic supply of firm-embedded productivity is required to observe the same value of s.

In Appendix I we show that this simple inference procedure works also if firm-embedded productivity is only partially rival, and only partially internationally mobile.

III. The Quantitative Model

We now extend the model along three dimensions that are important for quantitative analysis. First, we consider a world with multiple host countries. Second, we introduce physical capital that can be accumulated and internationally traded. Third, we endogenize the supply of firm-embedded productivity of each country as individuals choose between supplying management skills or labor.

III.A. The Model

We consider an infinite horizon world economy with M countries. Time is discrete and periods are indexed by t. A firm in country i with x units of management know-how in control of k units of capital and n units of labor produces output according to

$$y = Z^i x^{1-\nu} \left(k^\alpha n^{1-\alpha}\right)^\nu . \tag{12}$$

Firms hire labor and management know-how, and rent capital at prices w_t^i, r_{Kt}^i, and π_t^i, respectively. Since all firms operating in country i face the same input prices, output aggregation yields

$$Y_t^i = Z^i \left(X_t^i\right)^{1-\nu} \left(K_t^i\right)^{\alpha\nu} \left(N_t^i\right)^{(1-\alpha)\nu} , \tag{13}$$

where X_t^i, K_t^i, and N_t^i denote, respectively, the total amount of firm-embedded productivity, capital, and labor operating in country i.

The domestic supplies of labor N_t^i and of firm-embedded productivity $\bar{X}_t^i$ in each country are determined by individuals' choice between being workers or managers. Specifically, country i is populated by L^i individuals, each endowed with one unit of labor and $e\hat{x}^i$ units of management skills. The term $\hat{x}^i$ is country i's per-person average of management skills and e is an individual specific component drawn from a common c.d.f. $F(\cdot)$, with support $[0, \infty)$ and mean equal to one. In equilibrium, there is a threshold $\bar{e}_t^i$ (to be discussed below) in each country such that those individuals with $e \leq \bar{e}_t^i$ choose to be workers and those with $e > \bar{e}_t^i$ choose to manage firms. Then, in period t, country i has a supply of $N_t^i = L^i F\left(\bar{e}_t^i\right)$ units of labor and $\bar{X}_t^i = \hat{x}^i L^i \int_{\bar{e}_t^i}^\infty e dF(e)$ units of firm-embedded productivity.[11]

11. Common trends across countries in population and/or country-embedded productivity

In each country, a representative household collects the earnings of all workers and managers, and makes consumption and savings decisions. Preferences of the representative household are given by

$$\sum_{t=0}^{\infty} \beta^t \ln\left(C_t^i\right), \tag{14}$$

where $0 < \beta < 1$, and C_t^i is the aggregate consumption of country i in period t.

Households in country i own capital in the amount $\bar{K}_t^i$, which can be accumulated at a unitary cost of one consumption good and which depreciates at the rate δ. Capital can be rented to firms located in any country j at a rate r_{Kt}^j, subject to a tax on capital income τ_K^j. A unit of capital rented to firms located in country j earns a return net of tax and net of depreciation equal to $\left(r_{Kt}^j - \delta\right)\left(1 - \tau_K^j\right)$.

The budget constraint of the representative household is

$$C_t^i + \bar{K}_{t+1}^i = \left(1 - \tau_D^i\right) w_t^i N_t^i + \left(1 + \bar{r}_{Kt}^i\right) \bar{K}_t^i + \bar{\pi}_t^i \bar{X}_t^i + T_t^i, \tag{15}$$

where $\bar{r}_{Kt}^i$ denotes the average return to country i's capital, $\bar{\pi}_t^i$ denotes the after-tax return to country i's firm-embedded productivity $\bar{X}_t^i$, and T_t^i is a lump-sum rebate from the government. To abstract from tax distortions on the occupation choice margin, we assume that earnings of workers and domestic managers are taxed at the same rate τ_D^i.[12]

The representative household maximizes (14) subject to (15), a standard no-Ponzi scheme constraint on capital holdings, and an initial level of capital $\bar{K}_0^i$.

do not affect the results and are omitted to simplify the presentation.

12. See Cagetti and De Nardi (2006) for an analysis of taxation and the distortions on occupational choice. We also abstract from other within-country distortions across domestic firms (see, for example, Restuccia and Rogerson [2007], Caselli and Gennaioli [2005], and Guner, Ventura, and Yi [2006]).

Firm-embedded productivity and physical capital can both be reallocated contemporaneously across countries, subject to the world adding-up constraints

$$\sum_{i=1}^{M} X_t^i = \sum_{i=1}^{M} \bar{X}_t^i, \text{ and} \tag{16}$$

$$\sum_{i=1}^{M} K_t^i = \sum_{i=1}^{M} \bar{K}_t^i. \tag{17}$$

Given a set of taxes $\left\{\tau_D^i,\, \tau_F^i,\, \tau_K^i\right\}$ and initial conditions $\left\{\bar{K}_0^i\right\}$, an equilibrium is a set of allocations $\left\{N_t^i, \bar{X}_t^i, X_t^i, \bar{K}_t^i, K_t^i, Y_t^i, \bar{e}_t^i, s_t^i\right\}$ and prices $\left\{w_t^i,\ \bar{r}_{Kt}^i, r_{Kt}^i, \bar{\pi}_t^i,\ \pi_t^i\right\}$ that solve the optimization problems of households and firms, and satisfy the market clearing conditions in each country and in the world. We now characterize the equilibrium prices and allocations at any period t. Appendix II describes the computation of the equilibrium.

The equilibrium price of firm-embedded productivity is given by expression (3), and the equilibrium wage and rental rate of capital in each country are

$$w_t^i = (1-\alpha)\,\nu \frac{Y_t^i}{N_t^i} \quad \text{and} \quad r_{Kt}^i = \alpha\nu \frac{Y_t^i}{K_t^i}. \tag{18}$$

The occupation choice threshold $\bar{e}_t^i$ is unique because earnings of managers are proportional to the individual's value of e, while earnings of workers are independent of e. In equilibrium, the threshold is defined by the indifference of the marginal manager

$$\bar{e}_t^i \hat{x}^i \pi_t^i = w_t^i, \tag{19}$$

which pins down the domestic supplies of labor N_t^i and firm-embedded productivity $\bar{X}_t^i$.

We focus on equilibria in which country 1 is the single exporter of firm-embedded productivity ($X_t^1 \leq \bar{X}_t^1$), and countries $2, ..., M$ are host countries ($X_t^i \geq \bar{X}_t^i$). The share of firm-embedded productivity in country $i > 1$ supplied by country 1 is $s_t^i = 1 - \bar{X}_t^i / X_t^i$. The equilibrium allocation of firm-embedded productivity is determined by the equalization of after-tax returns between source and host countries

$$\left(1 - \tau_D^1\right) \pi_t^1 = \left(1 - \tau_F^i\right) \pi_t^i. \tag{20}$$

Note that the equilibrium of our model uniquely determines the aggregate amount of management know-how (but not the cross-section of managers) that is transferred to each country.

Similarly, the equilibrium allocation of physical capital operating in each country K_t^i is determined by the equalization of after-tax returns to physical capital across countries

$$\left(r_{Kt}^i - \delta\right) \left(1 - \tau_K^i\right) = \bar{r}_{Kt}^i = r_t^*, \tag{21}$$

where r_t^* is the world-wide return to capital. Note that differences in capital-income taxes induce differences in capital-output ratios K_t^i / Y_t^i across countries.

The amount of capital owned by each country $\bar{K}_t^i$ is determined by the Euler equation

$$C_{t+1}^i / C_t^i = \beta \left(1 + r_{t+1}^*\right). \tag{22}$$

Note that the equilibrium of the model uniquely determines the amount of foreign-controlled capital operating in each country, but does not pin down who owns this capital (because ownership does not impact its productivity).

International flows of capital are distinct from international flows of management know-how, and each can take place absent the other.

Adding up all sources of earnings at market clearing prices, we can derive from (15) the resource constraint of country i

$$(23)\quad C_t^i + K_{t+1}^i - (1-\delta) K_t^i + \bar{K}_{t+1}^i - K_{t+1}^i = Y_t^i + (1+r_t^*)\left(\bar{K}_t^i - K_t^i\right) + \Xi_t^i,$$

where Ξ_t^i denotes the after-taxes payments to foreign firm-embedded productivity:

$$(24)\qquad \Xi_t^i = \begin{cases} (1-\nu)\sum_{i=2}^{M}\left(1-\tau_{Ft}^i\right) s_t^i Y_t^i & \text{for source country } i=1 \\ -\left(1-\tau_{F,t}^i\right)(1-\nu)\, s_t^i Y_t^i & \text{for host countries } i=2,...,M \end{cases}.$$

The trade balance in each country is equal to output minus consumption minus domestic investment, $Y_t^i - C_t^i - \left[K_{t+1}^i - (1-\delta) K_t^i\right]$, and the current account is equal to the sum of the trade balance and international net-factor payments $r_t^*\left(\bar{K}_t^i - K_t^i\right) + \Xi_t^i$.

III.B. Additional Equilibrium Implications

We now discuss how the introduction of multiple countries, occupation choice, and physical capital shapes the determination of international flows of firm-embedded productivity. In an interior equilibrium, the share of inputs (capital and labor) in the host country controlled by foreign firms is obtained from equations (3), (13), and (20):

$$(25)\qquad s_t^i = 1 - \frac{\bar{X}_t^i}{\left(Z^i\right)^{1/\nu}\left(K_t^i\right)^{\alpha}\left(N_t^i\right)^{1-\alpha}}\left[\frac{\left(1-\tau_D^1\right)\pi_t^1}{(1-\nu)\left(1-\tau_F^i\right)}\right]^{1/\nu}.$$

General equilibrium interactions: Host countries compete with each other and with the source country to attract firm-embedded productivity. Given K_t^i, all general equilibrium interactions across countries are captured by the determination of π_t^1. For example, if tax reductions in the source country 1 or in other host countries $j \neq i$ increase $\left(1-\tau_D^1\right)\pi_t^1$, they lead to a reduction in the share of foreign controlled inputs in country i.

