Knowledge Spillovers and the Optimal Taxation of Multinational Firms*

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January 2012

Abstract

This paper examines a key policy question for many developing countries: Should they allow and even subsidize the entry and operation of multinational firms? I consider a model in which spillovers drive the formation of productive knowledge, the typical rationale for attracting multinational firms. I depart from most work on the gains of openness and instead of using simple counterfactual policies (i.e. compare complete openness or complete closedness with each other or with actual policies) I characterize the gains attainable under a Ramsey program, when taxes are set to maximize the welfare of the recipient country subject to the equilibrium behavior of national and foreign agents. I find that contrary to laissez-faire, openness under optimal taxation always leads developing countries to catch up with developed countries and improves their welfare. However, in stark contrast with some observed practice, I find that a developing country should only subsidize the entry of foreign firms if the domestic accumulation of know-how is also subsidized.

Keywords: Externalities; Gains from openness; Optimal taxation; Ramsey program.

*Preliminary and incomplete. Please, send comments to alexmonge@gmail.com. I am thankful to Andres Rodriguez, Venky Venkateshwaran, Neil Wallace and seminar participants at the Saint Louis Fed, Duke and the Cornell-Penn State Macro conference for useful suggestions.

1 Introduction

Entrepreneurial knowledge, the know-how to combine technology and market opportunities to set up and manage firms, can be the limiting factor for a country's aggregate productivity.[1] Countries with a short supply of entrepreneurial and managerial skills can import them from more developed countries, and recent work suggests that by doing so developing countries accrue significant output and consumption gains.[2] But, does the presence of foreign firms enhance or impair the country's own development of entrepreneurial skills? Would hosting foreign firms lead a developing country to catch up or to lag further behind? In terms of welfare, should developing countries allow or even subsidize the presence of foreign firms? This paper uses a simple general equilibrium growth model to answer these questions.

The model is as follows: Entrepreneurs lead firms, production teams of workers and mid-managers. As in Lucas (1978), the knowledge of the entrepreneur determines the productivity of the team. The model is an OLG economy in which the old set up, manage and are the residual claimants of firms, and the young build up knowledge from the knowledge of the old. Knowledge is the engine of growth and has a dual nature. On one hand, the knowledge of an individual is a rival factor that is restricted to the span-of-control of his own production activities. On the other hand, his knowledge is also a non-rival factor, as his productive ideas help everyone in the country to produce future skills. In a closed country, only national entrepreneurs can set up firms; in an open country, foreign entrepreneurs can enter and set up firms with local labor.[3] When foreign firms transplant their knowledge into a country, they are also transplanting non-rival ideas that are embedded in those skills. This apparent 'free-lunch' could greatly enhance the gains from openness to foreign knowledge, but also, as I show below, can actually lead to welfare losses.

A young entrepreneur builds up his productive knowledge upon two sources of ideas: the specific know-how running the firm in which he is a worker and the productive ideas implemented by the entire set of firms operating in the country. In this way, the model encompasses as special cases two common –but conflicting– views of the accumulation and diffusion of knowledge. In one extreme, the young individual's own firm is the only source of ideas, as in Boyd and Prescott (1987a,b), Chari and Hopenhayn (1991), Jovanovic and Nyarko (1995) and similar to Boldrin and

[1] An extensive literature links the productivity of firms to the quality of their management, e.g. Kaldor (1934), Lucas (1978), Rosen (1982), Prescott and Visscher (1980), Garicano (2000) and Bloom and Van Reenen (2007).

[2] See Antras, Garicano and Rossi-Hansberg (2006), Burstein and Monge-Naranjo (2009) and Eeckhout and Jovanovic (2010) The gains are even larger if these skills are non-rival factors, i.e. can be used simultaneously in many locations. See Ramondo (2008) McGrattan and Prescott (2008).

[3] The emphasis on the cross-border reallocation of management conforms with the observation that multinational firms heavily rely 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 literature on firm specific intangible assets (e.g. Barba-Navarretti 2004 and Markusen 2004).

Levine (2009). In the other extreme, the productive ideas implemented by each firm are uniformly exposed to all the young in the country. Variants of such assumption have a dominant presence in the literature on growth (e.g. Romer 1986, Klenow 1998 and Jones 2006), the impact of openness to trade on growth (e.g. Stokey 1991) and the impact of openness to multinational firms (e.g. Findlay 1978). I show in Monge-Naranjo (2011) that allowing for (partial) internalization makes the model consistent with empirical evidence that foreign direct investment (FDI) can push pre-existing domestic firms not to increase but to *reduce* their productivity.[4] Internalized learning is a natural explanation for the role of former multinational employees in the emergence of new domestic sectors in developing countries.[5][6] On the other hand, (partial) externalities may imply that openness to FDI does not per se lead developing countries to catch up and open up a number of policy issues, some of which are discussed in this paper.

