On Multinational Firms and the Accumulation of Skills*

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Comments welcome.

Abstract

In this paper I study the impact of multinational firms on the aggregate accumulation of skills in a developing country. Within the context of a simple general equilibrium environment, I examine three different growth models: (a) an exogenous growth model, (b) an endogenous growth model with an externality in the formation of skills and (c) an endogenous growth model in which skills are internally produced in the firm. In models (a) and (b), multinational firms impact the skill formation of the country via "spillovers", the subject of a vast empirical literature. In model (c), there are no externalities as skill transfers are fully internalized. I show that spillovers are neither necessary nor sufficient for multinational firms to propel a developing country to catch up with developed countries.

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1. Introduction

Does the presence of foreign firms help a developing country build up its productive skills? Can such contribution lead a developing country to fully catch up with developed countries? If so, Are externalities sufficient? Are they necessary? Should a government subsidize foreign firms? How? The purpose of this paper is to answer these questions using simple general equilibrium growth models.

I compare the dynamic behavior of a developing country that is open with one that is closed to hosting firms from developed countries. I examine three different models of growth: (a) an exogenous growth model; (b) an endogenous growth model with an externality in the accumulation of skills; and (c) an endogenous growth model where the engine of growth is the intra-firm formation of skills. For closed economies, the three models are observationally equivalent. For open economies, they produce starkly different dynamics.

There is a vast literature on the diffusion of productivity across countries. For the most part, the attention has been pointed at the diffusion of technological knowledge and the role played by the trade of goods. [1] By its very nature, technological knowledge is a "non-rival" factor in the sense that its use by one party does not congest the use by others. Once it is produced, a non-rival factor could be used at negligible cost by any number of agents.[2] Yet, much of the technological knowledge requires properly skilled individuals to be productive. Skills can limit productivity even when technology is available. Contrary to technology, skills are "rival" factors which have to be allocated among mutually exclusive tasks, firms, industries, regions or countries.

In this paper I focus on the accumulation of skills and the impact of foreign firms. The scarcity of skills is quite likely the main limitation in developing countries. It could easily explain why enormous income disparities persist in a world where most knowledge can be obtained –or at least located– after a few clicks

[1] For instance see Eaton and Kortum (2004), Grossman and Helpman (1991), Klenow-Rodriguez Clare (2005), and Rodriguez-Clare (2006).

[2] Jones (2006), Klenow (1998) and Romer (1990) discuss non-rival factors in the literature of growth.

in Google. Moreover, it can also explain why productivity innovations seem to diffuse more easily to developed countries than to developing countries.[3] Indeed, if implementing a technology entails costs, the scarcity of skills can imply that some technologies do not diffuse at all.

The implications of reallocating skills across countries have received some attention lately. For instance, Antras, Garicano and Rossi-Hansberg (2006) find that the reallocation of skills from the North to the South can have interesting distributional implications by reallocating individuals across occupations and by changing the sorting and composition of production teams. Burstein and Monge-Naranjo (2006) model the reallocation of firms from developed countries to developing countries and quantify significant gains in the output and aggregate consumption of host countries. They show that the gains are even larger if, within countries, individuals can be reallocated across occupations and specially, if foreign firms have positive productivity spillovers. These papers, however, take the endowments of skills as given, and hence, they are silent about the impact of foreign firms in their accumulation over time.

In this paper I study the accumulation of skills in a simple OLG environment. Production is carried out by teams composed by a manager and a set of workers. The productivity of a team is determined by the skills of the manager.[4] In each period, young individuals are workers and decide their investment in skills. On the basis of their skills, old individuals decide between being workers or being managers. A manager hires workers in a competitive labor market and become the residual claimant of his team.

A closed country is defined as one within which only national managers can lead production teams. An open country is one in which foreign managers can relocate their skills to the country and lead a team of local workers.[5] Such simple

[3] For instance, positive intraindustry spillovers of multinational firms are found for developed countries but not for developing countries. See Alfaro et al. (2006).

[4] As in Kaldor (1934), Rosen(1982), Lucas(1978), Oi (1983) and Boyd-Prescott (1987), the productivity of firms is ultimately determined by the skills of the individuals at the top of the management.

[5] In all cases, I assume that workers are fixed in their country. See Klein and Ventura (2004)

model conforms with the observation that multinational firms rely heavily on home expatriates –and home trained individuals– to manage their operations, specially in developing countries [see Chapters 5 and 6 of UNCTAD (1994).] It also conforms with the emphasis of the existent literature on firm specific intangible assets for multinational activity [e.g. Barba-Navarretti (2004), Markusen (2004).]

I examine three different models which have the accumulation of skills as the "engine of growth." For closed economies, the three models are indistinguishable. The first is a standard exogenous growth model in the sense that skills are exogenously and costlessly formed. Each period, the current generation of managers have a multiple $G > 1$ of the skills of the managers *operating* in the country in the previous period. Trivially, this implies that closed economies are always in a balanced growth path (BGP), and that the income of the country, relative to the rest of the world, remains constant.

For an open economy, the presence of foreign firms changes the set of skills active inside the country. In this model, similar to the seminal work of Findlay (1978), I assume that foreign firms have a positive externality that enhances the set of ideas surrounding young agents when they accumulate skills. As in Findlay's model, such spillovers are costless and their intensity is determined by the equilibrium mass of foreign firms. Over time, by simply opening up to foreign firms, a developing country would accelerate its growth rate and monotonically converges to the income level of developed countries.

Very different implications obtain with endogenous skill accumulation. To obtain growth with short-lived agents, in the second model I follow Stokey (1991) assuming that old agents have an externality on the formation of skills of young agets. Essentially, young agents invest to improve upon the ideas that there are being exposed to. These ideas are a local public good and managers are not being compensated for their contribution to it. Under suitable parameter restrictions but regardless of initial conditions, closed economies grow at a constant rate.

Open economies exhibit a more complex dynamics. Openness to foreign firms has two countervailing implications. The first one is a "spillover effect": as foreign

for an analysis of cross country labor mobility.

firms bring their productive knowledge boosting the formation of skills. The second is a "competition" or "profit squeeze" effect: in the future foreign firms compete with local busting the rate of return of investing in skills. As a result, open economies exhibit a form of predator-prey dynamics that can result in two steady states (of relative income). The two steady states can be reached depending of initial conditions. The main result of this model is that the competition effect dominates the spillover effect. The economy converges to a steady state in which there is no full convergence except under the extreme case in which local firms disappear for one period.

In the third model there are no externalities. The engine of growth is the formation of skills inside firms. As in Boyd-Prescott (1987a,b), Chari-Hopenhayn (1991) and Jovanovic-Nyarko (1995), the formation of skills of a young worker depends on the set of skills of the manager for whom he works.[6] Skill transfers require the conscious and direct involvement of the transferrer. A well functioning market for those transfers operates. As in Boyd-Prescott (1987a,b), both old and young agents fully foresee the costs and benefits of the skills and the equilibrium is efficient.[7] Productivity improvements are the outcome from mutually beneficial transactions, which, of course, can take place across national borders.

One contribution of this paper is to provide the conditions for existence, uniqueness and efficiency of a balanced-growth path in this economy.[8] An important complexity in this model is that skills are useful not only in producing goods and services but also in producing skills. Besides the convexity of the profit function with respect to the manager's skill in a Lucas (1978) 'span-of-control' model, the self-productivity of skills can easily lead to dynamic increasing returns unless the cost of producing skills is convex. Under those conditions, closed economies would behave similarly to the previous two models.

When foreign firms enter in a developing country, they can build up the skills

[6] See also the stochastic extensions of the Chari-Hopenhayn model by Agarwal, R. et al (2004) and Filson and Franco (2006).

[7] Adverse selection precludes the efficiency of the equilibrium in Jovanovic-Nyarko (1995).

[8] The conditions in Boyd and Prescott (1987) and Prescott and Boyd (1987) are not enough to insure this result.

of their workers. Competition with local and foreign managers imply that in equilibrium they transfer the same level of skills as firms operating in developed countries. Along this process, a new sector of national managers (and firms) arise, each one with the same level of skills as their peers in developed countries. The fraction of these new managers grows and in finite time will fully takes over the entire economy. Thereafter the country would have the same level of income as developed countries. Along this process, the sector of pre-existent firms not only fall in size but also in relative productivity.

There is ample evidence that skill formation at the interior of the firm is an important form of productivity diffusion. In the car industry in the US, Keppler (2001, 2002, 2006) documents that the genesis of the most important car makers can be traced to former employees of other important car makers. Agarwal et al (2004), Filson and Franco (2006) and Franco (2005) document the same for the rigid disk drive industry. In both of these cases, the authors provide ample information on the spin-offs and on the relationship between the characteristics and outcomes of parent firms with their progeny. At the international level there is also ample anecdotal evidence. Perhaps the best known case is the build up of a textile sector in Bangladesh by a Korean firm. [9] But, despite the evidence that some multinational firms spend significant resources in training their workers [see UNCTAD (1994)] little empirical work has been done on the skill formation by multinational firms. The exception is the recent paper by Poole (2006) who presents evidence on multinational firms in Brazil.