Occupation reallocation within a country: Expression (25) shows that a high supply of labor attracts foreign firm-embedded productivity. Conversely, a high presence of foreign firm-embedded productivity leads to a higher supply of labor. In particular, from equations (3), (18), and (19), the equilibrium threshold $\bar{e}_t^i$ is determined by

$$\frac{F\left(\bar{e}_t^i\right)\bar{e}_t^i}{\int_{\bar{e}_t^i}^{\infty} e dF\left(e\right)} = \frac{\nu\left(1-\alpha\right)}{\left(1-\nu\right)\left(1-s_t^i\right)}, \tag{26}$$

implying that $\bar{e}_t^i$ is increasing in s_t^i. An increase in s_t^i raises the marginal product of labor (raising w_t^i) and lowers the marginal product of management know-how (lowering π_t^i). Inflows of foreign firm-embedded productivity induce a reallocation of occupations that increases the supply of factors complementing foreign factors, and reduces the supply of those competing with foreign factors.

Capital reallocation: Capital and firm-embedded productivity are also complementary factors. From expression (25), a country with a high capital stock attracts foreign firm-embedded productivity. Conversely, a higher level of firm-embedded productivity in country i increases the marginal product of capital, and boosts the amount of capital operating therein. Note also from (21) that changes in the world-wide return to capital r_t^* lead to changes over time in the amount of capital and firm-embedded productivity operating in each country.

III.C. Using Observed Data to Infer Z^i and $\bar{X}^i$

We now show how, in countries with $s_t^i > 0$, country- and firm-embedded productivities can be inferred using aggregate data, tax data, and the equilibrium conditions of the model.

Using expressions (3), (13) and (20), we obtain the ratio of country-embedded productivities in host countries $i > 1$ relative to source country 1:

$$\frac{Z^i}{Z^1} = \left(\frac{Y_t^i/N_t^i}{Y_t^1/N_t^1}\right)^{(1-\alpha)\nu} \left(\frac{Y_t^i/K_t^i}{Y_t^1/K_t^1}\right)^{\alpha\nu} \left(\frac{1-\tau_D^1}{1-\tau_F^i}\right)^{1-\nu}. \tag{27}$$

Using (3), (16), and (20), we obtain a linear system of $M-1$ equations and $M-1$ supplies of firm-embedded productivities in host countries relative to source country 1:

$$\frac{\bar{X}_t^i}{\bar{X}_t^1} = \left(1-s_t^i\right)\left(\frac{Y_t^i}{Y_t^1}\right)\left(\frac{1-\tau_F^i}{1-\tau_D^1}\right)\left(1-\sum_{j=2}^{M}\frac{s_t^j}{1-s_t^j}\frac{\bar{X}_t^j}{\bar{X}_t^1}\right), \tag{28}$$

The last factor in (28) is equal to $X_t^1/\bar{X}_t^1$, the fraction of country 1's firm-embedded productivity that remains operating there, and is common for all host countries.

Expressions (27) and (28) have a very similar interpretation to (10) and (11) in the basic two-country model, with the additional inclusion of capital stocks, and the multiple-host country dimension captured by the last term in (28). Normalizing $\bar{X}_t^1 = 1$ and solving for Z^1 using (13), we can then solve for Z^i and $\bar{X}_t^i$ in all host countries.

It is important to note that in deriving expression (27) we did not impose (21), the equality of net-of-tax returns to capital and the world interest rate. Instead, our inference of Z^i requires information on the capital stocks operating in each country. Hence, given measures of K_t^i, the inferred values for Z^i are

independent of τ_K^i or any other source of variation in Y_t^i/K_t^i. Inferring $\bar{X}^i$ requires information on s_t^i but not on K_t^i, since the availability of capital impacts symmetrically domestic and foreign firms.

Note also that, if we observe the number of workers N_t^i, inferring Z^i and $\bar{X}^i$ does not require information on the shape of the distribution of firm management skills across individuals $F(\cdot)$. Expressions (27) and (28) would still apply even if $F(\cdot)$ varied across countries. If we observe only the sum of workers and managers L^i, then the shape of $F(\cdot)$ determines the equilibrium number of workers $N_t^i = L^i F\left(\bar{e}_t^i\right)$. More importantly, the shape of $F(\cdot)$ determines the response of occupation choices and the elasticity of $\bar{X}^i$ to inflows of foreign firm-embedded productivity.

As in Section 2, we define R^i to be the ratio of autarky prices of firm-embedded productivity in country 1 relative to country i. That is, $R^i = \pi^1/\pi^i$, with π^1 and π^i evaluated at an equilibrium with $\tau_F^j = 1$ in all host countries. If $R^i < 1$, then firm-embedded productivity is relatively scarce in country i. In this case, if $\tau_F^i = \tau_D^1 < 1$ while other countries remain in autarky, country i will host firm-embedded productivity from country 1 and world output will increase. As in many international trade models, the ratio of autarky prices in R^i is a useful indicator of potential gains from international firm mobility. We now provide simple sufficient conditions in terms of observable data to verify whether $R^i < 1$. These conditions are informative on the forces that attract foreign firm-embedded productivity to host countries.

Suppose we infer Z^i and $\bar{X}^i$ as described above based on data at time t. We consider two alternatives to evaluate R^i. The first alternative evaluates autarky prices under capital stocks and occupation choices fixed at their time t levels.

Using expressions (27) and (28), R^i is given by

$$R^i_{\text{fixed}} = \left(1 - s^i_t\right)^{\nu} \left(\frac{1-\tau^i_F}{1-\tau^1_D}\right) \left(\frac{X^1_t}{\bar{X}^1_t}\right)^{\nu}. \tag{29}$$

Since $X^1_t/\bar{X}^1_t \leq 1$, a sufficient condition for $R^i_{\text{fixed}} < 1$ is that the product of the first two terms in the right side of (29) be less than one. This inequality can be verified in the data without having to solve for the entire equilibrium of the model. If we observe a high s^i_t despite observing also a high τ^i_F, it must be that the host country is attractive to foreign firms.

The second alternative for R^i evaluates autarky prices at the *equilibrium* capital stocks under $\tau^i_K = 0$ (i.e. undistorted capital mobility), and again fixes occupation choices at their time t levels. Using (27), (28), and the equilibrium condition for capital (21), R^i is given by

$$R^i_{\text{flex}} = \left(1 - s^i_t\right)^{\frac{(1-\alpha)\nu}{1-\alpha\nu}} \left(\frac{1-\tau^i_F}{1-\tau^1_D}\right) \left(\frac{Y^1_t/K^1_t}{Y^i_t/K^i_t}\right)^{\frac{\alpha\nu}{1-\alpha\nu}} \left(\frac{X^1_t}{\bar{X}^1_t}\right)^{\frac{(1-\alpha)\nu}{1-\alpha\nu}}. \tag{30}$$

Since $X^1_t/\bar{X}^1_t \leq 1$, a sufficient condition for $R^i_{\text{flex}} < 1$ is that the product of the first three terms in the right side of (29) be less than one. This inequality can be verified in the data without having to solve for the entire equilibrium of the model. If despite the scarcity of capital (low K^i_t/Y^i_t), we observe that country i attracts foreign firm-embedded productivity, then removing distortions on capital (captured in our model by τ^i_K) will increase K^i_t/Y^i_t and will make the country even more attractive to foreign firm-embedded productivity.

IV. Quantitative Analysis

In this section we describe our data and choice of parameter values, and then we infer the country- and firm-embedded productivities of 31 host countries

relative to a conglomerate of 15 source countries.

IV.A. Data

We use data from Penn World Tables, Version 6.2, to measure output Y^i, aggregate employment L^i (i.e. the sum of workers and managers), and physical capital operating in each country K^i. Capital stocks are constructed using the standard perpetual inventory method (as in Caselli [2005]), with investment data at PPP prices, initial capital stocks based on investment rates between 1950 and 1980 (to maximize the set of countries with available data), and an annual depreciation rate of 6%.

Our benchmark measure of s_t^i, the share of foreign-controlled inputs in host countries, is based on the net share of capital that is controlled by foreign firms. We use data on stocks of FDI to proxy for the stock of capital with direct influence from foreign management. The notion of FDI in the data (as opposed to other forms of capital flows such as equity portfolio or debt) is closely connected with foreign-controlled capital in our model since FDI represents investments aimed at establishing a long-term interest in the country and significant influence on the management of the firm.[13] However, the stock of FDI is only an imperfect proxy for foreign controlled capital. Some of the FDI may not carry any effective control by investors, and some capital controlled by foreigners may not be registered as FDI (e.g. if a foreign firms uses financing from the host country). Moreover, FDI partly includes the purchase of assets such as intangibles or natural resources that are not usually included in measures of physical capital.[14]

13. UNCTAD defines FDI as "investment made to acquire lasting interest in enterprises operating outside of the economy of the investor. [...] the investor's purpose is to gain an effective voice in the management of the enterprise." See www.unctad.org/Templates/Page.asp?intItemID=3147&lang=1

14. FDI is typically broken into greenfield investments and mergers and acquisitions. In our model, greenfield FDI corresponds to a joint transfer of capital and firm-embedded productiv-

Our baseline measure of s_t^i is

$$s^i = \frac{\text{stock of inward FDI } - \text{ stock of outward FDI in country } i}{\text{total capital stock in country } i}. \tag{31}$$

We use stocks of FDI in U.S. dollars computed by Lane and Milesi-Ferretti (2006) on the basis of FDI flows and information on initial levels of the stocks. We follow a similar procedure to construct U.S. dollar-denominated capital stocks for the denominator in (31). Appendix III provides additional details.

A country is a net host (source) of FDI when its stock of inward FDI is larger (lower) than its stock of outward FDI (i.e. when the numerator in (31) is positive). Table 1 displays the average ratio of outward to inward FDI stocks over the period 1996-2000, for many countries. The table shows that most countries with a ratio higher than one are developed countries, and most countries with a ratio lower than one (and close to zero) are developing countries. Some developed countries, such as the United States, have very large assets and liabilities and their ratios are close to one, but their liabilities are mostly with other developed countries.[15]

We construct a single source country, indexed by $i = 1$, consolidating the data of the 15 major net source countries (listed in Appendix III) into our country 1.[16] We select a sample of 31 net host countries (listed in Table 2 and

ity from the source to the host country. Mergers and acquisitions corresponds to a transfer of firm-embedded productivity with a reassignment of the ownership on existing capital. Other forms of capital inflows such as portfolio equity flows or corporate debt correspond in our model to capital investments by foreign agents, or transfers of capital between domestic and foreign agents, that are not complemented with inflows of foreign firm-embedded productivity. Finally, other transfers of management know-how that are not associated to capital ownership (e.g. foreign managers working in a firm with domestically owned capital), correspond in our model to inflows of foreign embedded productivity with no changes in the quantity or ownership of capital, and are not included in any measure of capital flows in the data.