In the model, entry of foreign entrepreneurs impacts the accumulation of skills of the host country in three ways. First, a subset of the domestic workers are directly exposed to foreign knowledge. Second, the set of ideas circulating in the country is enhanced by the knowledge of foreign firms may, which benefits all the local young, including those working for domestic firms. Third, foreign entrepreneurs bid up the cost of labor in the country for all future periods. The first two are positive diffusion effects; the third is a negative competitive force that reduces the returns and the incentives of domestic entrepreneurs to invest in know-how.

In the presence of externalities, laissez-faire (zero taxes) openness does not push developing countries to catch up with the rest of the world. Even if their preferences, policies and inherent capacity to learn are the same and other barriers to knowledge are absent, there exists a unique balanced-growth path (BGP) in which the country does not catch up because the positive impact of the diffusion of foreign ideas is exactly compensated by the reduction in the returns to domestic skills from the *foreseen* future inflows in the next period. This happens because neither the accumulation of domestic knowledge nor the entry of foreign knowledge internalizes the benefit on the formation of skills of subsequent generations. As a matter of fact, for those countries that are initially close to the frontier, openness can be growth reducing and their relative output will decline. Furthermore, for some of those countries openness can reduce domestic aggregate profits by more than the increase in domestic wages and, if so, their overall welfare is also reduced.

I then explore the implications of taxes on domestic and foreign firms for the gains of openness to foreign knowledge. After characterizing equilibrium with arbitrary taxes, I set up the Ramsey program, where the taxes are set to maximize the welfare of the recipient country, subject to the

[4]See, for example, Aitken and Harrison (1999), Xu (2000), and Alfaro et. al (2006) and references therein.

[5]See Rhee and Belot (1990) for the cases of Bangladesh, Colombia and Indonesia.

[6]See Keppler (2001, 2002, 2006) for the car industry in the US and Agarwal et al (2004), Filson and Franco (2006) and Franco (2005) for the rigid disk drive industry.

budget constraint of the government and the equilibrium behavior of national and foreign agents. Contrary to laissez-faire, I find that openness under optimal taxation always leads to welfare gains. Moreover, openness with optimal taxation always leads developing countries to catch up with developed countries. However, in stark contrast with some observed practice, I find that a developing country should only subsidize the entry of foreign firms if the domestic accumulation of know-how is also subsidized.

Finally, I extend the model to allow old individuals to endogenously choose between managerial and labor occupations. This is a margin that has been argued to enhance the gains of openness in static environments.[7] When knowledge is endogenously built up, occupation choices can change the limiting behavior of open countries, delivering them from the laggard (interior) BGP towards fully catching up with developed countries or to converge to the latter faster (see Monge-Naranjo 2011). For the Ramsey program, occupation choices can be useful because the government can use the taxes to redirect factors from occupations that compete with foreign knowledge towards occupations that complement it. Doing so allows the country to catch up faster.

The model of knowledge formation in this paper is based on Monge-Naranjo (2011). However, that paper and related work by Beaudry and Francois (2010), Dasgupta (2010) and Sampson (2011), restrict attention to comparing complete openness with complete closedness. The general trend in the literature is to use increasingly sophisticated models to study different aspects of the gains from openness, but still focus on simple open vs. closed counterfactual policies. I depart from that trend in the literature and characterize the gains attainable under different policies, in particular under optimal Ramsey taxation. In doing so, I have abstracted from many aspects studied in the literature of multinational activity such as the endogenous choice of organization (see the recent survey by Antras and Rossi-Hansberg 2009 and references therein), and the choice of technologies that multinational firms send to their subsidiaries (e.g. Helpman 1984 and Keller and Yeaple 2010). The analysis also abstracts from international flows of labor (e.g., Rauch 1991; Klein and Ventura 2006) and of physical capital of physical capital (e.g. Castro 2004, Gourinchas and Jeanne 2003). I have also abstracted from interactions between technology diffusion, multinational activity and international trade in goods (e.g. Grossman and Helpman 1991, Eaton and Kortum 2006, Rodriguez-Clare 2007, and Alvarez, Buera, and Lucas 2010). The paper also omits other forms of knowledge or human capital (e.g. Krishna and Chesnokova 2009) and their interaction with technology adoption (e.g. Stokey 2010), and does not consider specificity or appropriateness of technologies (e.g. Basu and Weil 1998). I have also abstracted from cross-country spillovers (e.g. Damsgaard and Krusell 2008 and Klenow and Rodriguez-Clare 2005) Finally, the paper

[7] See Antras, Garicano and Rossi-Hansberg (2006), Burstein and Monge-Naranjo (2009) and more forcefully Eeckhout and Jovanovic (2009).

assumes that there are no frictions or tax distortions at the interior of countries in the allocation of workers across managers (e.g. Buera and Shin, 2010, Cagetti and De Nardi, 2006, Guner et al. 2008, Gennaioli and Caselli 2006, among others). Extending the model here with some of these dimensions could lead to interesting additional insights on the optimal policies and the gains from foreign knowledge for a developing country.