Instead, the empirical literature has been fixated on establishing the existence and the magnitude of technology spillovers. In particular, the focus has been placed on intraindustry spillovers. Interestingly, finding supportive evidence has proven to be quite an endeavor and most authors come back empty-handed. While there is some evidence of positive spillovers for developed countries [e.g. Griffith et al (2002)], for developing countries it has been hard to revert the negative results of Aitken and Harrison (1999).[10] What has been found is evidence of inter-industry

[9] This case was popularized by Easterly (2001).

[10] See Alfaro et al. (2006) for a detailed discussion of the empirical findings.

spillovers, in particular, to upstream industries [e.g.: Javorcik (2004) and Kugler (2005)]. But Javorcik also reports direct involvement of the multinational firms in upgrading the productivity of their suppliers. Such transactions are better seen as voluntary transactions, not spillovers. In this paper I argue that for productivity diffusion to materialize, foreign firms must have the incentives to get involved in building up the necessary skills. Competing domestic will optimally reduce their investments in upgrading productivity.

The rest of the paper is as follows. Section 2 lays out the basic environment and Section 3 characterizes the equilibrium of closed an open economies in the exogenous growth model. Section 4 considers the endogenous growth model with externalities. Section 5 develops the endogenous growth model, provide the conditions for existence and uniqueness of a balanced growth path and its efficiency examines the response of an economy that opens up. Section 6 concludes including some brief reflections on policy. An appendix contains the proofs of the main propositions.

2. The Model

Within the same simple environment I will consider alternative models for the accumulation of productive skills.

2.1. The environment.

Consider an infinite horizon, discrete time, overlapping generations model with two period lived agents. Each cohort is a continuum of size one of identical individuals. Individuals born at the beginning of time t value consumptions during time t and $t+1$. Their utility is

$$U_t^t = c_t^t + \beta c_{t+1}^t,$$

where, $0 < \beta < 1$ is a discount factor and c_τ^t is the consumption during period τ of an individual born in period t.

In each period of their life, individuals are endowed with one unit of time. In the first period, when the agent is young, he supplies his unit of time as a "worker". It is in this first period that agents acquire skills. In their second period of life, depending of their skills, agents decide between being a "manager" (a worker using his skills and expertise) or a worker.

There is a single consumption good. Production is carried out by teams of a manager and workers. A manager with skills z commanding n units of labor services produce y units of consumption goods according to the production function

$$y = zn^{\alpha},$$

where α is the "span-of-control" parameter, which dictates the degree of decreasing returns to the labor controlled by the manager. I will assume that $\alpha \in (0, 1/2)$, so that, as derived below, in the equilibrium of a closed economy, old agents strictly prefer to be managers.[11]

Financial and labor markets are competitive. By design, the equilibrium interest is equal to $R = \beta^{-1}$, the inverse of the discount factor. The sequence $\{w_t\}_{t=0}^{\infty}$ are the wages that clear the labor market. In what follows, I explore the equilibria in this environment under alternative assumptions of skill formation and openness of the economy. The assumptions on skills formation changes the nature of individual optimization. In turn, open and closed economies have different market clearing conditions.

A common problem in the different models is the optimal hiring of young workers by managers. Facing a wage w, a manager with productive skills z maximizes his rents $\pi(z, w)$

$$\pi(z, w) = \max_{\{n\}} \left\{ zn^{\alpha} - wn \right\}.$$

This is a simple and standard problem. The optimal hiring of labor is

$$n^{*}(z, w) = \left[\frac{\alpha z}{w} \right]^{\frac{1}{1-\alpha}}, \tag{2.1}$$

[11] If the rate of growth of the population is $g_n > 0$ and only a fraction $0 < \omega < 1$ of the young workers can become managers next period, the condition is relaxed to $\frac{\alpha}{(2+g_n-\omega)} < \frac{1-\alpha}{\omega}$. These features, while adding realism to the model, do not change the results of the paper. To save on notation, I will assume $g_n = 0$ and $\omega = 1$.

and the rents attained by the manager are

$$\pi(z, w) = \theta z^{\frac{1}{1-\alpha}} w^{\frac{-\alpha}{1-\alpha}}. \tag{2.2}$$

where $\theta \equiv [\alpha]^{\frac{\alpha}{1-\alpha}} (1-\alpha) > 0$.

This basic optimization problem is common for the different models for the formation of skills studied below. Under the first mechanism, productive skills are exogenously formed. The ideas to which young workers are exposed in their first period of life shape the productive knowledge they have when it is their turn to be managers. In the second mechanism, each young individual faces an investment decision in their level of skills. The set of ideas floating in their influences the productivity of that investment. Finally, in the third mechanism, the manager for which a young individual works in his first period of life will have a fundamental impact on the skills that he will have as a manager.

To understand the implications of foreign firms in the formation and diffusion of skills, I compare the equilibria of open and closed economies. In this context, a closed economy is one in which all teams have to be composed by managers and workers from the country. The open economy considered here is one in which foreign managers can lead teams of local workers. I look into these two extremes and solve for three alternative mechanisms for the accumulation of skills over time.

In what follows I will use the subscript n to indicate a national variable, the subscript f to indicate a foreign variable and the subscript g to indicate a "geographic" variable relevant to the home country n. Also, as I have done up to here, variables in lower case denote an individual variable while capital letters indicate an aggregate variable.

3. Exogenous Growth and Spillovers

Let us assume, as in a standard Solow growth model, that the engine of growth is a recurrent and exogenous improvement in the productive know-how available in the economy. Within the context of our model, this process can be thought of

as the young cohort learning, revising and improving the productive knowledge of the old cohort. For simplicity, I assume this process to be deterministic.

Specifically, if the set of managers operating in the country has an average Z_g of skills, then, each member of the next generation of national managers will have skills Z'_n given by

$$Z'_n = GZ_g, \tag{3.1}$$

where $G > 1$ is the gross growth rate. Closed and open economies will differ in the value of Z_g, the productive ideas to which their youth is exposed to.

3.1. Closed Economy.

Consider the case in which all the managers in the country have the same skills level z. The average skills for the cohort, Z_n, is also, trivially, equal to z. With identical managers and workers and with equal population sizes, in equilibrium, all managers hire one worker.

Expression 2.1 for the optimal hiring by each manager implies that the market clearing wage for young workers is

$$w = \alpha Z_n,$$

and hence the rents of each manager are

$$\pi = (1 - \alpha)\, z.$$

In closed economies, $Z_g = Z_n$, i.e. the geographic productive knowledge of the country is to the national average. The set of ideas out of which young agents can learn and improve are the ones embedded in the old cohort from their own country only. Over time $z'_n = Z'_n = GZ_n$.

Domestic output (denote Y_g) and national output (denoted Y_g) are both equal to Z_n. Aggregate consumption (denoted C) is also equal to Z_n, reflecting the fact that the accumulation of skills requires no real resources. Over time, all these variables follow the law of motion (3.1).

3.2. Small Open Economy

Consider now the opposite extreme: An economy that is open in the sense that foreign firms can frictionless operate in the country. In this context, it means that foreign managers can hire young workers of the country. I will consider only the small economy case, in the sense that the equilibrium of the country does not affect the variables for the foreign country (the rest of the world). In particular, the foreign country (the rest of the world) follows $Z'_f = GZ'_f$. I only consider the case of a country that is lagging behind the rest of the world in the sense that $Z_n < Z_f$.

3.2.1. Labor Market Clearing

With free entry from foreign firms, the conditions in the rest of the world will pin down the equilibrium wage for an open economy. With free entry, foreign managers must be indifferent between operating in their own country or in country n. In either one, their rents are

$$\pi_f = (1-\alpha) Z_f.$$

The equilibrium wage is now equal to the wage abroad:

$$w = \alpha Z_f. \tag{3.2}$$

Facing this wage, it is easy to see then, that each foreign manager operating in the country hires one worker:

$$n_f = 1,$$

while national managers, with their skills Z_n hire labor services in the amount

$$n_n = \left[\frac{Z_n}{Z_f}\right]^{\frac{1}{1-\alpha}}. \tag{3.3}$$

National managers attain rents

$$\pi_n = (1-\alpha)\frac{(Z_n)^{\frac{1}{1-\alpha}}}{(Z_f)^{\frac{\alpha}{1-\alpha}}}.$$

Up to here, I have been implicitly assuming old agents are better-off being managers as oppose to workers. For this to be the case, the condition needed is that $Z_n > \left[\frac{\alpha}{1-\alpha}\right]^{1-\alpha} Z_f$. Otherwise, both groups of young and old agents would be workers for foreign managers. In what follows I will develop the case in which national old agents are managers and then briefly explain the case in which all are workers.