15. Flows of FDI from developing to developed countries are small. According to BEA data, in 2001, 93% of all assets controlled by foreign affiliates in the U.S. were owned by nationals of other developed countries. Flows from developing to other developing countries also tend to be small. Based on our own calculations, during the 1990s the fraction of inflows of FDI originated from developed countries was 91% in Mexico, and roughly 80% in Argentina, Costa Rica, and Peru. See also Barba Navaretti and Venables (2004).

16. If management know-how and physical capital can move within the set of source coun-

Appendix III) with long data availability and low ratios of outward to inward stocks of FDI. We exclude net host countries with ratios of outward-to-inward stocks of FDI higher than .3 (such as Israel, Spain and Russia), because some of these countries are large sources of FDI to other host countries.

As an alternative measure of s^i, we use the fraction of wages paid by multinational firms relative to total wage payments in the host country. In our model, this ratio is equal to the share of labor controlled by foreign firm-embedded productivity. Producing this measure is complicated by the absence of data on total wage payments by multinationals in many host countries. However, if we assume that all foreign firms employ the same proportion of capital to labor, then the ratio of U.S.-to-total multinational wages payments is equal to the ratio of U.S.-to-total inward stocks of FDI. Given these considerations, our measure of the share of labor employed by foreign management is

(32)

$$s^i = \frac{\text{Wage payments by U.S. MNC in country } i}{\text{Total wage payments in country } i} \times \frac{\text{stock of inward FDI in country } i}{\text{stock of U.S. FDI in country } i}.$$

We can mitigate potential biases of FDI as a measure of foreign effective control with this alternative proxy for s^i if the relationship between FDI stocks and effective control does not systematically differ between U.S. and other source countries. We use data on total wages paid by U.S. multinational firms and stocks of outward U.S. FDI from the BEA, total stocks of inward FDI from Lane and Milesi-Ferretti (2006), and total wage compensation in host countries from the United Nations' National Account Statistics. Appendix C gives more details.

Table II displays the two shares s^i, as well as output-per-employee, employment, and capital-output ratio for each host country in our sample. All the

tries without facing geographic barriers or tax differences, then the equilibrium with multiple source countries coincides with the equilibrium in which sources countries are aggregate into a single country 1.

data corresponds to simple averages over the period 1996-2000. Columns 1–3 show that most net host countries are relatively poorer, smaller, and have lower capital-output ratios than the net source aggregate. Indeed, relative to source countries: (1) only Ireland, United Arab Emirates, and Saudi Arabia have higher output-per-worker; (2) only China and India are close or larger in size; and (3) only Thailand and Greece have higher capital-output ratios. Column 4 shows that a significant share of the capital stock in these host countries is controlled by foreign firms. The average capital-based share is 12.7%, and is as high as 45% in Ireland, and as low as 1% in United Arab Emirates. Column 5 reports the employment-based share, with an an average of 16.3% across our host countries. The correlation between the two alternative measures of the share is .5.

Our measures of taxes τ_F^i and τ_D^1 are constructed as effective, net-income taxes levied on firms, based on the notion that managers are the residual claimants of the firm. To measure net-income taxes on foreign firms, we follow Desai, Foley, and Hines (2004) and calculate the effective net income tax rates paid by foreign affiliates of U.S. multinationals in each host country. We use the surveys of U.S. Direct Investment from the BEA and measure τ_F^i as

$$\tau_F^i = \frac{\text{foreign income taxes}}{\text{net foreign income + foreign income taxes}}. \tag{33}$$

Gordon and Hines (2002) and Desai, Foley, and Hines (2004) argue that, albeit imperfect, this is an informative measure of the barriers to international firms. These taxes also proxy for other policy barriers to foreign firms.[17] Other details of the data are provided in Appendix C. Column 6 in Table 2 shows that the average tax over the period 1996-2000 is 34%, with significant variation across

17. For example, starting in 1989, Mexico eliminated some restrictions on foreign ownership of firms. For a detailed discussion of this policy change, see Perez-Gonzales (2005).

host countries. The values of τ_F^i range from 61% in United Arab Emirates and 57% in India, to 9% in Ireland.

To set the value of τ_D^1, we use the effective corporate tax rates calculated by Devereux, Griffith, and Klemm (2002). They adjust statutory tax rates for accelerated depreciation, tax credits, and debt in order to approximate the tax rates that are relevant for investment decisions. We set $\tau_D^1 = .29$, corresponding to the weighted average (using outward FDI stocks) of "average effective tax rates" for our set of net source countries over the period 1996-2000. We use average (as opposed to marginal), effective (as opposed to statutory), tax rates to be consistent with our measure of τ_F^i.

Worldwide taxation clauses and cross-border tax evasion cause some uncertainty about the effective taxes τ_F^i on foreign net income. Accordingly, we report sensitivity results using two alternative measures of τ_F^i. The first is based on the premise that worldwide taxation clauses imply a minimum tax rate τ_D^1 for country 1 firms, regardless on their location. The effective tax rate, $\tau_F^{M,i}$, in such case is

$$\tau_F^{M,i} \equiv \max\left\{\tau_D^1, \tau_F^i\right\}.$$

The second alternative is based on the premise that country 1 firms may manipulate the origin of profits and declare taxes in country 1 or in country i. In such case, the effective tax rate, $\tau_F^{m,i}$, is

$$\tau_F^{m,i} \equiv \min\left\{\tau_D^1, \tau_F^i\right\}.$$

Finally, we do not use direct measures of capital-income taxes, τ_K^i, but instead back-out their implied levels, using (21), which accounts for the observed capital/output ratios over the period $1996 - 2000$.

IV.B. Parameter Values

The parameters of the model are the depreciation rate δ, the discount factor β, the share of management know-how in the production function $1-\nu$, the share of physical capital $\alpha\nu$, and the within-country distribution of management skills $F(\cdot)$. The values of ν, α, and the shape of $F(\cdot)$ are key in determining both the static gains from reallocating management know-how across countries, and the extent to which the response of capital and the reallocation of individuals across occupations magnify these gains. We use information on the U.S. economy to guide our choice of these key parameters.

We choose the output share of capital so that the annual return to capital before taxes is equal to 5.5%. This is a weighted average of the annual returns on equity and corporate bonds in the U.S. over the period 1950-2005, calculated by Lustig, Van Nieuwerburgh, and Syverson (2007). The pre-tax return to capital in the model is $r_K - \delta = \alpha\nu\frac{Y}{K} - \delta$. Setting the period length to one year, and assuming $\delta = .06$ and $K/Y = 2.15$ (the average capital/output ratio in the U.S. over the period $1996 - 2000$), we obtain $\alpha\nu = .25$.

We set ν so that the share of non-management labor in output, $(1-\alpha)\nu$, is equal to 60%. This is the product of 67%, the average labor share in U.S. GDP over the period $1996 - 2000$ (calculated, using data from the BEA, as the ratio of employee compensation to GDP, net of indirect taxes, subsidies, and proprietor's income[18]), and 90%, the share of wage compensation in non-management occupations relative to total wage compensation in 2006 (wage compensation by occupation is calculated as the product of employment and average wage, using data from the Bureau of Labor Statistics). Using these two targets, we obtain $\alpha = .29$ and $\nu = .85$. Given the importance of these two parameters in determining the gains from international mobility of management

18. By substracting proprietor's income, we are assuming that proprietors and corporate firms use the same share of labor in output.

know-how, we also report results under $\nu = .8$, $\nu = .9$, and $\alpha\nu = .2$.[19]

We now discuss the choice of $F(\cdot)$. In our model, the amount of labor hired by a firm is proportional to its firm-embedded productivity x (regardless of the value of ν). If each firm is controlled by one manager, $F(\cdot)$ determines the shape of the size distribution of firms in a country under autarky, or in a source country that transfers a representative sample of its managers abroad. We set $F(\cdot)$ to be a Pareto distribution with unitary mean and slope parameter $b = 1.25$, so that the right-tail of the employment-based size distribution resembles the one for middle- and large-sized firms in the U.S (see Atkeson and Burstein [2007]). The parameter b also determines the elasticity of the occupation choice to inflows of foreign management. Using (26), it can be shown that that the elasticities of $\bar{X}^i$ and N^i with respect to s^i are increasing in b. In our sensitivity analysis, we consider higher and lower elasticity levels.

Finally, we set the discount factor to $\beta = (1.04)^{-1}$. Table III summarizes our baseline choice of parameter values.

IV.C. Inferred Country- and Firm-Embedded Productivities

Columns (7)-(10) in Table II report the values of Z^i/Z^i, $\left(\bar{X}^i/N^i\right) / \left(\bar{X}^1/N^1\right)$, R^i_{fixed}, and R^i_{flex} using the inference procedure, data and parameter values explained above. Column (7) shows that Z^i/Z^i is lower than one for all host countries except for Ireland, Saudi Arabia, and United Arab Emirates (these are the only three countries with higher output per worker than the source country conglomerate). Column (8) indicates that $\left(\bar{X}^i/N^i\right) / \left(\bar{X}^1/N^1\right)$ is lower than

19. The two alternative values for ν correspond to the range of values used in span-of-control models applied to U.S. data. See, for example, Atkeson, Kahn, and Ohanian (1996), Atkeson and Kehoe (2006), Cagetti and De Nardi (2006) and Guner, Ventura, and Xu (2006). The alternative value for $\alpha\nu$ is the average output share of reproducible capital reported by Caselli and Freyer (2006) for our overlapping set of countries.

one for all host countries. We can use these results to account for cross-country differences in output.

Output-per-worker of host countries relative to the source country is:

$$(34) \quad \frac{Y^i/N^i}{Y^1/N^1} = \left(\frac{Z^i}{Z^1}\right)\left(\frac{\bar{X}^i/N^i}{\bar{X}^1/N^1}\right)^{1-\nu}\left(\frac{1}{(1-s^i)\,X^1/\bar{X}^1}\right)^{1-\nu}\left(\frac{K^i/N^i}{K^1/N^1}\right)^{\alpha\nu}.$$

From this expression, we can evaluate the contribution of each of the following factors in accounting for cross-country differences in output-per-worker: (i) country-embedded productivity Z; (ii) domestic supply of firm-embedded productivity relative to workers $\bar{X}/N$; (iii) foreign inflow of firm-embedded productivity as proxied by the share of factors controlled by foreign firms s^i (a higher s^i and a lower $X^1/\bar{X}^1$ contribute to a higher output in country i); and (iv) capital-worker ratio K/N.