The rest of the paper proceeds as follows. In Section 2, I lay out the model. In Section 3, I set up the conditions for competitive equilibria of closed and open economies with arbitrary taxes. Section 4 studies closed economies, including the efficient allocation and its (limiting) implementation with proportional taxes. Section 5 consider economies that allow entry of foreign skills and ideas, study the implications of arbitrary taxes and defines and characterizes the growth and welfare implications of optimal taxation . Section 6 consider the same issues but in an economy with endogenous occupation choices. Section 7 concludes with a discussion of a number of important open issues.

2 The Model

Consider a discrete time, infinite horizon OLG economy with a single consumption good. Individuals live for two periods. In each period, the population consists of equal sized cohorts (normalized to one) of young and old persons. A person born at time t that consumes c_t^t and c_{t+1}^t in periods t and $t+1$, respectively, attains utility

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

where $0 < \beta < 1$.

As in Lucas (1978), the consumption good is produced by 'firms', teams of one manager and a group of workers. Managers can also be seen as entrepreneurs since they will be the residual of firms.[8] The (person-specific) skills or knowledge of an entrepreneur determines the productivity of the firm under his control. With $z \geq 0$ units of entrepreneurial skills and $n \geq 0$ units of labor, a firm produces

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

units of the consumption good. The degree $\alpha \in (0, 1)$ of decreasing returns to labor n is also the span-of-control parameter in this economy.[9]

[8] This formulation of equilibrium is equivalent to one in which firms with constant returns to scale (and zero-profits in equilibrium) are the ones hiring "managerial" services from the entrepreneurs. For a model that distinguishes between the economic functions of entrepreneurs and managers, see Holmes and Schmitz (1994).

[9] These teams can be seen as "firms" or as parts of a conglomerate of teams within the boundaries of the same firm.

In each period of life, every person has an endowment of one unit of time. When young, that unit can only be supplied as labor; when old, that unit could also be used to supply entrepreneurship services, i.e. setting up and controlling a firm. The returns to entrepreneurship are foreseen by the young as they decide whether and how much to invest in acquiring knowledge.

Accumulation of skills is made on the basis of the productive ideas to youth is exposed to. Let $z^E \geq 0$ denote the exposure to ideas of an individual. It contains contributions from two sources: (i) the knowledge z of the particular entrepreneur for whom the youth works for; and (ii) an average Z_t^O of the knowledge implemented by of all firms, domestic and foreign, that operate inside the country at the time. While z can vary across young persons, Z_t^O is the same for all of the agents in the country that are young in period t. In particular, I will assume that

$$z^E = (z)^{\gamma} \left(Z_t^O\right)^{1-\gamma}, \tag{1}$$

where $0 \leq \gamma \leq 1$ will be called the *internalization* parameter because it determines how much a young person learns internally from his job, and, as explained below, the extent in which the gains of learning can be internalized by the relationship between a manager and his workers. Notice that z^E is increasing and linearly homogeneous in the levels of both sources of knowledge. Moreover, notice that there are no "size" effects, i.e. the number (mass) of firms does not impact the level z^E.

The average Z_t^O is a national "public good", i.e. a non-rival factor available to everyone in the country.[10] It is determined as follows: Let μ_t be the (endogenous, as explained below) probability measure that indicates the allocation of the country's total labor across firms with different knowledge levels. That is, for any Borel set $B \subset \mathbb{R}_+$, $\mu_t(B)$ indicates the share of the labor in control of entrepreneurs with knowledge levels in B. Then, Z_t^O is a generalized (or Hölder) weighted mean of all the active firms:

$$Z_t^O = \left[\int_{\mathbb{R}_+} (z)^{\rho} \mu_t(dz)\right]^{\frac{1}{\rho}}, \tag{2}$$

where the parameter ρ can assume any value in the extended real numbers. This formulation encompasses many familiar average formulas. The arithmetic, geometric and harmonic means correspond to, respectively, $\rho = 1, 0, -1$. If $\rho \to -\infty$, Z_t^O is the minimum value in the support of μ_t, while if $\rho \to \infty$, it is the maximum value.

Given the exposure to productive ideas z^E, the cost (in terms of current consumption) for a young individual to acquire any level $z' \geq 0$ of skills for the next period is $z^E \phi\left(z'/z^E\right)$, where

[10] Notice the dual nature of entrepreneurial knowledge. On one hand, as in Boldrin and Levine 2009, knowledge are skills, and as such, a rival factor that is tied to the time of the holder; it cannot be used simultaneously in multiple tasks. On the other hand, as in Romer 1986, knowledge are ideas; as long as $\gamma < 1$ there are non-rival and partially non-excludable factors that could be used by any young forming entrepreneur in the country without crowding out the use by others.