Denote by m the mass of foreign firms that operate in the country. Labor market clearing requires that the demand for labor from foreign and domestic firms must be equal to the supply, the population of young individuals, which here it is given by:

$$m + n_n = 1.$$

Using 3.3, the equilibrium mass of foreign firms is given by the expression:

$$m = 1 - \left[\frac{Z_n}{Z_f}\right]^{\frac{1}{1-\alpha}}. \tag{3.4}$$

In this model the motivation of foreign firms is "vertical", i.e. seeking lower cost for labor. The closer is the country to the world frontier, (the closer is Z_n to Z_f) the tougher is the domestic competition and lower the entry of foreign firms.

The geographic output Y_g of the country is equal to the rents of foreign and domestic managers plus the wages. Using expressions (3.4), and after some simplification, we get (somewhat surprisingly) that

$$Y_g = Z_f.$$

This is, the country's geographic output converges to the rest of the world.

Free entry of foreign firms with superior productivity brings the geographic output of the county to the world level. Domestic firms are squeezed by the competition. As they hire fewer units of labor, their marginal product of labor raises to the world level.

Despite the fact that the country can boast having a geographic output level at part with the rest of the world, its national output Y_n and consumption C,

does not include foreign profits and are only

$$C = Y_n = Z_f \left[\alpha + (1-\alpha) \left(\frac{Z_n}{Z_f} \right)^{\frac{1}{1-\alpha}} \right].$$

Clearly, $C = Y_n < Z_f$. As some of the rents are repatriated to source countries, even if the geographic output is at par with the rest of the world, nationals of the country pay for their lower skills in the form of a lower national output and consumption.

If instead $Z_n < \left[\frac{\alpha}{1-\alpha}\right]^{1-\alpha} Z_f$, then both young and old workers will be workers under foreign managers. In this case $m = 2$, $Y_g = 2Z_f$ and $C = Y_n = 2\alpha Z_f < Z_f$.

3.2.2. Skill formation.

Obviously, if we assume that the skills in the country and in the rest of the world follow the laws of motion (**??**) and (**??**) then the ratio Z_n/Z_f remains constant over time. The static equilibrium described above is also a steady state.

Consider instead that as the presence of foreign firms brings new knowledge to the productive activities in the country, it also enhances the quantity and quality of the ideas to which young agents are exposed to. Assumptions of this sort are embedded in the infinitely lived agents frameworks of Romer (1986) and Lucas (1988). Overlapping generations models simply force a more explicit treatment.

In the context of multinational firms, Findlay (1978) directly assumes that the superior technology of foreign firms spills over the productivity of local firms. Findlay's paper is the theoretical foundation of the large empirical literature on spillovers using data on Foreign Direct Investment (FDI).

Some basic properties are required for the set of ideas Z_g to which young agents are exposed to in their formative years and shape up their production of skills. First, Z_g should be increasing in both Z_n and Z_f when $0 < m < 1$; (b) the relative importance of Z_f increases with m; and (c) there are no scale effects, and therefore Z_g is homogeneous of degree one in Z_n and Z_f One particular functional form that satisfies all three of these requirements is the geometric average

$$Z_g = (Z_f)^m (Z_n)^{1-m}. \tag{3.5}$$

Here, m is the fraction of young workers in foreign firms and captures the degree in which foreign firms impact the set of ideas floating in environment. In this formulation, Z_g is a local public good. As pure externalities, I assume that these ideas impact symmetrically all young workers regardless of where they work. Neither local nor foreign managers receive compensation for their contribution to the ideas available to young workers. It might be helpful to think of this model as a happy hour diffusion: Imagine that everyday, after work, all the young workers go to a bar for a happy hour. Among more other things –and with objectives different than training– they tell each other the specifics of what they do and how they do it. After repeated happy hours, the set of ideas in the brain of each and every one is Z_g.

Each member of the next crop of local managers command skills:

$$z'_n = Z'_n = GZ_g.$$

Using the expressions (3.5) and the equilibrium mass of foreign firms (3.4) then, the growth rate of the skills of local managers follows:

$$\frac{Z'_n}{Z_n} = G\left(\frac{Z_f}{Z_n}\right)^{\left[1-\left(Z_n/Z_f\right)^{\frac{1}{1-\alpha}}\right]}. \tag{3.6}$$

Very clearly, if a country is lagging behind (low Z_n/Z_f), firms from the rest of the world would find it profitable to operate in that country. Foreign firms bring new ideas to the country (for which they are not compensated), and these ideas accelerate the formation of skills for the future local firms.

A simply manipulation of the (3.6) and using (**??**) renders the transition function for the relative productivities (Z_n/Z_f) of the country with respect to the rest of the world:

$$\frac{Z'_n}{Z'_f} = \left(\frac{Z_n}{Z_f}\right)^{1-\left(Z_n/Z_f\right)^{\frac{1}{1-\alpha}}}$$

Clearly, if $Z_n/Z_f < 1$, then $Z'_n/Z'_f > Z_n/Z_f$ and the dynamics is monotone. Countries lagging behind catch up over time. The inflow of foreign firms booster the formation of skills of future generations of firms. Indeed, regardless of initial conditions, the system will converge to $Z_n/Z_f = 1$. At this point, the equilibrium value of m is 0. Foreign firms breed the competition that would eventually have them disappear from the country.

The following proposition summarizes the main results for this model:

Proposition 3.1. *Assume that $0 < \alpha < 1/2$ and use the superscript t to index time periods. If the initial conditions satisfy $[\alpha/(1-\alpha)]^{1-\alpha} Z_f^0 < Z_n^0 < Z_f^0$, then, the sequences $\left\{Z_n^t/Z_f^t, Y_n^t/Y_g^t\right\}_{t=0}^{\infty}$ are strictly increasing and $\{m^t\}_{t=0}^{\infty}$ is a strictly decreasing and*

$$\begin{aligned} \lim_{t\to\infty}\left(\frac{Z_n^t}{Z_f^t}\right) &= \lim_{t\to\infty}\left(\frac{Y_n^t}{Y_g^t}\right) = 1, \\ \lim_{t\to\infty} m^t &= 0. \end{aligned}$$

If $Z_n^0 < [\alpha/(1-\alpha)]^{1-\alpha} Z_f^0$ then $m^0 = 1$, $m^t = 0$ and $\left(Z_n^t/Z_f^t\right) = \left(Y_n^t/Y_g^t\right) = 1$ all $t \geq 1$.

A model along these lines, Findlay (1978), has motivated a large body of empirical research trying to quantify the spillovers of multinational firms. A model similar to this one may also be in the back of the mind of policy makers that actively pursue the multinational corporations to locate in their countries. I will now argue that the naïveté in the assumed accumulation of skills can lead to seriously misleading conclusions.

4. Endogenous Growth and Spillovers

Contrary to the assumption of the previous model, productive know-how is costly to accumulate. Most of what we can do is the result of experimentation or training. Real resources such as time and consumption goods, are used in the formation

of skills. Even if simple and highly productive ideas are readily available, they normally require properly skilled individuals to make them productive.

As in Stokey (1991), the skills of older cohorts determine the ease in which younger cohorts acquire their skills. The higher the skills of old individuals the more productive are young individuals in procuring skills for themselves. I adapt Stokey's model of skills formation to an environment in which the presence of foreign firms redefines the effective skills that surround young agents at the time they form their skills. As in Stokey, the mechanism is via an externality. Managers, foreign or old, are not compensated for their impact in the skills formation.

Assume that to be able to master z' units of productive knowledge next period, a young individual must incur a cost

$$Z_g \phi\left(\frac{z'}{Z_g}\right)$$

of consumption goods in the current period. Here Z_g is the productive knowledge in the environment where the youngster live. The function $\phi(\cdot)$ is the standard function used to model adjustment costs. It is continuous, strictly increasing, strictly convex and I assume that $\phi(0) = 0$. For the rest of the paper I will use the functional form

$$\phi(x) = v_0 \frac{(x)^{1+v}}{1+v},$$

where both v_0 and v are positive constants. In what follows the short-hand $\phi(\cdot)$ is used to condense some formulas.

In this environment, skills form endogenously. Each young agent decides how much to accumulate. The costs are as I just explained. The benefits will be the next period profits. Therefore, given Z_S and foreseeing w', the cost of hiring workers next period, the optimization problem of a young worker is

$$\max_{\{z'\}} \left\{ \beta \pi(z', w') - Z_g \phi\left[\frac{z'}{Z_g}\right] \right\}, \tag{4.1}$$

where $\pi(z', w')$ is given by (2.2) and is discounted because it applies only in the next period. This optimization consist of the difference of two convex functions.

For now on, I will make the assumption that, for any pair Z_S, w', $\phi(\cdot)$ is "move convex" than $\pi(\cdot, w')$.[12]

Condition 1: $v > \frac{\alpha}{1-\alpha}$.

It is easy to verify that under this condition, the following result holds.