Columns (1)-(4) in Panel A, Table IV show that the gap in output-per-worker over the period 1996-2000 for source-relative-to-host countries can be decomposed as follows: 49% of the gap is accounted for by higher country-embedded productivities, 18% from higher domestic supply of firm-embedded productivities, and 35% from higher capital-worker ratios. Moreover, by importing foreign firm-embedded productivity, host countries close the gap by 2%.[20]

Columns (1)-(4) in Panel B report a variance decomposition (à la Klenow and Rodriguez-Clare [1997]) of the logarithm of output-per-worker across host countries. Differences in country-embedded productivity account for 54% of

20. Using equations (27), (28), and (34), we can obtain an expression for the contribution of firm-embedded relative to country-embedded productivities on output-per-worker for host relative to source countries,

$$\frac{\log\left(\frac{X^i/N^i}{X^1/N^1}\right)^{1-\nu}}{\log Z^i/Z^1} = \frac{(1-\nu)\left[\log\frac{1-\tau_F^i}{1-\tau_D^1} + \log\frac{Y^i/N^i}{Y^1/N^1}\right]}{(1-\alpha)\,\nu\log\left(\frac{Y^i/N^i}{Y^1/N^1}\right) + \alpha\nu\log\frac{Y^i/K^i}{Y^1/K^1} + (1-\nu)\log\frac{1-\tau_D^1}{1-\tau_F^i}}.$$

If $\tau_F^i = \tau_D^1$ and $K^i/Y^i = K^1/Y^1$ then, with $\nu = .85$ and $\alpha = .29$, the value of this ratio would be .25. Since in the data we observe $\tau_F^i > \tau_D^1$ and $K^i/Y^i < K^1/Y^1$, we obtain a higher value for this ratio of .33.

variance of output-per-worker, while differences in firm-embedded productivity and capital-labor ratios play a more minor role (16% and 30%, respectively).

These results suggest that firm-embedded productivity is roughly 1/3 as important as country-embedded productivity in accounting for cross-country differences in output-per-worker. Rows (2)-(4) and rows (6)-(8) report the results when we use our alternative measure of s^i (based on employment) and when we use alternative values of ν (.8 and .9). Notice that with the employment-based measure of s^i, the results are very similar, while the relative contribution of firm-embedded productivity grows as we lower ν.

We can also quantify the contribution of distortions in the world allocation of firm-embedded productivity and capital in accounting for cross-country differences in output-per-worker. In particular, expression (27) can be re-arranged as:

$$\frac{Y_t^i/N_t^i}{Y_t^1/N_t^1} = \left(\frac{Z^i}{Z^1}\right)^{\frac{1}{(1-\alpha)\nu}} \left(\frac{1-\tau_F^i}{1-\tau_D^1}\right)^{\frac{1-\nu}{(1-\alpha)\nu}} \left(\frac{K_t^i/Y_t^i}{K_t^1/Y_t^1}\right)^{\frac{\nu}{1-\nu}}. \tag{35}$$

In the absence of distortions in the world-allocation of firm-embedded productivity and capital ($\tau_F^i = \tau_D^1$ and $K_t^i/Y_t^i = K_t^1/Y_t^1$), differences in output-per-worker across countries arise only due to differences in country-embedded productivities.

We quantify the role of distortions in the world allocation of firm embedded-productivity and capital using our measures of τ_F^i and K_t^i/Y_t^i, and report results in columns (5)-(8) of Table IV. Country-embedded productivity is the leading factor, accounting for 81% of the gap in output-per-worker of source relative to host countries. Distortions in the world allocation of firm-embedded productivity and capital play a smaller role, accounting for 2% and 17% of this gap, respectively (see Panel A). Country-embedded productivities account for an even higher share (roughly 89%) of the variance of output-per-worker across

host countries (see Panel B). These results suggest that barriers to the mobility of firm-embedded productivity have a small role in accounting for the large observed difference between poor and rich countries in output-per-capita.[21] However, the output gains from eliminating these barriers could be substantial as a fraction of a country's initial output. Our policy counterfactuals serve to quantify these gains.

Columns (9) and (10) in Table II display the inferred ratios of autarky prices, R^i_{fixed} and R^i_{flex}, which are informative on the gains for host countries. These ratios are lower than one for all but four countries. This indicates that most countries in our sample are attractive hosts of foreign management know-how. Note that there are large differences across countries: the standard deviations of the logarithm of R^i_{fixed} and R^i_{flex} are 23% and 30%, respectively.

We can use expressions (29) and (30) to quantify the sources of variation in the inferred ratios R^i_{fixed} and R^i_{flex}. First, shares s^i and taxes τ^i_F account for 63% and 37% , respectively, of the average value of the logarithm of R^i_{fixed}. Second, shares s^i, taxes τ^i_F, and capital-output ratios K^i/Y^i account for 36%, 23%, and 41%, respectively, of the average value of the logarithm of R^i_{flex}. Hence, all three factors in (29) and (30) contribute largely to our inferred average autarky price of firm embedded-productivity in host relative to source countries. We also find that differences in K^i/Y^i and τ^i_F are more important than differences in s^i in accounting for the variation of R^i_{fixed} and R^i_{flex} across host countries.

21. Similarly, Waugh (2008) shows that cross-country differences in the intensity of international trade in goods have a small role in accounting for cross-country differences in output.

V. The Gains of Reallocating Firm-Embedded Productivity

Next, we quantify the output and welfare consequences of eliminating barriers to international flows of firm-embedded productivity. In particular, we use our model and the inferred values of $\bar{X}^i$ and Z^i to conduct a series of policy counterfactuals on τ_F^i.

Our first series of counterfactuals quantifies the gains of moving from "From autarky to undistorted mobility". We assume that initially all countries are in autarky, and then consider the consequences of opening up. Specifically, τ_F^i falls from 100% to $\tau_D^1 = 22\%$. We consider two cases: (1) each host country opens up unilaterally while the other host countries remain in autarky ($\tau_F^j =$ 100% for all $j \neq i$) and (2) all host countries open-up simultaneously. For these counterfactuals, we set $\tau_K^i = 0$ to abstract from distortions on capital accumulation, and assume that $\bar{K}_0^i = K_0^i$ so that current accounts initially are equal to zero.

Our second series of counterfactuals quantifies the gains of moving "From observed to optimal unilateral taxes". We assume that initially all countries set taxes τ_F^i and τ_D^1 at the observed 1996-2000 levels, capital-income tax taxes at the levels $\bar{\tau}_K^i$ backed out from (21) over the period 1996-2000, and $\bar{K}_t^i = K_t^i$. Then, we assume that each host country i sets $\tau_F^i = \tau_F^{i*}$ to maximize its welfare, assuming that all other taxes (τ_D^1, τ_K^j for all j, and τ_F^j for all $j \neq i$) remain unchanged.

We report steady state output gains, and welfare gains defined as the equivalent variation in consumption (i.e. the percentage change in the initial consumption path that makes consumers indifferent between the old and new policies). Welfare gains take into account the investment required to increase the capital

stock, and the transition dynamics due to variations in capital stocks and the worldwide return to capital r^*.[22]

To isolate the contribution of different margins, we consider three different cases: (1) fixed capital stocks in each country and every period at the levels in 1996-2000 (fixed K) and fixed occupation choices at the initial equilibrium levels (fixed OC); (2) flexible capital stocks each period at their equilibrium levels (flex K) and fixed OC; and (3) flex K and flexible occupation choices each period to their equilibrium levels (flex. OC).

V.A. From Autarky to Undistorted Mobility

Unilateral

Results are reported in Panel A, Table V. Columns (1)–(2) present the results under Case 1. The average gains across host countries are 4.7% for output and 2.2% for welfare. There is wide variation in the gains (standard deviation of 4.1% for output and 2.0% for welfare), ranging from 18% in output and 10% in welfare (Nigeria), to zero gains in four host countries with $R^i_{\text{fixed}} \geq 1$ (see Table III). Figure I, panel A, displays a strong negative relationship between output and welfare gains and the inferred ratios R^i_{fixed}, which summarize the relevant information on shares and taxes to assess the attractiveness of a given country as a host of foreign firm-embedded productivity. Given that the typical host country is relatively small, output in country 1 on average falls by only .1%, and welfare remains roughly unchanged.[23]

22. Within the period of the policy change, capital is reallocated across countries, but the world's aggregate capital stock is fixed. Along the transition to a new steady state, there are changes in the amount of capital owned and operated by each country, in the world's aggregate stock of capital, and in r^*_t. Changes in r^*_t also lead to changes over time in the world-allocation of firm-embedded productivity (unless all τ^i_K are equal, in which case s^i_t adjusts immediately to the new steady state level). In our policy counterfactuals, the worldwide return to capital r^*_t increases slightly along the transition, but never by more than 15 basis points. Our welfare numbers are very similar if we do not impose market clearing in the world market for capital and instead assume that r^*_t remains constant.

23. Ramondo (2006) shows that the gains from reductions in physical barriers to multina-

Columns (4)–(5) present the gains under Case 2. Inflows of firm-embedded productivity boost capital accumulation in host countries. On average, output and welfare gains increase to 11.1% and 4.5% respectively (with large standard deviations of 8.3% and 4.3%, respectively.). Figure I, panel B, illustrates the negative relationship between the gains to each country and R^i_{flex}. Countries with a lower R^i_{flex} stand to gain more by importing foreign firm-embedded productivity. Only Thailand, with $R^i_{\text{flex}} > 1$, does not gain from removing barriers to foreign firm-embedded productivity.

Columns (7)–(8) report the gains under Case 3. Reallocating individuals across occupations leads to higher average gains of 12.4% for output and 5% for welfare (with standard deviations of 9.3% and 4.7%, respectively).

Global

Panel B, Table V, presents the gains when all source countries lower τ^i_F simultaneously. Host countries gain less because now they are competing with each other to attract a limited supply of country 1's firm-embedded productivity. Average output and welfare gains for the host countries are, respectively, 3.6% and 1.6% under Case 1, 7.6% and 3.0% under Case 2, and 8.7% and 3.4% under Case 3.