$\phi : \mathbb{R}_+ \to \mathbb{R}_+$ is a non-negative, continuously differentiable and strictly convex function with $\lim_{x\to 0} \phi(x) = \phi'(x) = 0$ and $\lim_{x\to\infty} \phi(x) = \phi'(x) = \infty$. Total and marginal costs of investing are strictly increasing and strictly convex in z' and strictly decreasing in z^E. Indeed, the marginal cost of z' is $\phi'\left(z'/z^E\right) = v_0 \left(z'/z^E\right)^v$, which depends only one the ratio z'/z^E, i.e. how far an individual accumulates skills relative to his exposure to ideas z^E. It is convenient to focus on the functional form

$$\phi\left(\frac{z'}{z^E}\right) = \frac{v_0}{1+v}\left(\frac{z'}{z^E}\right)^{1+v}, \tag{3}$$

where v_0, $v > 0$. I shall keep $\phi(\cdot)$ and $\phi'(\cdot)$ as shorthands in some of the formulas below.

The parameters ρ, v and γ are key for the formation and diffusion of knowledge. The *curvature* parameter v determines the impact of z^E on the costs of acquiring z'; it determines whether and how quickly knowledge grows over time. The *diffusion* parameter ρ determines how easily superior ideas impact the value of Z^O and how foreign ideas may diffuse inside a country. The higher the value of ρ, the higher the impact of superior ideas on the common pool Z^O. In the extreme, if $\rho = +\infty$, and only the very best of all the ideas are considered in Z^O. In the opposite extreme, a value $\rho = -\infty$, implies that only the worst ideas are understood and can be used to build up skills.

Most importantly, by allowing any value $0 \leq \gamma \leq 1$, the model encompasses two common –but conflicting– views of the accumulation and diffusion of knowledge. On one hand, if $\gamma = 0$, then a common value $z^E = Z^O$ holds for everyone and externalities are the only engine of accumulation and diffusion. Such assumption has a dominant presence in the literature on growth (e.g. Romer 1986 and Lucas 1988), the impact of openness to trade on growth (e.g. Stokey 1991) and the impact of openness to multinational firms (e.g. Findlay 1978). On the other hand, if $\gamma = 1$, then the exposure to ideas –and hence, the ability to accumulate skills– are uniquely determined by one's own firm. This gives rise to a richer relationship between young and old entrepreneurs, one that fully internalize the costs and benefits of accumulating skills. Such is the view in Boyd and Prescott (1987a,b), Chari and Hopenhayn (1991), Jovanovic and Nyarko (1995), and others. By allowing any $0 \leq \gamma \leq 1$, the model here combines the impact of externalities with labor markets that compensate for differences in the learning opportunities across firms with different knowledge levels.

Finally, a government in the country collects taxes and (possibly) disburses subsidies. Following the Ramsey tradition, I assume that governments can only charge proportional taxes on the net-income of the different individuals. However, I allow these taxes to vary across types of individuals. In particular, let $\tau = \left\{\tau_t^W, \tau_t^E, \tau_t^F\right\}_{t=0}^{\infty}$ denote, respectively, the tax rates on the net-earnings of domestic workers, domestic entrepreneurs and foreign entrepreneurs operating inside the country for each period $t \geq 0$. Tax rates can be negative (subsidies) but can never be above 1. For simplicity, I assume zero government expenditures but the analysis can be easily extended to economies in which the government spends a constant fraction of the country's domestic output.

3 Competitive Equilibria

I consider perfect foresight competitive equilibria. The key component of the price system is a sequence of wages function $\{w_t : \mathbb{R}_+ \rightarrow \mathbb{R}_+\}_{t=0}^{\infty}$, where $w_t(z)$ is the price that an entrepreneur with skills z pays for a worker at time t. The dependence of the price on the old manager's skill z is explained below. In equilibrium, the discount factor β pins down the interest rate.

In this section tax policies are taken as given. For clarity of exposition, this section abstracts from occupation choices, which will be fully examined in Section 5.

Consider first the decisions of an old entrepreneur who has already acquired a given level of skills z. Facing market wages $w_t(z)$, he attains pre-tax earnings $\pi[z, w_t(z)] \equiv \max_{\{n\}} \{zn^{\alpha} - w_t(z)n\}$. Net-of-taxes, his income is

$$\left(1 - \tau_t^E\right) \pi\left[z_t, w_t(z)\right] = \left(1 - \tau_t^E\right) \left[\alpha^{\frac{\alpha}{1-\alpha}} (1-\alpha)\right] z^{\frac{1}{1-\alpha}} \left[w_t(z)\right]^{\frac{-\alpha}{1-\alpha}}. \tag{4}$$

Notice that because the tax τ_t^E is on his net-income it does not distort his optimal hiring of labor,

$$n^*\left[z, w_t(z)\right] = \left[\frac{\alpha z}{w_t(z)}\right]^{\frac{1}{1-\alpha}}, \tag{5}$$

which is increasing and convex in z and decreasing in $w_t(z)$.