Lemma 4.1. *If condition* 1 *holds, then the optimal level of skills is given by the first order condition*

$$\beta\alpha^{\frac{\alpha}{1-\alpha}}\left[\frac{z'}{w'}\right]^{\frac{\alpha}{1-\alpha}} = v_0\left[\frac{z'}{Z_g}\right]^{v}. \tag{4.2}$$

If condition 1 *does not hold, the optimal acquisition of skills is* $z' = 0$.

However, the previous lemma is not sufficient to characterize the optimal skills. An individual has the option of remaining a worker in both periods of his life. I explain the additional conditions in the context of closed and open economies.

4.1. A Closed Economy

Consider an economy in which all managers command productive knowledge Z_n. As the economy is closed, the geographic productive knowledge coincides with the national value, $Z_g = Z_n$. The market clearing wages for this period and the next are, respectively, $w = \alpha Z_n$ and $w' = \alpha Z_n' = \alpha G Z_n$. In the current period, each national manager gets rents

$$\pi_n = (1-\alpha)\, z. \tag{4.3}$$

Under condition 1, the optimal accumulation of skills by young agents satisfies expression (4.2). After imposing the market clearing condition for a closed economy, the growth of productive skills follows:

$$\frac{Z_n'}{Z_n} = G \equiv \left[\frac{\beta}{v_0}\right]^{\frac{1}{v}}. \tag{4.4}$$

For the economy to exhibit sustain growth, $G > 1$, I will impose the following:

Condition 2. $\beta > v_0$.

[12] In the sense that, for any Z_g and w', the function $\zeta(z') \equiv Z_g \phi^{-1}(\pi(z', w'))$ is concave.

This condition simply states that the time efficiency of producing skills is above the discount rate, and therefore, it is individually optimal to accumulate skills above of those embedded in the current generation of old agents.

For the previous equation to be an equilibrium, each of the young agents must find it optimal to accumulate skills at the said rate G. The option of being a worker in both periods and not accumulating any skills renders a lifetime utility $Z_n[\alpha + \beta\alpha G]$; on the other hand, training optimally and becoming a manager renders a lifetime utility of $Z_n[\alpha - \phi(G) + \beta(1-\alpha)G]$. The net gain of becoming a manager is $Z_n[\beta(1-2\alpha) - \phi(G)]$. I will restrict the parameters as follows:

Condition 3. $(1-2\alpha) > \frac{1}{1+v}$.

Under this case, using (4.4), the following result is direct:

Lemma 4.2. *If Condition 4 holds then $\beta(1-2\alpha) > \phi(G)$ and hence, individuals find it optimal to invest in skills and become managers.*

Under Conditions 1, 2, and 3, the economy behaves similar to the exogenous growth economy. The production of consumption goods, however, must finance also the cost of accumulating skills. In the aggregate, the economy spends

$$Z_n \phi(G),$$

units for the accumulation of skills. Therefore, in any point in time, Y_g, Y_n and C are given by

$$\begin{aligned} Y_g &= Y_n = Z_n, \\ C &= Z_n[1 - \phi(G)], \end{aligned}$$

which over time all variables grow according to 4.4.

4.2. A Small Open Economy.

Now, consider the small open economy. The intratemporal equilibrium conditions are the same as in the exogenous growth case: free entry of foreign firms, pins the wage of local young workers to the international level $w = \alpha Z_f$ and each foreign

managers hires $n_f = 1$ young workers. Similarly, if $Z_n \geq [\alpha/(1-\alpha)]^{1-\alpha} Z_f$, then, old agents strictly prefer to be managers, each hiring $n_n = [Z_n/Z_f]^{\frac{1}{1-\alpha}}$ units of labor; a mass of $m = 1 - [Z_n/Z_f]^{\frac{1}{1-\alpha}}$ of foreign firms operate in the country.

The accumulation of skills, follows (4.2). The openness to foreign firms has two countervailing effects. First, there is the "spillover" effect: as in the exogenous growth model, foreign firms bring productive ideas that spillover to the young agents at the time they are accumulation their skills. The geographic knowledge Z_g is higher than the national value of Z_n, reducing the cost of accumulating skills. Therefore, given w' the optimal z' would be higher. Second, there is a "competition effect". The entry of foreign firms will bid up w', the cost of labor for the next period, reducing the returns to investing in skills.[13]

Using the market clearing wage $w' = \alpha G Z_f$ for the next period, expression for Z_g in terms of m and the expression (4.2) for the formation of skills, then, $\left[Z'_n/Z'_f\right]$, the relative skills of national managers in the next period follows the transition function

$$\left(\frac{Z'_n}{Z'_f}\right) = \left(\frac{Z_n}{Z_f}\right)^{\mu(1-m)},$$

where $\mu \equiv \left[\frac{(1-\alpha)v}{(1-\alpha)v-\alpha}\right] > 1$ under condition 1. Notice that the presence of foreign firms ($m > 0$) helps closing the gap between national managers with the foreign managers. If $Z_n/Z_f < 1$, the closer is m to 1, the ratio $\left[Z'_n/Z'_f\right]$ approaches unity. Alternatively, using the same equations, the growth of national skills is given by

$$\left(\frac{Z'_n}{Z_n}\right) = G\left(\frac{Z_n}{Z_f}\right)^{(\mu-1)-m\mu}.$$

Clearly, as the fraction m goes up, the growth rate of domestic skills increase when $Z_n/Z_f < 1$. The larger is the gap, for a given m, the larger would be the acceleration in the formation of skills. The current presence of foreign firms is associated with an acceleration and catching up of the level of national skills.

However, openness, in this model need not lead to convergence. Taking as given the value of m ignores the countervailing effect that in the next period,

[13] Aitken and Harrison (1999) discuss a similar "competition" effect driven by strategic interaction in the context of a static partial equilibrium model.

national firms have to face the competition of foreign firms. To evaluate the implications of openness, it is necessary to characterize the global dynamics of the national skills.

The global dynamics in this model is quite simple. Using the equation (3.4) of m as function of Z_n and Z_f, we obtain

$$\left(\frac{Z_n'}{Z_f'}\right) = \Gamma_0\left(\frac{Z_n}{Z_f}\right) \equiv \left(\frac{Z_n}{Z_f}\right)^{\mu\left[Z_n/Z_f\right]^{\frac{1}{1-\alpha}}}, \tag{4.5}$$

and

$$\left(\frac{Z_n'}{Z_n}\right) = G\left(\frac{Z_n}{Z_f}\right)^{\mu\left[Z_n/Z_f\right]^{\frac{1}{1-\alpha}}-1}.$$

The function $\Gamma_0(\cdot)$ does not yet define the transition function of the level of skills of the country relative to the rest of the world, because we need to consider the option of old agents to be workers. In any event, the features of this simple function embody the dynamics of a small open economy.

For instance, the system exhibits predatory-prey dynamics: as foreign firms enter, local managers accelerate their skills formation and reduce their distance with the rest of the world. This is reinforced by the fact that as they increase their skills, next period the mass of foreign firms diminish, reducing the effective competition for workers. In turns, the stock of productive ideas that young agents are being exposed to is also diminished, the country increases its lag with respect of the world, implying a higher presence of foreign firms in the subsequent period and so on.

As displayed in Figure 1, the function $\Gamma_0(\cdot)$ has two fixed points. The first one is:

$$\frac{Z_n}{Z_f} = 1,$$

which occurs when the country is at par with the rest of the world, and the country is not subject of spillovers or foreign competition. The second fixed point is

$$\frac{Z_n}{Z_f} = R_L \equiv \left[\frac{1}{\mu}\right]^{1-\alpha} < 1.$$

where the superindex L simply highlights the fact that R_L is below 1, and hence, it is a "laggard" steady state. In this case, the country never catches up with the rest of the world. In the balanced growth path, the country will constantly host a fraction $m^L = \frac{\alpha}{(1-\alpha)v}$ of foreign firms, and the competition and spillover effects offset each other.

The function $\Gamma_0(\cdot)$ capture the incentives of future managers for accumulating skills. These incentives and the choice of occupations determine the transition function $\Gamma(\cdot)$ Up until now, I have ignored the occupation choice of old agents. With it, the dynamics can be quite stark.

It is easy to compute the ratio R_S that define optimal occupation choices. Indeed, if

$$Z_n/Z_f < R_S \equiv [\alpha/(1-\alpha)]^{1-\alpha},$$

then old agents would be better off by working for a foreign manager. Notice that since $\alpha < 1/2$, $R_S < 1$. Under the condition above, national firms are wiped, all young agents work for a foreign manager, and $Z_g = Z_f$. In this case, next period $Z'_n = Z'_f$, and the country fully catches up and foreign firms disappear.