In contrast to the unilateral case, global policy changes have a non-negligible impact on the source country. In Cases 1-3, output in country 1 falls by 1.4%, 3.5% and 3.4%, and worldwide output rises by .4%, .7% and .9%, respectively. Even if these policies setting $\tau^i_F = \tau^1_D$ maximize world output, welfare in country 1 falls because it loses part of its tax revenues to host countries. If we instead assume that new policies set $\tau^i_F = \tau^1_D = 0$ (so that firms from country 1 do not pay taxes in host countries) we obtain the same change in output in each country, but both source and host countries experience welfare gains.

tional production (as opposed to our policy barriers) can be significantly larger in a Ricardian model with non-rival firm-embedded productivity that leads to two-way flows of multinational production.

V.B. From Observed to Unilateral Optimal Taxes

Panel C, Table V, reports the implications for host countries of unilaterally setting τ_F^i at the optimal level τ_F^{i*} that maximizes their welfare, keeping all other taxes constant. The optimal tax τ_F^{i*}, displayed in columns (3), (6), and (9), is shaped by two forces. First, large countries set a high τ_F^{i*} to restrict the inflows of firm-embedded productivity and reduce its world price π_1. Second, countries with low capital-output ratios set a high τ_F^{i*} to restrict inflows of foreign firm-embedded productivity and to reduce the inefficiently high level of capital. When capital is fixed (Case 1), only the first force is operative. The biggest countries in our sample, China and India, set τ_F^{i*} at roughly 4%, and all other countries set τ_F^{i*} close to zero (the average level of τ_F^{i*} is 0.3%). If capital adjusts to its equilibrium level (Cases 2 and 3), countries with high (low) capital-output ratios find it optimal to set a positive (negative) level of τ_F^{i*}. The average τ_F^{i*} under Case 3 is -10%.

Columns (1)-(9) report average output and welfare gains in host countries of 7.9% and 1.9% under Case 1, 14.1% and 3.4% under Case 2, and 16.8% and 4.1% under case Case 3. There is large variation in the gains across host countries, which are now magnified by differences in the initial levels of τ_F^i.

V.C. Sensitivity Analysis

We now examine the sensitivity of our results to alternative measures of τ_F^i, τ_D^1, τ_K^i, and s_t^i, and to variations in the values of ν, α and b. For each variation, we first infer the values of Z^i and $\bar{X}_i$, and then compute the output and welfare gains of unilaterally reducing τ_F^i, "From Autarky to Undistorted Mobility", under Case 3. Row (1) of Table VI presents our baseline average output and welfare gains of 12.4% and 5.0%.

Rows (2) and (3) report the gains under our two alternative measures of taxes

τ_F^i. Under $\tau_F^{M,i} \equiv \max\left\{\tau_D^1, \tau_F^i\right\}$ the average output and welfare gains increase to 13.7% and 5.5%, while under $\tau_F^{m,i} \equiv \min\left\{\tau_D^1, \tau_F^i\right\}$ they fall to 7.9% and 2.8%. As expected, higher values of τ_F^i lead to lower inferred ratios of autarky prices R_{flex}^i, and higher gains from importing firm-embedded productivity.

Row (4) reports the gains if we impose equal marginal products of capital across countries. Here we are motivated by findings in Caselli and Freyer (2007) that marginal products of reproducible countries do not vary systematically across countries. To this end, we set $\tau_K^i = 0$, and infer Z^i and $\bar{X}_t^i$ assuming that capital-output ratios are equal across countries (instead of using our measured 1996-2000 capital stocks). This results in higher inferred values of R_{flex}^i because differences in capital-output ratios between source and host countries disappear. The average gains from our policy counterfactuals are smaller, but still sizeable (7.1% and 2.6%).

Row (5) reports the gains when we proxy s_t^i using the fraction of wages paid by multinationals. The average gains increase slightly, to 13.5% and 5.5%, because the average employment-based share is higher than the average capital-based share.

Rows (6) and (7) consider the sensitivity of our results to changes in the output share of management know-how, $1-\nu$. If we reduce ν to .8, the average gains increase to 17.2% and 6.9% for output and welfare. If we raise ν to .9, the gains fall to 8% and 3.2%.

Row (8) reports the gains if we reduce the output share of physical capital $\alpha\nu$ to .2. This is the average share of reproducible capital in output, as reported by Caselli and Freyer (2007) for the common set of countries in our samples. Average output and welfare gains fall to 10.1% and 4.1%, because of the reduced ability to complement inflows of firm-embedded productivity with capital accumulation.

Finally, row (9) displays the gains if we increase the slope parameter of the Pareto distribution of management skills to $b = 3$, which roughly triples the elasticity of $\bar{X}^i$ and N^i with respect to $1 - s^i$ (recall that Cases 1 and 2 set these elasticities to zero). With higher elasticities, the average output and welfare gains rise to 18.5% and 7.4%, respectively.

Overall, we conclude that the alternative parameterizations and measures of foreign-controlled inputs and taxes imply average gains in the same range as our baseline results (i.e. roughly 12% for output and 5% for welfare).

V.D. Two Extensions

As a final step, we consider two extensions of our model. First, we introduce locally provided intermediate management services. Second, we allow for productivity spillovers from foreign to domestic firms.

Local intermediate managers. The availability of qualified local management is often cited by foreign firms as an important criterion in the selection of host countries.[24] We extend our model to include intermediate management services that are locally provided by the domestic work force. The production function is

$$y = Z^i x^{1-\nu} \left(a^\gamma n^{1-\gamma-\alpha} k^\alpha\right)^\nu, \tag{36}$$

where a is the amount of intermediate management services available to the firm leader, and γ is the output share of intermediate management. In equilibrium, individuals with $e \leq \bar{e}_t^i$ are workers and individuals with $e > \bar{e}_t^i$ supply an aggregate amount of skills $\hat{x}^i L^i \int_{\bar{e}_t^i}^{\infty} e dF(e)$ that is split between intermediate management A_t^i and firm-embedded productivity $\bar{X}_t^i$.

24. See, for example, Larrain, Lopez-Calva and Rodriguez-Clare (2000). Antras, Garicano, and Rossi-Hansberg (2006b) also study the role of locally provided middle-level management in multinational activity.

In Appendix IV we show that our inference procedure pins down $Z^i \left(A_t^i\right)^{\gamma\nu}$ instead of Z^i. A bigger presence of foreign firm-embedded productivity gives rise to a reallocation of domestic firm leaders to intermediate manager and worker occupations ($\bar{X}_t^i$ falls, N_t^i and A_t^i increase), both of which complement the presence of foreign firm-embedded productivity. This additional margin for reallocation implies greater gains than in our baseline model, because firm leaders can redeploy their skills e when becoming intermediate managers. For example, if we set $\gamma = .1$ and keep the output share of capital and firm-embedded productivity unchanged, the average output and welfare gains for our set of host countries are 20.4% and 8.9% (see row (10) in Table VI).

Spillovers. The extent of productivity spillovers of foreign to domestic firms is the subject of an extensive empirical literature (see Keller [2004] for a survey). To explore the quantitative importance of spillovers in our model, we adapt the original formulation of Findlay (1978) and assume that average management skills $\hat{x}^i$ evolves according to

$$\hat{x}_{t+1}^i = \max\left\{\hat{x}_t^i \ , \ \left(\hat{x}_t^1\right)^{\zeta s_t^i}\left(\hat{x}_t^i\right)^{1-\zeta s_t^i}\right\}. \tag{37}$$

The parameter $\zeta \in [0,1]$ governs the degree to which foreign know-how diffuses to local firm-leaders. In our baseline model, $\zeta = 0$, so $\hat{x}_t^i$ remains constant over time. If instead $\zeta > 0$, then local-firm management skills increase over time (if $\hat{x}^1 > \hat{x}^i$) as a by-product of hosting foreign firms.[25] Over time, the presence of foreign firm-embedded productivity declines (and eventually disappears) as foreign firms breed their own domestic competition in the future.

Spillovers can have a sizeable impact on the welfare implications of hosting foreign-embedded productivity. If we set $\zeta = 1$ in our baseline parameterization,

25. Here, as in Findlay (1978), the diffusion of firm-leading skills is a costless by-product of hosting foreign firms. Monge-Naranjo (2007) studies models in which the cost and returns to diffusion of skills are considered explicitly.

the average welfare gains increase to 17.3%, as reported in row (11) in Table VI. Welfare gains are bigger because the returns to a higher firm-embedded productivity remain in the host country, instead of being repatriated to the source country.

VI. Concluding Remarks

In this paper, we construct a model of cross-country income differences to investigate the aggregate consequences of reallocating firm management know-how from developed to developing countries. Using the model and aggregate data, we decompose cross-country productivity differences into internationally mobile and immobile components. Based on this decomposition, we conduct policy counterfactuals that eliminate tax barriers to foreign control of local factors of production. These counterfactuals imply average gains for host countries on the order of 12% for output and 5% for welfare (with wide variation across countries).

Our framework allows us to back-out the relative supplies of firm-embedded productivity that can account for observed measures of foreign-controlled inputs in developing countries at a point in time. This paper is silent about the origins of cross-country differences in the endowments of management know-how. An important task for future research is to quantify the gains of reallocating firm-embedded productivity across countries in models in which management know-how can be accumulated over time.

Our aggregate quantitative framework does not address a number of interesting issues related to multinational activity, such as differences across countries, sectors, and firms in the organization of production, financial structure, and international trade in goods, or the existence of multiple types of management know-how. Future research should provide a framework for accommodating

some of these features and, with more detailed data at the sector and firm level, provide a better understanding of the differences in country- and firm-embedded productivities.

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Appendix I: Partial Mobility and Partial Non-Rivalry

This appendix incorporates geographic barriers and partial non-rivalry into our basic model of Section II. To capture geographic barriers, we assume that only a fraction $0 < \theta \leq 1$ of the firm-management skills transferred from the source country reaches the host country. A fraction $1 - \theta$ is lost, due either to geographic and cultural barriers in the host country, or to the lost connections and local knowledge in the source country. To capture non-rival elements, we assume that the source country loses only a fraction $0 < \lambda \leq 1$ of each unit of firm-embedded productivity exported to a foreign country. Our basic model is the special case with $\theta = \lambda = 1$.