Given $w_t(z)$, $\pi[\cdot, w_t(z)]$ is strictly increasing and convex; given z, $\pi(z, \cdot)$ is strictly decreasing in $w_t(z)$. The total response of the functions π and n^* to variations in z will be even more steeply positive and convex in z because, as seen below, the equilibrium function $w_t(z)$ is non-increasing in z.

Consider now the decisions of a young person. First, he must select the firm for which to work for. Second, he must decide whether and how much to invest in entrepreneurial skills. With respect to the latter, given an exposure to ideas z^E and the next period's cost of labor $w_{t+1}(\cdot)$, the optimal investment in entrepreneurial skills z' solves

$$V\left[z^E, w_{t+1}(\cdot),\right] \equiv \max_{z'} \left\{ \left(1 - \tau_{t+1}^E\right) \beta\pi\left[z', w_{t+1}(z')\right] - z^E \phi\left(\frac{z'}{z^E}\right) \right\}. \tag{6}$$

Here, I am assuming that investments in skill formation $z^E \phi\left(z'/z^E\right)$ are not deductible from labor earning taxes.[11] The key determinant of the optimal investment in skills z' are the exposure to

[11] If investment costs were not tax-deductible, then $V\left[z^E, w_{t+1}(\cdot),\right] \equiv \max_{z'} \left\{ \left(1 - \tau_{t+1}^E\right) \beta\pi\left[z', w_{t+1}(z')\right] - \left(1 - \tau_t^W\right) z^E \phi\left(\frac{z'}{z^E}\right) \right\}$. With this alternative assumption, the precise formulas below will be changed but not the substance of the results.

ideas z^E, the future cost of labor $w_{t+1}(\cdot)$ and the foreseen taxes τ_{t+1}^E on entrepreneurial labor. Under the conditions laid out in Proposition 1 below, optimal investments in skills are determined by the condition

$$\beta\left(1-\tau_{t+1}^E\right)\left[\pi_1\left[z', w_{t+1}(z')\right]+\pi_2\left[z', w_{t+1}(z')\right]\frac{\partial w_{t+1}(z')}{\partial z'}\right]=\phi'\left(\frac{z'}{z^E}\right), \tag{7}$$

where $\pi_1(\cdot)$ and $\pi_2(\cdot)$ stand for, respectively, the first derivative of π with respect to the the skill z of the manager and the wage $w_{t+1}(z)$ he will have to pay for labor.

Let $z_{t+1}=\zeta_t\left[z^E\right]$ denote the optimal accumulation of skills for each period t. It is increasing in z^E as a better exposure of ideas reduces the marginal costs of investment, i.e. the RHS of equation (7). However, as discussed in Section 5, if z^E is too low, the optimal choice may be zero as those youth will remain workers when old. The function $\zeta_t(\cdot)$ is shaped by the wage function $w_{t+1}(\cdot)$. Higher future wages, i.e. higher levels for $w_{t+1}(\cdot)$, reduce the investment in skills because it reduces the marginal return to skills in production ($\pi_{12}>0$). Moreover, the slope of $w_{t+1}(\cdot)$ also matters for investment in skills. Because $\pi_2<0$, the more skilled entrepreneurs will pay lower wages because their workers value the better learning opportunities. Finally, notice that $\zeta_t(\cdot)$ is directly affected by the tax rate τ_{t+1}^E on the returns to entrepreneurial knowledge.

When choosing which firms to work for, the young fully perceive the implied differences in learning opportunities across firms. For simplicity, as in Chari and Hopenhayn (1991) and others, all young individuals are identical and in equilibrium they must be indifferent to work for the different active firms. Then, the wages paid by firms with two different know-how levels $z_0<z_1$ must compensate for differences in learning opportunities,

$$\left(1-\tau_{t+1}^W\right)\left[w_t(z_0)-w_t(z_1)\right]=V\left[z_1^E, w_{t+1}(\cdot)\right]-V\left[z_0^E, w_{t+1}(\cdot)\right], \tag{8}$$

where $z_0^E=(z_0)^\gamma\left(Z^O\right)^{1-\gamma}<z_1^E=(z_1)^\gamma\left(Z^O\right)^{1-\gamma}$. Less skilled managers must pay higher wages, $w_t(z_0)\geq w_t(z_1)$ as the higher skilled managers provide better learning opportunities, $V\left[z_1^E, w_{t+1}(\cdot)\right]\geq V\left[z_0^E, w_{t+1}(\cdot)\right]$. The proper interpretation of (8) is as differences in the cost of *effective* units of labor, which may not directly translate into differences into workers earnings differences when there is heterogeneity across workers too.[12]

Let λ_t be a positive and fine measure that describes the managers operating in the country at time t. In general, λ_z^t can be composed of a measure of domestic managers λ_t^H and a measure of foreign managers λ_t^F. For reasons that will become apparent below, I assume that λ_z^t has a bounded support in the non-negative numbers. Given wages $w_t(z)$, the amount of labor hired by