On the other hand, before investing in skills, each agent compares the alternative of being a worker in both periods and invest nothing in skills versus the alternative of optimally investing in skills and being a manager next period. The first of this alternatives yield $Z_f[\alpha + \beta\alpha G]$; the second would yield $Z_f\alpha - Z_g\phi(Z'_n/Z_n) + \beta\pi_n(Z_n, Z_f)$. After some algebra, it can be shown that the young agent would prefer to be a worker in both periods if and only if

$$\Phi\left(\frac{Z_n}{Z_f}\right) \equiv (1-\alpha)\Gamma_0\left(\frac{Z_n}{Z_f}\right)^{\frac{1}{1-\alpha}} - \frac{1}{1+v}\Gamma_0\left(\frac{Z_n}{Z_f}\right)^{\frac{1+\mu}{\mu}}\left(\frac{Z_n}{Z_f}\right)^{-(1+v)} < \alpha,$$

where $\Phi\left(\frac{Z_n}{Z_f}\right)$ indicates the Contrary to the closed economy, the occupation choice can not be directly imposed using parameter restrictions as it depends on the skills of the country relative to the rest of the world.

[**Insert Figure 1:** Γ_0]

Incorporating the occupation choice of old agents, the transition function $\left(\frac{Z'_n}{Z'_f}\right) = \Gamma\left(\frac{Z_n}{Z_f}\right)$ for the relative skills is

$$\left(\frac{Z'_n}{Z'_f}\right) = \Gamma\left(\frac{Z_n}{Z_f}\right) \equiv \begin{cases} 1 & \text{if } Z_n/Z_f < R_S, \\ 0 & R_S < Z_n/Z_f, \text{ and } \Phi\left(\frac{Z_n}{Z_f}\right) < \alpha \\ \Gamma_0\left(\frac{Z_n}{Z_f}\right) & \text{otherwise.} \end{cases} \tag{4.6}$$

The first branch indicates that with low enough local skills, the only set of skills operating in the country are foreign. In this circumstances, since the learning of the young generation is based only on foreign know-how, they will catch up with their foreign counterparts. The second branch indicates that if it is optimal for young workers to also be workers in the next period, then they would accumulate no skills. The third branch is the transition in the case of interior optimum for local managers.

Proposition 4.3. *The following results hold: (a) If* $\Phi(R_L) < \alpha$ *or* $R_L < R_S$*, then* $Z_n/Z_f = 1$ *is the unique resting point of* Γ *and is globally stable. (b) If instead* $\Phi(R_L) > \alpha$ *and* $R_L > R_S$*, then both* $Z_n/Z_f = 1$ *and* $Z_n/Z_f = R_L$ *are resting points and* R_L *is locally stable. Moreover, if for all* $x \in (R_S, 1)$*,* $\Gamma_0(x) > R_S$ *and* $\Phi(x) > \alpha$*, then,*

$$\lim_{t\to\infty}\left(Z_n^t/Z_f^t\right) = \begin{cases} R_L & \text{if } \left(Z_n^0/Z_f^0\right) > R_S \\ 1 & \text{otherwise.} \end{cases}$$

Proof. See appendix. ■

Figure 2 displays this transition function. Notice that it can be non-monotone. In one extreme, if the local skills are way below the rest of the world, the economy will converge in one period. Alternatively, if the economy is already at par with the rest of the world, it will remain there. However, if the country starts just a bit below the world frontier, it will eventually lag behind and converge to a relatively low value of relative productivity.

Figure 2 shows that even if occupation choice precludes the economy to fall into a laggard steady state, openness could trigger a period in which the relative

skills of national managers would fall behind (cyclically) and eventually hit a low in which national firms disappear. Of course, one period after the collapse of the national firms, the economy converges to the world level.

[**Insert Figure 2: two panels showing different case for** Γ_0, Φ, Γ]

In any event, from the two counteracting effects, the competition effect is likely to dominate, at the very least temporarily. Expecting that by opening to foreign firms, the spillovers will suffice to raise national productivity to the world level is warranted to lead to disappointment since, foreseeing future foreign competition, those individuals that are deciding to invest in productive skills may reduce, not increase their investments.

5. Endogenous Growth and Internal Diffusion of Skills

In the third model I assume that the formation of skills takes place inside the firms. There are no externalities. As in Boyd-Prescott (1987a,b), Chari-Hopenhayn (1991) and Jovanovic-Nyarko (1995), the formation of skills of a young worker depends on the set of skills of the manager for whom he works.[14] Here, the effective transfer of skills requires the conscious and direct involvement of the transferrer, and because of that, a well functioning market for those skills operate. In this model, as in Boyd-Prescott (1987a,b), both old and young agents fully foresee the costs and benefits of skills. The equilibrium skill formation is socially efficient.[15] In sum, productivity improvements in this model result from mutually beneficial transactions between the transferrer and the transferee. These transactions, of course, can take place across national borders.

[14] See also the extensions of the Chari-Hopenhayn model by Agarwal, R. et al (2004) and Filson and Franco (2006).

[15] In Chari-Hopenhayn (1991) skill formation is exogenous. In Jovanovic-Nyarko (1995) adverse selection precludes the efficiency of the equilibrium.

5.1. Technology and the problem of the Firm

As before, a firm is a team of a manager and n workers.[16] In addition of consumption goods y, firms produce skills z' that young workers can use in the next period when they are managers. The technology frontier of (y, z') is as follows. A team of n workers led by a manager with skills z can produce y units of consumption goods and z' units of skills for each one of the young worker according to:

$$y = z\left[n^{\alpha} - n\phi\left(\frac{z'}{z}\right)\right]. \tag{5.1}$$

where $\phi(\cdot)$ is the same increasing, convex and twice differentiable function above.

Managers, according to their with skills z, hire workers in competitive labor markets. Young workers are indifferent to work for any of the firms, since regardless of the manager's skill z regardless of . This is, at time t young agents obtain the same discounted utility, denoted by W_t, regardless of the skill z of the managers under which they are working. In perfect foresight equilibria, workers and managers foresee the returns $\pi_{t+1}(z')$, that the currently young agents would obtain next period as managers with skills z'.

By providing skills z' to one worker, the firm incurs a cost $z\phi\left(\frac{z'}{z}\right)$ in foregone output and induces a (discounted) return $\beta\pi_{t+1}(z')$ for the future manager. By providing skills z', a manager only needs to compensate a young worker the amount $[W_t - \beta\pi_{t+1}(z')]$ to be able to hire him. Therefore, the return $\pi_t(z)$ that a manager obtains is the result of the optimal choice of n, the number of workers and z', the training provided to each of them:

$$\pi_t(z) = \max_{(n,z')}\left\{z\left[n^{\alpha} - n\phi\left(\frac{z'}{z}\right)\right] - n\left[W_t - \beta\pi_{t+1}(z')\right]\right\}. \tag{5.2}$$

The first result is that the costs and benefit of skill transmission are fully internalized when the solution to (5.2) is bounded. For this, we assume the following

[16] In the previous two models, since learning is outside the firm, we could interpret n to be units of labor services. In this model n needs to be, literally, the number of workers. Integer problems do not arise since we can assume that, need it be, a young agent can work for two or more identical managers (managers with the same z). Likewise, a manager can hire

condition.

Condition 5. The function $\pi_{t+1}(\cdot)$ is increasing and satisfies the conditions that $\pi_{t+1}(0) = 0$, and $\lim_{x\to+\infty}\left[\frac{\pi_{t+1}(x)}{\phi(x)}\right] = 0$.

This condition simply says that, eventually, the cost of providing skills eventually overcome the returns of those skills. It is a generalization of condition 1 used above. Under this condition, the optimal provision of skills if finite and, given z and W_t, the maximized value $\pi_t(z)$ is bounded.

Proposition 5.1. *Assume that Condition* 4 *holds. Then, (a) the optimal transfer* $z_t'^*(z)$ *of skills is independently of the number of workers in the firm* $n_t^*(z)$*; and (b) the returns to the manager are increasing in* z *and given by*

$$\pi_t(z) = (1-\alpha)\, z\, [n_t^*(z)]^{\alpha},$$

his marginal contribution to the production of goods (gross of training costs). (c) The function $n_t^*(z)$ *is strictly increasing in* z*.*

Proof. See appendix. ■

This result is quite intuitive. Given the market price W_t of a young worker, managers optimize how they provide W_t, either in terms of consumption goods or in terms of training. The optimal provision of skills requires that the marginal return of those skills equalize the marginal cost for the firm of providing them.

The profits $\pi_t(z)$ move more than proportionally with z. This is because $n^*(z)$ is a strictly increasing function of z, a result that arise from two reasons. First, $n_t^*(z)$ is increasing because the marginal product of labor in producing goods goes up with z as in the Lucas' span of control model of the previous two sections in which skill formation is the firm,. Second, $n_t^*(z)$ is further increased because with a higher value z reduces the cost of any training level level z', reducing the effective cost of labor for the entrepreneur.

A direct implication of the previous proposition is the following:

Corollary 5.2. *The optimal* $z_t'^*(z)$ *is strictly increasing in* $n_{t+1}^*(\cdot)$*.*

The returns of skills increase with the number of young workers that the current trainee will have under his control next period as a manager. Obviously, if he is expecting to be a worker and have no one under his control, his returns would be zero. In general, if in equilibrium the trainee expects to have more young workers, his returns would be higher and, in equilibrium, he would receive more training. The higher the future rate of growth of the size of the firm's progeny, the higher the current growth in the accumulation of skills.