Denoting by X^M the units of firm-embedded productivity that are reallocated from country 1 to country 2, the total amount of firm-embedded productivity operating in each country is

$$X^1 = \bar{X}^1 - \lambda X^M \tag{38}$$

$$X^2 = \bar{X}^2 + \theta X^M. \tag{39}$$

For any X^M, aggregate outputs are still given by (2).

Given taxes τ_D^1 and τ_F^2, the equilibrium condition that pins down X^M is

$$(40) \qquad \left(1-\tau_D^1\right)\pi^1 = \left(1-\tau_F^2\right)\theta\pi^2 + (1-\lambda)\left(1-\tau_D^1\right)\pi^1.$$

In equilibrium, the net-of-tax return to a unit of firm-productivity operating at full efficiency in country 1 must equal the return to operating $(1-\lambda)$ in country 1 and θ units in country 2. This equilibrium condition can be simplified to

$$(41) \qquad \lambda\left(1-\tau_D^1\right)\pi^1 = \theta\left(1-\tau_F^2\right)\pi^2.$$

In addition, if $\theta^2\left(1-\tau_F^2\right)/\left(1-\tau_D^1\right) \leq \lambda^2\left(1-\tau_D^2\right)/\left(1-\tau_F^1\right)$, then there are no flows of firm-embedded productivity from country 2 to country 1, and $X^M > 0$.

Following the same logic as in Section II, in an interior equilibrium the share of labor in country 2 that is controlled by country 1 firm-embedded productivity is

$$(42) \qquad s = \frac{1 - \frac{\lambda\bar{X}^2/N^2}{\theta\bar{X}^1/N^1}\left(\frac{1-\tau_D^1}{1-\tau_F^2}\frac{\lambda^{1-\nu}Z^1}{\theta^{1-\nu}Z^2}\right)^{1/\nu}}{1+\frac{\lambda\bar{X}^2}{\theta\bar{X}^1}}.$$

Note that s is increasing in θ (i.e. decreasing in geographic barriers) and decreasing in λ (i.e. decreasing in the rival component of firm-management skills). Observe also that θ and λ impact s only through $\frac{\lambda^{1-\nu}Z^1}{\theta^{1-\nu}Z^2}$ and $\frac{\bar{X}^2\lambda}{\bar{X}^1\theta}$.

We can obtain an expression for $\frac{\theta^{1-\nu}Z^2}{\lambda^{1-\nu}Z^1}$ in terms of relative per-capita output levels and taxes that coincides with the one used to infer Z^1/Z^2 in the basic model (see (10)):

$$(43) \qquad \frac{\theta^{1-\nu}Z^2}{\lambda^{1-\nu}Z^1} = \left(\frac{Y^2/N^2}{Y^1/N^1}\right)^{\nu}\left(\frac{1-\tau_D^1}{1-\tau_F^2}\right)^{1-\nu}.$$

We can also obtain an expression for $\frac{\bar{X}^2\lambda}{\bar{X}^1\theta}$ in terms of observable data that coincides with the one used to infer $\bar{X}^2/\bar{X}^1$ in the basic model (see (11)):

$$\frac{\bar{X}^2\lambda}{\bar{X}^1\theta} = \frac{1-s}{\left(\frac{Y^1}{Y^2}\right)\left(\frac{1-\tau_D^1}{1-\tau_F^2}\right)+s}. \tag{44}$$

In this extended model, we can infer only relative country- and firm-embedded productivities normalized by the geographic barriers and rival components of firm embedded productivity. The right-hand side of (43) and (44) coincides with the right-hand side of (10) and (11) of the basic model, and hence do not depend on θ or λ.

We can also infer $Z^1\left(\bar{X}^1\right)^{1-\nu}$ and $Z^2\left(\bar{X}^2\right)^{1-\nu}$ using the equilibrium expressions for aggregate output

$$Y^1 = Z^1\left(\bar{X}^1\right)^{1-\nu}\left(1-\frac{s}{1-s}\frac{\lambda\bar{X}^2}{\theta\bar{X}^1}\right)^{1-\nu}\left(N^1\right)^{1-\nu} \tag{45}$$

$$Y^2 = Z^2\left(\frac{\bar{X}^2}{1-s}\right)^{1-\nu}\left(N^2\right)^{\nu}. \tag{46}$$

With observations on Y^i, N^i, s, τ_D^1 and τ_F^2 we can infer the values of $\frac{\lambda^{1-\nu}Z^1}{\theta^{1-\nu}Z^2}$, $\frac{\bar{X}^2\lambda}{\bar{X}^1\theta}$, $Z^1\left(\bar{X}^1\right)^{1-\nu}$ and $Z^2\left(\bar{X}^2\right)^{1-\nu}$, and then solve for the equilibrium under any tax rates τ_D^1 and τ_F^2. As long as θ and λ remain constant, the equilibrium allocations are invariant to their particular level. Therefore, without loss of generality, we assume $\theta = \lambda = 1$.

The previous results also apply in the one source-multiple hosts model. Moreover, the results also extend to a multiple sources-multiple hosts model with different geographic barriers across pairs of source and host countries. Assume that tax differences and geographic barriers are negligible within the set of source countries, and only a fraction θ_j^i of the firm-management skills from

source country j arrives to host country i. In this case, each host country i will receive management flows only from the source country j with the lowest θ_j^i. Then, setting $\theta^i = \min_j \left\{\theta_j^i\right\}$, the results above follow.

Appendix II: Computing the Quantitative Model

We now describe our algorithm to solve for the equilibrium, given taxes $\left\{\tau_D^1, \tau_F^i, \tau_D^i\right\}$ and initial conditions $\left\{\bar{K}_0^i\right\}$.

1. Guess a sequence of worldwide return to capital $\{r_t^*\}_{t=0}^T$, where T is sufficiently large.

2. For each $0 \leq t \leq T$:

a. Guess X_t^1.

b. Solve for N_t^1, $\bar{X}_t^1$, X_t^1, K_t^1, Y_t^1, $\bar{e}_t^1$, s_t^1, w_t^1, r_{Kt}^1 and π_t^1 using the expressions for N_t^1, $\bar{X}_t^1$ and aggregate output (13), the equilibrium conditions for capital and occupation choice (21), (26), and the equilibrium expressions for π_t^1, w_t^1, and r_{Kt}^1 given by (3) and (18).

c. Solve for N_t^i, $\bar{X}_t^i$, X_t^i, K_t^i, Y_t^i, $\bar{e}_t^i$, s_t^i, w_t^i, r_{Kt}^i and π_t^i for all $i > 1$, using the definitions of N_t^i and $\bar{X}_t^i$, the expression for aggregate output (13), the definition of s_t^i, the equilibrium condition for s_t^i (25), the equilibrium conditions for capital and occupation choice (21), (26), and the equilibrium π_t^i, w_t^i and r_{Kt}^i given by (3) and (18).

d. Repeat steps (a)-(c) until the world adding-up constraint (16) is satisfied.

3. Solve for a new sequence of interest rates $\{\hat{r}_t^*\}_{t=0}^T$ that clears the world market for capital, given the allocations obtained in step (2).

a. Find the sequence of consumption $\left\{C_t^i\right\}_{t=0}^\infty$ in each country that satisfy the Euler equations $\left(C_t^i\right)^{-1} = \beta\left(1 + \hat{r}_{t+1}^*\right)\left(C_{t+1}^i\right)^{-1}$, and the intertemporal budget

constraint

$$(47) \qquad \sum_{t=0}^{\infty} \frac{C_t^i}{\hat{R}_t^*} = \sum_{t=0}^{\infty} \frac{Y_t^i + \Xi_t^i - K_{t+1}^i + (1-\delta) K_t^i}{\hat{R}_t^*} + (1 + r_0^*) \left(\bar{K}_0^i - K_0^i\right),.$$

where $\hat{R}_t^* \equiv \prod_{j=1}^{t-1} \left(1 + \hat{r}_j^*\right)$ for $t \geq 1$. In deriving expression (47), we imposed a transversality condition on net capital holdings $\bar{K}_t^i - K_t^i$. We can truncate the intertemporal budget constraint at T and assume that the allocations are time invariant from T onwards.

b. Back-out the level $\left\{\bar{K}_{t+1}^i\right\}$ from the resource constraints (23).

c. Solve for $\{\hat{r}_t^*\}_{t=0}^T$ that satisfies condition (17) for $0 \leq t \leq T$.

4. If $\{\hat{r}_t^*\}_{t=0}^T$ is sufficiently close to $\{r_t^*\}_{t=0}^T$ stop, otherwise repeat steps (2) and (3) using $r_t^* = \hat{r}_t^*$ as the initial guess.

Appendix III: More Details of the Data

Country 1 is an aggregate of the set of net-source countries displayed in Table 1 for the period 1996-2000, excluding Kuwait and Taiwan due to missing information. The set of 15 net-source countries that form country 1 includes Canada, Denmark, Finland, France, Germany, Italy, Japan, Republic of Korea, Netherlands, Norway, South Africa, Sweden, Switzerland, United Kingdom, and United States.

Our set of host countries $i = 2, ..., 32$ includes Argentina, Bolivia, Botswana, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, Greece, Guatemala, Honduras, Hungary, India, Indonesia, Ireland, Mexico, New Zealand, Nigeria, Paraguay, Peru, Philippines, Poland, Saudi Arabia, Thailand, Turkey, United Arab Emirates, Uruguay, Venezuela, and Zimbabwe.

The stocks of FDI in Lane and Milesi-Ferreti (2006) are denominated in U.S. dollars, and calculated using information on initial stocks, and annual FDI flows

in U.S. dollars from the Balance of Payments, corrected for fluctuations in real exchange rates with the U.S. This methodology is described in detail in pages 6-7 in Lane and Milesi-Ferreti (2006), and pages 291-292 in Lane and Milesi-Ferreti (2001). Capital depreciation is accounted for implicitly in measures of FDI flows as a negative entry in undistributed profits. For consistency, our measure of capital in (31) is computed using the same perpetual inventory method to construct initial capital stocks denominated in U.S. dollars, and then using U.S. dollar investment values corrected for fluctuations in the real exchange rate and an annual depreciation of 6%. Investment rates in local prices are obtained from PWT 6.2, and U.S. dollar GDPs and CPI-based real exchange rates between the U.S. and host countries are obtained from the World Bank Development Indicators.