[12]For instance, an economy with heterogeneous entrepreneurs and heterogeneous workers and small fixed costs of hiring each worker. More productive firms would want to hire more units of effective labor, and to minimize on the fixed costs, in equilibrium they would hire the workers endowed with the most effective units. Such positive assortive matching could lead to higher earnings for workers in the more productive firms.

an entrepreneur with skill level z is given by (5), and the distribution of labor employed across skill levels is given by

$$\mu_t(B) = \frac{\int_B n^* [z, w_t(z)] \lambda_t(dz)}{\int_{\mathbb{R}_+} n^* [z, w_t(z)] \lambda_t(dz)}, \text{ for any Borel set } B. \tag{9}$$

In each period t, the government collects (or pays if negative) taxes from domestic entrepreneurs, foreign entrepreneurs and domestic workers in the amounts. As of time $t = 0$, the government budget constraint, is given by

$$\sum_{t=0}^{\infty} \beta^t \left[\tau_t^E \int_{\mathbb{R}_+} \pi [z, w_t(z)] \lambda_t^H(dz) + \tau_t^F \int_{\mathbb{R}_+} \pi [z, w_t(z)] \lambda_t^F(dz) + \tau_t^W \int_{\mathbb{R}_+} w_t(z) \mu_t(dz) \right] \geq 0, \tag{10}$$

because the government has zero expenditures.

Given a government policy $\tau = \{\tau_t^E, \tau_t^W, \tau_t^F\}$, a *competitive equilibrium* is a price system $\{w_t(\cdot)\}_{t=0}^{\infty}$, profit and labor hiring functions $\pi[z, w_t(z)]$, $n^*[z, w_t(z)]$, a pair of sequence of skill-acquisition functions $\{V[z^E, w_{t+1}(\cdot),], \ \zeta_t(z^E)\}_{t=0}^{\infty}$, and sequences of aggregate exposure to ideas $\{Z_t^O\}_{t=0}^{\infty}$, and non-negative measures of domestic and foreign firms $\{\lambda_t^H, \lambda_t^F\}_{t=0}^{\infty}$, such that: (i) the government budget constraint (10) is satisfied for $t = 0$; moreover, for any $t \geq 0$: (ii) $\pi[z, w_t(z)]$, $n^*[z, w_t(z)]$ solve the profit maximization problem of the old; (iii) $V[z^E, w_{t+1}(\cdot),]$, $\zeta_t(z^E)$ solve the optimal acquisition of skills for the young for any level $z^E \geq 0$, and $w_t(\cdot)$ satisfies the indifference condition (8); (iv) the value Z_t^O is given by (2) for $\mu_t(\cdot)$ defined by (9), given $\lambda_t = \lambda_t^H + \lambda_t^F$; (iv) the distribution of skills for the domestic firms $\{\lambda_t^H\}_{t=0}^{\infty}$ evolves according to $\{\zeta_t\}_{t=0}^{\infty}$, i.e. for any Borel set $A \subset \mathbb{R}_+$, $\lambda_{t+1}^H(A) = \int_{\mathbb{R}_+} \mathbf{1}_A\{\zeta_t[(z)^\gamma (Z_t^O)^{1-\gamma}]\}\mu_t(dz)$; and (v) an entry condition for foreign firms $\{\lambda_t^F\}_{t=0}^{\infty}$ and (vi) market-clearing for the domestic labor market that pin down $\{w_t(\cdot)\}_{t=0}^{\infty}$.

Sections 3 and 4 complete the definition of competitive equilibrium examining different conditions (v) and (vi) for foreign entry domestic labor market clearing.

4 A Closed Economy

This section considers the case when $\lambda_z^{F,t} = 0$ for all t. In such a *closed economy*, domestic entrepreneurs are the only ones demanding local labor. Moreover, domestic entrepreneurs are the only source of ideas for the knowledge formation of future generations. Closed economies can be seen as a case in which $\tau_t^F = 1$ in all periods.

4.1 Homogeneous Managers

Consider first the case when all of the have the same level of knowledge $z = Z_0 > 0$, i.e. $\lambda_0^H = \delta_{Z_0}$, a Dirac distribution. Regardless of the value ρ, the average Z_0^O is also equal to Z_0; likewise, regardless of the value of γ, all young workers are exposed to the same level of ideas $z^E = Z_0$. Therefore, at time $t = 0$ all firms pay the same wage $w_0 > 0$ and hire the same units of labor, $n_0^* = 1$. Moreover, since all the young are exposed to the same level of ideas and foresee the same wage function $w_1(\cdot)$ for $t = 1$, they invest the same amount in skills $Z_1 > 0$. Then $\lambda_1^H = \delta_{Z_1}$. The same logic applies for any period t and the initial homogeneity will be preserved over all the generations. Thus, the entire dynamics of the country can be traced by a sequence $\{Z_t\}_{t=0}^{\infty}$ of knowledge levels for each generation.