5.1.1. A simplified example.

Before examining the dynamics for closed and open economies, it is convenient to examine a simplified example of the optimal skill diffusion for the firm level. Assume that the market price of young workers in period t and $t+1$ are, respectively, W_1 and W_2. Also, and for reasons outside the model, $\pi_{t+2}(z'') = 0$ for all $z'' \geq 0$, so, in period $t+1$ managers do not transfer any skills to young workers.

Under these conditions, it is optimal that in period $t+1$, managers do not transfer any skills to young workers. Therefore, their rents are

$$\pi_{t+1}(z') = \theta \left[z'\right]^{\frac{1}{1-\alpha}} \left[W_2\right]^{\frac{-\alpha}{1-\alpha}}.$$

For period t, given $\pi_{t+1}(z')$, the optimal skill formation $z_t'^*(z)$ for each worker under a manager with skill z is from managers with it is optimal to transfer skills in the amount Given this, the optimal transfer of skills in period t by managers with skills z is

$$z_t'^*(z) = (z)^{\mu} \left[\frac{\beta\theta}{(1-\alpha)\, v_0}\right]^{\frac{\mu}{v}} \left[W_2\right]^{1-\mu},$$

which varies directly and more than proportionally with z because $\mu > 1$ and goes down with W_2. For a manager with skills z, the effective cost of labor is the market price W_1 plus the cost of transferring skills minus the (discounted) returns of those skills as is

$$W_1 - \left\{\beta\pi_{t+1}([z_t'^*(z)] - z\phi\left(\frac{z_t'^*(z)}{z}\right)\right\} = W_1 - z\eta\left[\frac{z}{W_2}\right]^{\frac{\alpha[1+v]}{[v(1-\alpha)-\alpha]}},$$

where the equality results from replacing $z_t'^{*}(z)$, simplifying and regrouping terms into a constant $\eta > 0$.[17] Notice that the effective cost of labor is lower than W_1 and that it decreases with the skill z of the manager. These two results are the reflection of the value of z in transferring skills and that more able managers are more efficient teachers and trainers of young workers.

Indeed, for some arbitrary values of (z, W_2), the effective cost of labor could be negative, indicating that young workers are to work for free and even pay the manager for the value of the training received. In this case, because the technology of training is linear in n, the rents for the manager would be infinite. This problem will not arise in equilibrium because the market clearing values of W_1 would has to increase until the effective cost of labor for all the managers is strictly positive.

Therefore, the number of young workers under the control of a manager with skills z is

$$n_t^*(z) = \left[\frac{\alpha z}{W_1 - z\eta \left[\frac{z}{W_2} \right]^{\frac{\alpha[1+v]}{[v(1-\alpha)-\alpha]}}} \right]^{\frac{1}{1-\alpha}}, \tag{5.3}$$

and his rents are

$$\pi_t(z) = (1-\alpha) z^{\frac{1}{1-\alpha}} \left[\frac{\alpha}{W_1 - z\eta \left[\frac{z}{W_2} \right]^{\frac{\alpha[1+v]}{[v(1-\alpha)-\alpha]}}} \right]^{\frac{\alpha}{1-\alpha}}.$$

For the same W_1 both values are strictly higher and more elastic to variations in z than in the standard Lucas' span of control model of the previous two sections where training took place outside the firm.

5.2. Closed Economies

Consider now an economy in which all managers have a level of know-how z. Obviously, this means that $Z_n = z$. Since the production of goods has decreasing

[17] The formula is $\eta \equiv \left[\frac{v(1-\alpha)-\alpha}{(1+v)(1-\alpha)} \right] \left[\frac{1}{(1-\alpha)v_0} \right]^{\frac{1}{v(1-\alpha)-\alpha}} [\beta\theta]^{\frac{(1+v)(1-\alpha)}{v(1-\alpha)-\alpha}}$ where $\theta \equiv [\alpha]^{\frac{\alpha}{1-\alpha}}(1-\alpha)$ as defined above.

returns to n and the cost of producing skills is linear in n, managers with the same skills hire the same number of workers. Since in the first period all managers have the same skills, then each one will hire $n_n = 1$ workers.

As shown in the previous proposition, the optimal level of skills transferred are independent of the number of workers for a manager and solve

$$\max_{\{z'\}} \left[\beta \pi_{t+1}(z') - z\phi\left(\frac{z'}{z}\right) \right]. \tag{5.4}$$

Therefore, all firms will transfer (and all young will receive) the same training z', implying that, along the equilibrium path, within a period, all managers will be identical ($z = Z_n$) and each one will hire $n_n = 1$ workers. Under such circumstances, the rents of all managers are

$$\pi_n = (1-\alpha) Z_n.$$

Because of this, the solution $z'^*(z)$ to (5.4) would be proportional z, implying that for a constant G, the law of motion of the aggregate (average) level of skills follows

$$Z'_n = G Z_n.$$

Since the costs and benefits of skills are internalized, then the market clearing value of W would satisfy

$$W = z\left[\alpha + \beta(1-\alpha)G - \phi(G)\right].$$

Therefore, to characterize a balanced-growth path we only need to determine the value of G. Unless $z' = 0$ or $z' = +\infty$, and even if the problem 5.2 is not globally concave, the global optimal skill formation must locally satisfy a the necessary first order condition

$$\beta \pi'_{t+1}(z') = \phi'\left(\frac{z'}{z}\right). \tag{5.5}$$

and an envelope condition:

$$\pi'_t(z) = n^\alpha - n\phi\left(\frac{z'}{z}\right) + \left(\frac{z'}{z}\right)\phi'\left(\frac{z'}{z}\right). \tag{5.6}$$

Impose $n = 1$, use the functional form for $\phi(\cdot)$ and let $G = \left(\frac{z'}{z}\right)$, implying the equation

$$v_0 G^v = \beta \left[1 + \frac{v v_0 G^{1+v}}{1+v}\right]. \tag{5.7}$$

The left hand side of this equation is the marginal cost while the right hand side is the marginal benefit. A root G of this expression is only relevant if satisfies three conditions: (a) it is a "maximization", i.e. the marginal benefit crosses the marginal cost from above; (b) net output is positive:

$$1 - \phi(G) > 0,$$

and (c) agents prefer to be workers during their youth and managers during their prime age instead of workers in both periods. For this to be the case in a balance growth path, we need that

$$\beta(1 - 2\alpha) G > \phi(G),$$

i.e. the (discounted) difference in the income of managers vs. workers compensate for the training costs.

The existence and uniqueness of a BGP requires restrictions on the parameters so that there is no explosive or implosive growth.

Condition 5. The parameters (v_0, v, β) satisfy the inequalities

$$v_0(1+v)/[1+v(1+v_0)] < \beta < (v_0/[1+v])^{\frac{1}{1+v}}.$$

Proposition 5.3. *(Existence and Uniqueness of a BGP.) Assume that Condition 4 holds. Then there exist a unique $G \in \left(1, \beta^{-1}\right)$ that solves (5.7), satisfies the "maximization" condition for skills, old agents prefer to be managers and net output $1 - \phi(G)$ is positive.*

[Insert Figure 3: a double panel. a) Parameter restrictions; b) RHS and LHS]

Figure 3 graphs the RHS and the LHS of (5.7) for a set of parameter that satisfy condition 5. At $G = 0$, the RHS is positive and LHS is equal to 0. Since the RHS is more convex than the LHS, if the curves cross, they cross twice. The second crossing is not relevant because it defines a local minimum. Therefore, the optimal G is either the first crossing or a point to the right of G. A degenerate solution $G \to \infty$ is ruled out because we require $1-\phi(G)$ to be positive. Condition 5 implies that the first crossing is above 1 (and hence, the economy grows) but below β^{-1} (hence, the value of the firm is bounded from above) and that the second crossing implies $1 - \phi(G)$ to be negative. Therefore, under condition 5, the first crossing is the global optimum.