For our employment-based measure of s_t^i, we measure total wage payments in host countries using information on 'Compensation of Employees' reported in the United Nation's national account statistics. The measure is available only for 21 of the 31 host countries. For the remaining countries (Dominican Republic, Ecuador, Guatemala, Indonesia, Nigeria, Paraguay, Saudi Arabia, Turkey, United Arab Emirates, Uruguay, and Zimbabwe), we assume that the ratio of compensation of employees to GDP is equal to the average of the 21 host countries in our sample for which we have data.

Our measure of τ_F^i is calculated as arithmetic average for the period 1996-2000 of the expression in (33). We exclude country-year observations for which the resulting value is either negative or higher than 1. The BEA does not report the information needed to compute τ_F^i for 5 of our host countries so we use the tax rates of neighboring countries. For Bolivia we use the average of Argentina, Brazil, Chile, Colombia, Ecuador, Peru, and Venezuela; for Paraguay and Uruguay we use the average of Argentina and Brazil (the other Mercosur

countries); and for Botswana and Zimbabwe we use South Africa's rate.

We set τ_D^1 using the average effective corporate tax rates calculated by Devereux, Griffith, and Klemm (2002) and reported in http://www.ifs.org.uk/data/internationaltaxdata.zip, sheet A5. In computing the weighted average tax rate across our set of net-source countries, we exclude Denmark, South Africa, and South Korea, which are not included in this dataset. We also consider in our sensitivity analysis using the marginal effective corporate tax rates calculated by these authors.

Appendix IV: Local Intermediate Managers

Aggregate output in each country is

$$Y_t^i = Z^i \left(A_t^i\right)^{\gamma\nu} \left(X_t^i\right)^{1-\nu} \left(K_t^i\right)^{\alpha\nu} \left(N_t^i\right)^{(1-\gamma-\alpha)\nu}, \tag{48}$$

where A_t^i is the domestic supply of intermediate management services.

The equilibrium prices of intermediate management services and firm-embedded productivity are $\upsilon_t^i = \nu\gamma Y_t^i / A_t^i$ and $\pi_t^i = (1-\nu) Y_t^i / X_t^i$, respectively. In an interior equilibrium, $\upsilon_t^i = \pi_t^i$, since individuals must be indifferent between (1) using their skills to lead firms and (2) providing intermediate managerial services. The threshold $\bar{e}_t^i$ is defined by $w_t^i = \hat{x}^i \bar{e}_t^i \pi_t^i$. Using these two conditions and the adding-up constraint $\bar{X}_t^i + A_t^i = \hat{x}^i L^i \int_{\bar{e}_t^i}^{\infty} e dF(e)$, for all hosts:

$$\frac{\int_{\bar{e}_t^i}^{\infty} e dF(e)}{\bar{e}_t^i F\left(\bar{e}_t^i\right)} = \frac{\nu\gamma + (1-\nu)\left(1 - s_t^i\right)}{(1-\gamma-\alpha)\nu}, \qquad \text{and} \tag{49}$$

$$A_t^i = \frac{\gamma}{(1-\gamma-\alpha)} \hat{x}^i \bar{e}_t^i F\left(\bar{e}_t^i\right) L^i. \tag{50}$$

A rise in s_t^i leads to an increase in $\bar{e}_t^i$ (from (49)), an increase in the domestic supply of labor $N_t^i = F\left(\bar{e}_t^i\right) L^i$, and an increase in the supply of managerial services A_t^i (from (50)). From the adding-up constraint, the domestic supply of firm-embedded productivity $\bar{X}_t^i$ must fall.

The equilibrium share of inputs controlled by foreign firms is given by (25), where $\tilde{Z}_t^i \equiv Z^i \left(A_t^i\right)^{\gamma\nu}$ takes the place of Z^i. An increase in the supply of managerial services raises $\tilde{Z}_t^i$, and reinforces the inflow of foreign firms.

Following our inference procedure, we obtain $\tilde{Z}_t^i / \tilde{Z}_t^1$ and $\bar{X}_t^i / \bar{X}_t^1$ using (27) and (28), where $\tilde{Z}_t^i$ takes the place of Z^i. With assumptions on $F(\cdot)$ and γ, we can then determine Z^i.

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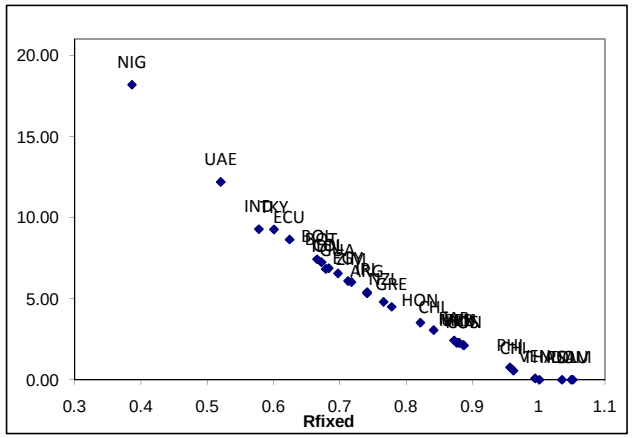
Table III: Parameter Values

Parameter	**Value**	**Target**
Depreciation rate (δ)	.06	–
Discount factor (β)	1/1.04	–
Output share of capital ($\alpha\nu$)	.25	U.S. annual pre-tax return on capital = 5.5%
Output share of management know-how (ν)	.85	U.S. non-management labor share in output = 60%.
Slope of Pareto distribution of management skills (b)	1.25	Slope of U.S. employment-based firm size distribution = $-.25$

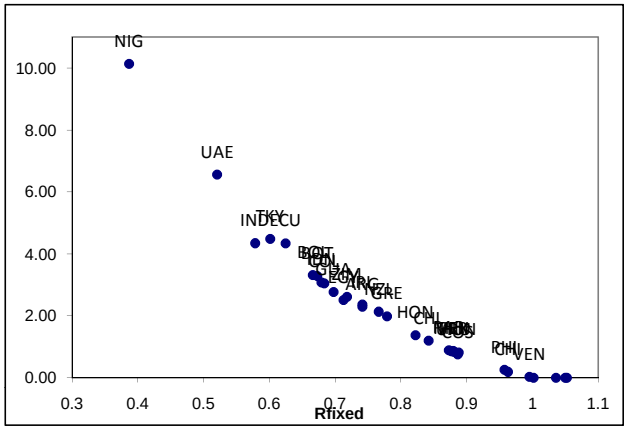
Figure I: Policy Counterfactuals, From Autarky to Undistorted Mobility

Panel A: Fixed Capital, Fixed OC (Case 2)

Output Gains

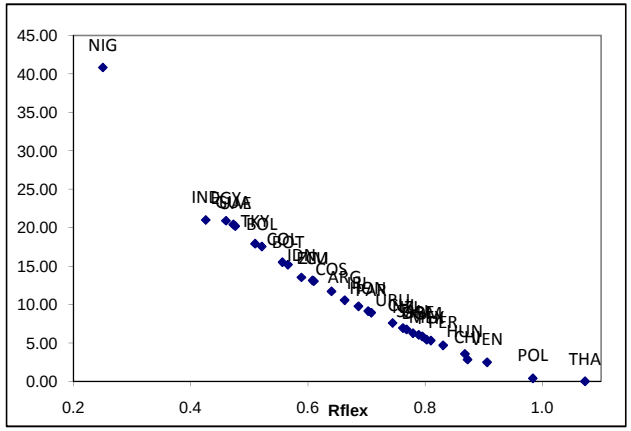


Welfare Gains



Panel B: Flexible Capital, Fixed OC (Case 2)

Output Gains



Welfare Gains

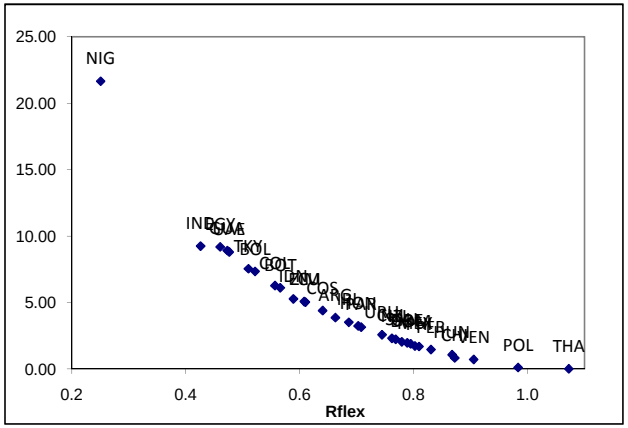


Table I: Net Sources and Net Hosts of Foreign Direct Investment

Stock of FDI Assets / Stock of FDI Liabilities, Average 1996-2000

Japan	7.99	Papua New Guinea	0.15
Kuwait	6.30	Latvia	0.15
Taiwan	2.96	Ghana	0.14
Switzerland	2.16	Thailand	0.14
Finland	1.98	Indonesia	0.13
Sweden	1.86	Estonia	0.13
Germany	1.59	Burkina Faso	0.12
Italy	1.56	Senegal	0.12
United Kingdom	1.54	Kenya	0.12
France	1.46	Philippines	0.12
Norway	1.44	Turkey	0.12
Netherlands	1.43	Moldova	0.11
Korea	1.43	Slovak Republic	0.11
South Africa	1.26	Morocco	0.10
Denmark	1.24	Malta	0.10
Canada	1.12	Cyprus	0.09
United States	1.10	China	0.09
Iceland	1.01	Saudi Arabia	0.09
Gabon	0.89	Paraguay	0.09
Hong Kong	0.83	India	0.09
Belgium	0.79	Algeria	0.09
Austria	0.78	Togo	0.08
Australia	0.71	Iran	0.08
Spain	0.70	Pakistan	0.07
Israel	0.59	Mali	0.07
Russia	0.59	Azerbaijan	0.06
Lebanon	0.56	Mexico	0.06
Singapore	0.56	Botswana	0.06
Brazil	0.55	Benin	0.06
Swaziland	0.50	Qatar	0.06
United Arab Emirates	0.44	Bulgaria	0.06
Ethiopia	0.42	El Salvador	0.06
Portugal	0.40	Madagascar	0.06
Jamaica	0.38	Czech Republic	0.05
Malaysia	0.37	Poland	0.05
Niger	0.33	Romania	0.05
Côte d'Ivoire	0.32	Namibia	0.04
Bahrain	0.31	Peru	0.04
Mauritius	0.30	Kyrgyz Republic	0.04
Ireland	0.30	Hungary	0.04
Venezuela	0.27	Lao	0.03
Zimbabwe	0.27	Uruguay	0.03
Uganda	0.26	Egypt	0.03
Greece	0.24	Malawi	0.02
New Zealand	0.24	Costa Rica	0.02
Slovenia	0.23	Ecuador	0.02
Fiji	0.23	Bangladesh	0.02
Nigeria	0.20	Trinidad and Tobag	0.02
Brunei	0.19	Guinea	0.02
Cameroon	0.19	Dominican Republi	0.02
Argentina	0.18	Sri Lanka	0.02
Chile	0.18	Haiti	0.01
Albania	0.17	Lithuania	0.01
Cambodia	0.16	Ukraine	0.01
Chad	0.16	Belarus	0.01
Colombia	0.16	Oman	0.01
		Congo	0.01
		Bolivia	0.01

Source: Lane and Milesi-Ferretti (2006).