Under those circumstances, $n_t^* = 1$ for all firms. Workers wages and entrepreneurs' profits are equal to $w_t = \alpha Z_t$ and $\pi_t = (1-\alpha) Z_t$, respectively. Using these, and defining $G_t \equiv Z_{t+1}/Z_t$ to be the gross growth rate of knowledge, the optimality condition (7) boils down to

$$\beta \left(1 - \tau_{t+1}^E\right) \left[1 + \frac{\gamma v v_0 \left(1 - \tau_{t+1}^W\right)}{1+v} \left(G_{t+1}\right)^{1+v}\right] = v_0 \left(G_t\right)^v. \tag{11}$$

Clearly, higher taxes τ_{t+1}^E reduce the accumulation of knowledge G_t by the current young generation because they reduce their marginal net-of-taxes returns. More interestingly, the current accumulation G_t of knowledge is higher when future young generations are foreseen to accumulate more knowledge, i.e. when G_{t+1} is higher, because the returns to accumulate knowledge are not only in terms of producing goods but also in terms of producing skills for the future generations.

Restrict attention now to balance growth paths (BGP), equilibria in which entrepreneurial knowledge grows at a constant rate G. The value of G must be a root of the implied equation (11) when $G_t = G_{t+1} = G$ and $\tau_{t+1}^E = \tau^E < 1$,

$$\beta \left(1 - \tau^E\right) \left[1 + \frac{\gamma v v_0 \left(1 - \tau^W\right)}{1+v} \left(G\right)^{1+v}\right] = v_0 \left(G\right)^v. \tag{12}$$

Proposition 1 in Monge-Naranjo (2011) examines the case of $\tau^E = \tau^W = 0$. Following exactly the same steps leads to the following results for any $-\alpha/(1-\alpha) < \tau^E < 1$:

Proposition 1 (Closed economy BGP) *For a closed economy with $-\alpha/(1-\alpha) < \tau^E < 1$ the following hold:* ***(a)*** *An equilibrium BGP with homogeneous skills exists if either (i) $\gamma > 0$, $v > 1/(1-\alpha)$ and $\beta\left(1-\tau^E\right) \leq \left(v_0/\left[\gamma^v(1+v)\right]\right)^{\frac{1}{1+v}}$ or (ii) $\gamma = 0$ and $v > 1/(1-\alpha)$;* ***(b)*** *if an equilibrium BGP exists it is unique ;* ***(c)*** *the economy exhibits sustained growth, i.e. $G > 1$ if $\beta\left(1-\tau^E\right) > v_0(1+v)/(1+v+vv_0\gamma)$;* ***(d)*** *if either condition in (a) holds and initially the economy is populated by homogeneous entrepreneurs, then the only equilibrium is the BGP; other non-explosive fluctuations in G_t are ruled out.*

The curvature parameter v must be high enough for a BGP to exist. Otherwise, it may be possible that the left-hand-side of (12) always lays above the right-hand-side; if so, the optimal accumulation would be degenerated to $+\infty$. Under conditions in part (a) there are two roots, but the higher one is ruled out because it corresponds to a local minimum. Being in the lower root also rules out self-fulfilling (extrinsic) fluctuations.

The condition $\tau^E > -\alpha/(1-\alpha)$ arises from the budget constraint of the government (10) since the government cannot impose a tax $\tau^W \geq 1$ on workers to subsidize entrepreneurs. Other than that, the government could set any tax $\tau^E < 1$ because it effectively disposes of lump-sum taxation on workers. As we will see in Section 5, occupation choices would impose additional restrictions on taxes τ^E and τ^W.

4.2 Heterogeneous Managers

Consider now a non-degenerate but bounded support in the distribution of skills for the initial old generation.[13] For any level z, and given Z^O_{t+1}, $w_{t+1}(\cdot)$ and $w_{t+2}(\cdot)$, the first order condition for the optimal acquisition of skills z' is

With all of this, after simplifying, equation (7) becomes

$$\beta\left(1-\tau^E_{t+1}\right)\left(\frac{\alpha z'}{w_{t+1}(z')}\right)^{\frac{\alpha}{1-\alpha}}\left\{1+\frac{\left(1-\tau^W_{t+1}\right)\alpha v v_0 \gamma (z')^\gamma \left(Z^O_{t+1}\right)^{1-\gamma}}{(1+v)\, w_{t+1}(z')}\left[\frac{z''}{(z')^\gamma \left(Z^O_{t+1}\right)^{1-\gamma}}\right]^{1+v}\right\} = v_0\left(\frac{z'}{z^E}\right)^v, \tag{13}$$

where z'' is the foreseen acquisition of skills of the young workers at period $t+1$ working for the currently forming entrepreneur. This expression is derived first using (8) to obtain, $\frac{\partial w_{t+1}(z')}{\partial z'} = -\left(1-\tau^W_{t+1}\right) V_1[\left(z^E\right)', w_{t+2}(z'')]\frac{\partial \left(z^E\right)'}{\partial z'}$, and then the envelope condition on (6) to get $V_1\left[\left(z^E\right)', w_{t+2}(z'')\right] = -\frac{v v_0}{1+v}\left[\frac{z''}{(z')^\gamma \left(Z^O_{t+1}\right)^{1-\gamma}}\right]^{1+v}$. See Monge-Naranjo (2011) for further details.