I now verify that the equilibrium allocation is efficient. Assume that a social planner starts with a cohort of old agents, all with the same expertise Z_n. The planner must decide how many young workers to assign to each manager and how much skills Z'_n to invest in each of the young workers. [18] Because of decreasing returns in production, each manager will be allocated the same number of young workers, and the aggregate production of goods is Z_n. The aggregate cost of skill formation is $Z_n\phi(Z'_n/Z_n)$. Therefore, the resources available for consumption in the period are $Z_n[1-\phi(Z'_n/Z_n)]$ and the value function $S(Z_n)$ for the planner is defined by the Bellman Equation (BE)

$$S(Z_n) = \max_{\{Z'_n\}} \{Z_n[1-\phi(Z'_n/Z_n)] + \beta S(Z'_n)\}.$$

This problem can be equivalently written as the optimal choice of the rate of growth $G = Z'_n/Z_n$. Therefore, the problem can be written as

$$S(Z_n) = \max_{\{G\}} \{Z_n[1-\phi(G)] + \beta S(GZ_n)\}.$$

Since the return function is homogeneous of degree one (HD1) in Z_n and the feasible set is clearly convex, then, the operator defined by this BE maps HD1 functions into itself. However, the operator is not a contraction unless we restrict

[18] Additional restrictions on the parameters (v_0, v, α) must be imposed so that the social planner would not want to break the symmetry. See the appendix for the full argument and the sufficient conditions for symmetry.

the feasible set $G \in [0, G_0]$ for any $G_0 < \beta^{-1}$. Thus restricted, following Alvarez and Stokey (1998), it can be shown that the unique fixed point of this BE is of the form $S(Z_m) = S_0 Z_m$ for a constant S_0 that satisfies

$$S_0 = \max_{G \in [0, \beta_0^{-1}]} \left\{ \left[1 - v_0 \frac{(G)^{1+v}}{1+v} \right] + \beta G S_0 \right\} \tag{5.8}$$

The first order condition for an interior optimum is

$$v_0 G^v = \beta S_0, \tag{5.9}$$

and is sufficient. Therefore, the constant S_0 must satisfy

$$S_0 = 1 - v_0 \frac{\left(\left[\frac{\beta S_0}{v_0} \right]^{\frac{1}{v}} \right)^{1+v}}{1+v} + \beta G S_0.$$

If instead, we use (5.9) and write the previous equation in terms of G we obtain (5.7), the equilibrium growth rate. Imposing Condition 4, is the same we can take G_0 arbitrarily close to β^{-1} and hence, not binding. Under this condition, there is an unique optimal G and it coincides with the equilibrium one.

5.3. Small Open Economy.

Now, consider the case of free entry of foreign managers in a small economy. Instead of spillovers, foreign managers directly transfer skills to the workers under their control. The technology frontier of $(y, z'; z, n)$ is the same for domestic and foreign managers. The difference is that, as before $Z_f > Z_n$ foreign managers are more advanced than local managers.

To rule out an arbitrage, foreign managers must be indifferent between operating inside the country or staying abroad. The absence of frictions implies that all the adjustment is in the extensive margin of the mass of foreign managers entering the country. Each one obtains a return $\pi_f = (1 - \alpha) Z_f$. The market clearing price of a local young agent is the same as in the rest of the world $W_n = W_f$.

Foreign managers face the same problem and market conditions as in their home country. Therefore, they hire one young worker and transfer GZ_f units of skills.

National managers face the same problem and market conditions but they have a lower level of skills Z_n. In any point in time, young workers have to be indifferent among the managers for which they can work. Managers provide the same compensation W_n but with different combination of payments and skill transfers.

The equilibrium is simplified by the fact that in any point in time there can be at most three 'types' of managers. The first are the foreign managers. The second type are 'new' sector of managers who were directly trained by a foreign managers or can trace a foreign manager in his genealogical tree of training. All those 'new' managers are identical of each other because each cohort has the BGP G times the skills of the previous one. Finally, there are the 'deep-rooted' managers, which are the progeny of managers who never worked for foreign managers.

To compute an equilibrium it is convenient to solve the social planner's problem of the country. The planner has to decide how many workers to assign to each of the managers and how much to invest in the skills of each. The planner considers the output generated in each production unit, the cost of skill formation and the market compensation of foreign managers.

Denote by $x \in [0,1]$ the mass of deep-rooted and $1-x$ the mass of new national managers. The 'state' for the recursive planner's problem is (x, Z_n, Z_f). He has to choose the future values x' and Z_n'. With x production units and (x'/x) workers allocated to each and skills Z_n' for the next cohort, aggregate output net of training costs are as follows:

The the deep-rooted sector provides

$$Z_n x \left[(x'/x)^a - (x'/x)\, \phi\left(Z_n'/Z_n\right) \right] = Z_n \left[x^{1-\alpha} \left(x'\right)^a - x' \phi\left(Z_n'/Z_n\right) \right],$$

the national new sector provides

$$(1-x)\, Z_f \left[1 - \phi\left(G\right)\right],$$

and the foreign sector provides

$$\left[(1-x')-(1-x)\right] Z_f \left[\alpha - \phi\left(G\right)\right] = \left[x - x'\right] Z_f \left[\alpha - \phi\left(G\right)\right].$$

These expression arise by condition 5 and hence, the G of the BGP is efficient. Since the social planner takes as given π_n, the market price of a foreign manager, it would be optimal to assign one worker to each of the $(1-x)$ new local managers and to invest in $Z_f G$ units of skills in each of these workers. Any expansion or contraction of this sector will be done in the linear extensive margin of how many foreign managers to bring to the country. Since each foreign manager is paired with one worker, the expansion of the new sector is equal to $(1-x')-(1-x)$. The aggregate output from the foreign sector not only subtracts the cost of training but also the repatriated profits of foreign managers.

Therefore, adding the three and rearranging, the total net output available for consumption $C_1\left(x, Z_n, Z_f, x', Z_n'\right)$ is

$$\begin{aligned} C_C\left(x, Z_n, Z_f, x', Z_n'\right) \equiv\ & Z_n\left[x^{1-\alpha}\left(x'\right)^{a} - x'\phi\left(Z_n'/Z_n\right)\right] && (5.10)\\ & + Z_f\left\{\left[1-\phi\left(G\right)\right] - x\left[1-\alpha\right] - x'\left[\alpha - \phi\left(G\right)\right]\right\} && (5.11) \end{aligned}$$

an expression that clearly indicates the trade-off between allocating one worker to the deep-rooted sector versus the new sector.

However, I have ignored occupation choice. The social planner also has the option to allocate the old agents to be workers under a foreign firm. The country would bring x extra foreign manager, pair each of them with each one of the x old agents. The foreigner receives his market price $(1-\alpha) Z_f$ and the country receives αZ_f because there is no investment in training for old agents. In this case, the total net output available for consumption is

$$C_L\left(x, Z_f\right) \equiv Z_f\left\{\left[1-\phi\left(G\right)\right] - x\left[1-2\alpha\right]\right\}, \tag{5.12}$$

which does not depend on Z_n since the deep-rooted sector is being shut down and the values x' and Z_n' are being set to zero.

The value function V for the social planner's problem is

$$V(x, Z_n, Z_f) = \max\{V_C(x, Z_n, Z_f), V_L(x, Z_f),\}$$

where $V_C(x, Z_n, Z_f)$ is the value under maintaining some agents in the deep rooted sector and $V_L(x, Z_f)$ is the value under the alternative of 'liquidating' the deep-rooted sector. They are given by

$$V_C(x, Z_n, Z_f) = \max_{\{x' \in [0,1], Z_n' \geq 0\}} \{C_C(x, Z_n, Z_f, x', Z_n') + \beta V(x', Z_n', GZ_f)\},$$

and

$$V_L(x, Z_f) = C_L(x, Z_f) + \beta S(GZ_f),$$

where $S(\cdot)$ is the value function of the closed economy.

Notice that both C_L and C_C are $HD1$ in Z_f. Following Alvarez and Stokey (1998) as I before, Z_f can be factored out and solve the problem using the ratio $r \equiv \frac{Z_n}{Z_f}$. To do this, define

$$\begin{aligned} c_C(x, r, x', r') &\equiv r\left[x^{1-\alpha}(x')^{a} - x'\phi(Gr'/r)\right] + [1 - \phi(G)] - x[1-\alpha] - x'[\alpha - \phi(G)], \\ c_L(x, x') &\equiv [1 - \phi(G)] - x[1 - 2\alpha]. \end{aligned}$$

The normalized BE satisfies:

$$\upsilon(x, r) = \max\{\upsilon_C(x, r), \upsilon_L(x)\}, \tag{5.13}$$

where the normalized value of continuing is

$$\upsilon_C(x, r) = \max_{\{x' \in [0,1], r' \geq 0\}} \{c_C(x, r, x', r') + \beta\upsilon(x', r')\}, \tag{5.14}$$

and the normalized value of liquidating is

$$\upsilon_L(x) = c_L(x) + \beta G S_0, \tag{5.15}$$

where S_0 is as defined above for the closed economy.

Lemma 5.4. *If condition 5 holds, there exists a unique solution υ to the BE defined by (5.13), (5.14) and (5.15).*

This result is immediate because under condition 5, $G\beta < 1$, and the BE is a contraction.

[Insert Figure 4: a triple panel. a) V; b) R; c) x]

The solution of this problem is very simple. For a developing country $r < 1$. It is immediate that $c_C(x, r, x', r')$ is strictly increasing in r. Therefore, (5.14) maps increasing functions $v(x', r')$ with respect to r' into strictly increasing functions $v_C(x, r)$ w.r.t. r. Since $v_L(x)$ does not depend on r, for all x there is an $r_L(x)$ so that for all $r \leq r_L(x)$, it is optimal liquidate the sector and allocate the labor units embedded in the old agents and put them to work for foreign or new sector firms. In this case, $v(x, r) = v_L(x)$. Therefore, given x, the value function $v(x, r)$ has initially a flat section and then a strictly increasing section.