Table II: Aggregate Data for Net-Host Countries, 1996-2000

	1	2	3	4	5	6	7	8	9	10
	Data, 1996-2000						**Baseline Inference**			
Host Country	Y^i/L^i	L^i	K^i/Y^i	s^i	s^i	τ_F^i	Z^i/Z^1	$(\bar{X}^i/N^i)/(\bar{X}^1/N^1)$	R^i_{fixed}	R^i_{flex}
	(as a fraction of source country agglomerate)			capital	employment					
Argentina	0.57	0.035	0.70	0.087	0.132	0.41	0.80	0.41	0.74	0.66
Bolivia	0.14	0.008	0.44	0.314	0.172	0.32	0.38	0.09	0.67	0.52
Botswana	0.30	0.002	0.57	0.120	0.346	0.45	0.57	0.19	0.67	0.57
Chile	0.54	0.014	0.70	0.230	0.137	0.22	0.74	0.44	0.84	0.76
China	0.11	1.801	0.73	0.089	0.092	0.23	0.29	0.11	0.96	0.87
Colombia	0.28	0.040	0.52	0.071	0.103	0.46	0.57	0.19	0.68	0.56
Costa Rica	0.39	0.003	0.36	0.202	0.092	0.21	0.71	0.33	0.89	0.64
Dominican Republic	0.27	0.008	0.42	0.141	0.173	0.12	0.55	0.28	1.05	0.79
Ecuador	0.23	0.012	0.89	0.175	0.117	0.46	0.44	0.14	0.62	0.61
Egypt	0.23	0.061	0.26	0.134	0.088	0.41	0.59	0.16	0.71	0.46
Greece	0.60	0.011	1.03	0.042	0.271	0.40	0.75	0.46	0.78	0.79
Guatemala	0.21	0.011	0.30	0.133	0.117	0.42	0.54	0.14	0.70	0.47
Honduras	0.12	0.005	0.61	0.087	0.382	0.34	0.32	0.10	0.82	0.70
Hungary	0.43	0.012	0.90	0.165	0.321	0.24	0.61	0.37	0.89	0.87
India	0.11	1.026	0.39	0.020	0.029	0.57	0.36	0.06	0.58	0.43
Indonesia	0.16	0.250	0.64	0.051	0.026	0.48	0.38	0.11	0.68	0.59
Ireland	1.02	0.004	0.72	0.451	0.218	0.09	1.06	0.69	0.74	0.69
Mexico	0.37	0.095	0.75	0.088	0.200	0.30	0.59	0.32	0.88	0.80
New Zealand	0.78	0.005	0.96	0.225	0.397	0.30	0.87	0.57	0.77	0.77
Nigeria	0.05	0.113	0.24	0.408	0.461	0.55	0.26	0.02	0.39	0.25
Paraguay	0.27	0.005	0.52	0.078	0.037	0.31	0.54	0.23	0.87	0.71
Peru	0.22	0.023	0.82	0.099	0.174	0.29	0.42	0.19	0.88	0.83
Philippines	0.17	0.076	0.59	0.079	0.120	0.24	0.39	0.16	0.96	0.81
Poland	0.31	0.048	0.84	0.055	0.113	0.20	0.50	0.31	1.04	0.98
Saudi Arabia	1.09	0.015	0.39	0.099	0.120	0.15	1.29	1.12	1.05	0.78
Thailand	0.22	0.088	1.21	0.065	0.125	0.22	0.38	0.22	1.00	1.07
Turkey	0.24	0.074	0.60	0.021	0.065	0.55	0.51	0.14	0.60	0.51
United Arab Emirates	1.10	0.003	0.76	0.011	0.039	0.61	1.24	0.57	0.52	0.48
Uruguay	0.48	0.004	0.59	0.069	0.056	0.31	0.73	0.42	0.88	0.74
Venezuela	0.37	0.022	0.73	0.090	0.205	0.20	0.58	0.36	0.99	0.91
Zimbabwe	0.14	0.013	0.60	0.050	0.140	0.45	0.36	0.10	0.72	0.61
Average	0.37	0.125	0.64	0.127	0.163	0.34	0.59	0.29	0.79	0.68
Median	0.27	0.014	0.61	0.089	0.125	0.31	0.55	0.22	0.78	0.70
Standard Deviation	0.29	0.362	0.23	0.105	0.114	0.14	0.26	0.23	0.16	0.18

Table IV: Accounting for Cross-Country Differences in Output per Worker

		1	2	3	4	5	6	7
		Decomposition in Terms of Factors of Production				**Decomposition in Terms of Policy Distortions**		
		Contribution of:				Contribution of:		
	Panel A: Differences between Host and Source Countries, 1996-2000 (average host versus source)	$\left(\frac{Z^i}{Z^1}\right)$	$\left(\frac{\tilde{X}^i/N^i}{\tilde{X}^1/N^1}\right)^{1-\nu}$	$\left(\frac{1}{(1-s^i)X^1/\tilde{X}^1}\right)^{1-\nu}$	$\left(\frac{K^i/N^i}{K^1/N^1}\right)^{\alpha\nu}$	$\left(\frac{Z^i}{Z^1}\right)^{\frac{1}{(1-\alpha)\nu}}$	$\left(\frac{1-\tau_F^i}{1-\tau_D^1}\right)^{\frac{1-\nu}{(1-\alpha)\nu}}$	$\left(\frac{K_t^i/Y_t^i}{K_t^1/Y_t^1}\right)^{\frac{\nu}{1-\nu}}$
1	Benchmark	48.9%	18.4%	-2.3%	34.9%	81.1%	1.9%	17.0%
2	Employment-based shares	49.0%	19.1%	-2.9%	34.9%	81.1%	1.9%	17.0%
3	$\nu = 0.8$	45.6%	24.5%	-3.0%	32.8%	80.3%	2.7%	17.0%
4	$\nu = 0.9$	52.2%	12.3%	-1.5%	37.0%	81.7%	1.2%	17.1%
	Panel B: Variation within Host Countries, 1996-2000 (variance-covariance decomposition)							
5	Benchmark	53.9%	16.4%	-0.03%	29.7%	89.3%	2.3%	8.4%
6	Employment-based shares	53.9%	16.7%	-0.3%	29.7%	89.3%	2.3%	8.4%
7	$\nu = 0.8$	50.2%	21.9%	0.0%	28.0%	88.3%	3.3%	8.4%
8	$\nu = 0.9$	57.6%	10.9%	0.0%	31.5%	90.1%	1.5%	8.4%

Table V: Policy Counterfactuals

	1	2	3	4	5	6	7	8	9
	Fixed K and Fixed OC			**Flex K and Fixed OC**			**Flex K and Flex OC**		
	Output	Welfare		Output	Welfare		Output	Welfare	
Panel A: From Autarky to Undistorted Mobility: Unilateral									
Host countries									
Average	4.7	2.2		11.1	4.5		12.4	5.0	
Median	4.5	2.0		9.1	3.2		10.4	3.6	
Standard Deviation	4.1	2.2		8.3	4.3		9.3	4.7	
Source countries	-0.05	-0.01		-0.16	-0.03		-0.18	-0.04	
World	0.01			0.04			0.05		
Panel B: From Autarky to Undistorted Mobility: Global									
Host countries									
Average	3.6	1.6		7.6	3.0		8.7	3.4	
Median	3.1	1.3		5.3	1.7		6.2	1.9	
Standard Deviation	3.8	2.0		7.9	3.8		9.0	4.2	
Source countries	-1.4	-0.4		-3.5	-0.7		-4.2	-0.9	
World	-0.1			0.9			1.1		
Panel C: From Observed to Optimal Taxes: Unilateral									
Host countries			Optimal Tax			Optimal Tax			Optimal Tax
Average	7.9	1.9	0.3	14.1	3.4	-10.2	16.8	4.1	-10.2
Median	6.7	1.2	0.0	12.9	2.5	-10.5	15.8	3.1	-10.5
Standard Deviation	4.2	1.7	1.0	6.9	2.8	8.0	7.9	3.3	7.9
Source countries	-0.10	-0.03		-0.19	-0.04		-0.24	-0.05	
World	-0.01			-0.02			-0.02		

Table VI: Policy Counterfactuals, Sensitivity Analysis

		1	2	3	4
	From Autarky to Undistorted Mobility, Unilateral, Flex K and Flex OC				
		Output		**Welfare**	
		Average	Median	Average	Median
1	Benchmark parameters, shares, and taxes	12.4	10.4	5.0	3.6
	Alternative Measures of Taxes				
2	$\tau_F^{M,i} \equiv \max\{\tau_D^1, \tau_F^i\}$	13.7	12.7	5.5	4.6
3	$\tau_F^{m,i} \equiv \min\{\tau_D^1, \tau_F^i\}$	7.9	6.7	2.8	2.1
4	Equalized marginal product of capital	7.1	5.3	2.6	1.6
5	Employment-based shares	13.5	12.0	5.5	4.3
	Alternative Parameter Values				
6	$\nu = 0.8$	17.2	14.1	6.9	4.8
7	$\nu = 0.9$	8.0	6.9	3.2	2.4
8	$\alpha\nu = 0.2$	10.1	7.9	4.1	2.7
9	$b = 3$	18.5	18.4	7.4	6.3
10	Local Intermediate Managers	20.4	17.9	8.9	6.0
11	Spillovers	17.3	10.1	14.5	8.7