With respect to x, notice that $c_L(x)$ is strictly decreasing in x since $\alpha < 1/2$ implying that $v_L(x)$ is strictly decreasing in x. This is because, in a BGP, it would be more productive to have those x agents instead of workers being managers with a ratio $r = 1$ of skills. Also, whenever $r < 1$, $c_C(x, r, x', r')$ is strictly decreasing with respect to x. Hence, (5.14) maps decreasing functions $v(x', r')$ with respect to r' into strictly decreasing functions $v_C(x, r)$ w.r.t. x. Therefore, when $r < 1$, $v(x, r)$ strictly decreasing for all $0 < x < 1$. This is a result that we expected. The more mass we have in the laggard sector the lower the aggregate output.

[Insert Figure 5: opening up: fraction, relative productivity, aggregate output]

Figure 5 considers the evolution of an closed economy that opens up. In the initial stage $x = 1$ and $r < 1$. The optimal response is for the deep-rooted sector to shrink and fully disappear in finite time. Notice that over time the optimal response is also to reduce r. In the period before the planner sets $x = 0$, it is pointless to invest any resources in skills and then $r' = 0$. After that, foreign firms disappear from the country, the economy is fully renewed catching up developed countries.

It is important to notice that the transfer of skills from multinational firms materialize in a new sector of firms, not in the pre-existing sector of firms. Indeed, somewhat in line with empirical findings, the presence of foreign firms should hurt the productivity of pre-existing firms because of the competition effect and the absence of spillovers. The economy as a whole fully catches up because, even with the competition effect in full force, the transfer of skills fully internalize the costs and benefits.

6. Concluding Remarks.

In this paper I used simple general equilibrium growth models to study the impact of multinational firms on the formation of skills and the long run behavior of output a small developing country. Within the context of a simple model environment, I examined three different growth models: (a) an exogenous growth model, (b) an endogenous growth model with an externality in the formation of skills and (c) an endogenous growth model in which skills are internally produced in the firm. The impact of multinational firms on the host country in models (a) and (b) is via spillovers. These two models are rather standard in the growth literature and the existence and measurement of spillovers have been the subject of a vast empirical literature. Spillovers are also the tenet underlying much debate and policy proposals and programs. I show that spillovers are not sufficient to propel the country to catch up with developed countries.

In model (c) there are no spillovers and any transfer of skills is the result of a market transaction. In a competitive environment, firms will optimally transfer a level of skills that gradually obliterate the existent sector and creates a new sector of domestic firms that are at par with the ones in developed countries. In finite time, the small country converges to the income level of developed countries. Spillovers are not necessary.

These results are very suggestive about the role of government policy. In model (a), a benevolent government would definitely want to subsidize foreign firms. In model (b) optimal policy can be quite kinky. For instance, if local skills are very

low, a subsidy would be pointless since the country will converge next period. For higher initial level of skills, the government may want to subsidize foreign firms fully obliterating the local firms for one period and converge to the developed country level in the next. The competition effect in this model can also introduce interesting issues of time consistency.

In model (c) the equilibrium is efficient and the government must not subsidize. However, if there are obstacles to the transmission of skills from foreign firms to local agents, a government may want to undo the obstacle by providing a subsidy. But it is necessary to go beyond these somewhat speculative arguments. Optimal government policy in models with obstacles to the flow of firms and/or the transmission of skills deserve a rigorous and comprehensive consideration.

A. Proofs

Proof of Lemma XXX (Transition Function for Endogenous Growth with Spillovers)

First, notice that if the conditions for (a) hold, then necessarily the economy will reach the set $[0, R_S]$ in a finite number of steps and therefore converge to 1. On the other hand, if the conditions for (b) hold, given that the function Γ_0 crosses the 45^0 line from above and that it is continuous, there is an $\epsilon > 0$ such that the ball $B(R_L, \epsilon)$ is such that $B(R_L, \epsilon) \subset (R_L, 1)$, $\Gamma_0[B(R_L, \epsilon)] \subset B(R_L, \epsilon)$, and $\Gamma_0'(x)$ all $x \in B(R_L, \epsilon)$. Therefore, R_L is locally stable. Finally, if $\Gamma_0(x) > R_S$ and $\Phi(x) > \alpha$, then if the economy starts in a position where old agents become managers, it will always remain there, and in this case the limiting point is R_L.■

Characterization of the problem of managers.

Under Condition 3 the optimal provision of skills if finite and, given z and W_t, the maximized value $\pi_t(z)$ is bounded. However, under condition 3, the optimal $z_t'^*(z)$ is finite. Notice that

$$\begin{aligned}
\pi_t(z) &= \max_{(n,z')} \left\{ z\left[n^\alpha - n\phi\left(\frac{z'}{z}\right)\right] - n\left[W_t - \beta\pi_{t+1}(z')\right] \right\} \\
&= \max_{(n,z')} \left\{ zn^\alpha - nW_t + n\left[\beta\pi_{t+1}(z') - z\phi\left(\frac{z'}{z}\right)\right] \right\} \\
&= \max_{(n)} \left\{ zn^\alpha - nW_t + n\left[\max_{\{z'\}} \left\{ \beta\pi_{t+1}(z') - z\phi\left(\frac{z'}{z}\right) \right\}\right] \right\}
\end{aligned}$$

which proves (a). The maximization $\max_{\{z'\}}\left[\beta\pi_{t+1}(z') - z\phi\left(\frac{z'}{z}\right)\right]$ is not necessarily convex and the optimal is not necessarily interior, but under condition 3, the maximum is attained by a finite value of $z_t'^*(z)$. If $z_t'^*(z) = 0$, then the maximization reduces to

$$\begin{aligned}
\pi_t(z) &= \max_{(n)} \left\{ z\left[n^\alpha\right] - nW_t \right\} &\text{(A.1)} \\
&= (1-\alpha)\, z\left[n_t^*(z)\right]^\alpha, &\text{(A.2)}
\end{aligned}$$

where the second equality follows from the necessary and sufficient condition $z\alpha\left[n_t^*(z)\right]^{\alpha-1} = W$. If instead $z_t'^*(z) > 0$, then

$$\pi_t(z) = \max_{(n)} \left\{ zn^\alpha - nW_t + n\left[\left\{ \beta\pi_{t+1}([z_t'^*(z)] - z\phi\left(\frac{z_t'^*(z)}{z}\right)\right\}\right] \right\},$$

which is a convex maximization. The necessary and sufficient first order condition for $n_t^*(z)$

$$z\alpha\left[n_t^*(z)\right]^{\alpha-1} = W_t - \left\{ \beta\pi_{t+1}([z_t'^*(z)] - z\phi\left(\frac{z_t'^*(z)}{z}\right)\right\}. \qquad \text{(A.3)}$$

Multiplying both sides of this equation by n, and the result in the maximand, we obtain the stated result in (b). To verify (c), notice that the envelope theorem implies that the derivative of the RHS of (A.3) while the LHS is strictly increasing in z for any given $n_t^*(z)$. Therefore, $n_t^*(z)$ has to increase with z.

Balanced Growth Path with Internal Diffusion.

Both LHS and RHS expressions are continuous and strictly increasing as functions of G. To save on notation, LHS(x) and RHS(x) indicate the respective expressions evaluated at x. First, notice that $LHS(0) = 0$ and $RHS(0) = \beta > 0$. Also,

for $\beta \in (0,1)$ and $v, v_0 > 0$, $RHS(\cdot)$ has more curvature than $LHS(\cdot)$ and RHS is eventually higher than the LHS. By direct derivation, both curves have the same slope at β^{-1}. Then, if $RHS\left(\beta^{-1}\right) > LHS\left(\beta^{-1}\right)$ then $RHS(x) > LHS(x)$ for all $x \geq 0$ and no BGP exists. Instead, iff $\beta < (v_0/[1+v])^{\frac{1}{1+v}}$ then, $RHS\left(\beta^{-1}\right) < LHS\left(\beta^{-1}\right)$. In such case, there are two values $0 < G_0 < \beta^{-1} < G_1$ such that $RHS(G_0) = LHS(G_0)$ and $RHS(G_1) = LHS(G_1)$ and $RHS(x) \leq LHS(x)$ $\forall x \in (G_0, G_1)$. In addition iff $v_0(1+v)/[1+v(1+v_0)] < \beta$, then $LHS(1) < RHS(1)$ implying that $1 < G_0 < G_1$. Interestingly iff $\beta < (v_0/[1+v])^{\frac{1}{1+v}}$ then $LHS\left((v_0/[1+v])^{\frac{1}{1+v}}\right) > RHS\left((v_0/[1+v])^{\frac{1}{1+v}}\right)$ implying that necessarily $G_1 > ([1+v]/v_0)^{\frac{1}{1+v}}$. This rules out G_1 because it implies $\phi(G_1) > 1$. Therefore, only G_0 satisfies both conditions and since $G_0 \in \left(1, \beta^{-1}\right)$ the argument is complete.■

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