The proof of the following limited but useful results are also in Monge-Naranjo (2011).

Proposition 2 *Assume constant taxes $\tau^E_t = \tau^E > -\alpha/(1-\alpha)$. If an equilibrium exist: (a) the wage function $w_t(z')$ is non-increasing; (b) if $v > \alpha/(1-\alpha)$, the function $z_{t+1} = \zeta_t(z)$ is strictly increasing. Additionally, (c) if $\gamma > 1-\alpha/[(1-\alpha)v]$, then $\zeta_t(z_1)/\zeta_t(z_0) > z_1/z_0$ for any $z_1 > z_0$ in the support of λ_t.*

Albeit limited, this simple result has important implications for the limiting behavior of the skill distribution:

Corollary 1 *If either $\gamma > 1-\alpha/[(1-\alpha)v]$ or $\gamma = 0$, then, any equilibrium starting with initial distribution with bounded support will asymptotically converge to a homogenous firms BGP.*

[13] Boundedness is required. Otherwise only the limiting entrepreneur would hire the entire mass of young workers.

Most obviously, if $\gamma = 0$, pre-existing heterogeneity disappears after one period. More interestingly, if $\gamma > 1-\alpha/\left[(1-\alpha)v\right]$, i.e. one's own manager is a leading source of ideas, then pre-existing differences in the exposure to ideas will lead to widening gaps in skill formation. In this case, the economy exhibits *dispersion-induced homogeneity*: It converges to a pool of homogeneous entrepreneurs because the top end of the distribution reproduces at a faster pace than the lower end; in the limit, all the remaining entrepreneurs would be the offsprings of the initially highest skilled entrepreneur(s).

4.3 Efficient Allocations

In this section I consider allocations that maximize the net-present value of the country's aggregate consumption. I first discuss the social planner's allocation of (young) labor $n_t(z)$ across old managers and the investment decisions $z_{t+1}(z)$ on each young worker at time t. Then, I show how some of those allocations can be decentralized with the appropriate tax rates.

Given a initial distribution λ_0, a social planner would choose sequences $\{n_t : \mathbb{R}_+ \to \mathbb{R}_+\}_{t=0}^{\infty}$ and $\{z_{t+1} : \mathbb{R}_+ \to \mathbb{R}_+\}_{t=0}^{\infty}$, to maximize the value of

$$S(\lambda_0) = \sum_{t=0}^{\infty} \beta^t \left\{ \int_{\mathbb{R}_+} \left[z\left[n_t(z)\right]^{\alpha} - n_t(z)\, z_t^E(z)\, \phi\left(\frac{z_{t+1}(z)}{z_t^E(z)} \right) \right] \lambda_t(dz) \right\},$$

subject to the adding up constraint

$$\int_{\mathbb{R}_+} n_t(z)\, \lambda_t(dz) = 1,$$

and the law of motion for the distribution of skills

$$\lambda_{t+1}[A] = \int_{\mathbb{R}_+} \mathbf{1}_A\{z_{t+1}(z)\} n_t(z)\, \lambda_t(dz)\,, \text{ for any Borel set } A \subset \mathbb{R}_+.$$

Here $z_t^E(z) \equiv z^{\gamma}[\int \boldsymbol{x}^{\rho} n_t(x)\, \lambda_t(dx)]^{\frac{1-\gamma}{\rho}}$ is the implied exposure to ideas of each worker, as pinned down by each person's own manager z, and the outside exposure to ideas as pinned down by λ_t and n_t.

A social planner internalizes two aspects of labor allocations and learning decisions that are omitted in a laissez-faire competitive equilibrium. First, the investments $z_{t+1}(z)$ also consider the impact on the exposure to ideas for *all future* young workers, not only those working for the individual entrepreneur. Second, the allocation of labor $n_t(z)$ also consider the implied impact on the exposure to ideas of all *current* young workers. This effect is positive for high z and negative for low z.

The internalization of these two forces magnifies the differences in the allocation of labor and in the learning investments across firms with different managerial skills levels. The proof for the following proposition is in the Appendix:

Proposition 3 *Let* $\left\{n_t^{LF}(\cdot),\ z_{t+1}^{LF}(\cdot)\right\}_{t=0}^{\infty}$ *and* $\left\{n_t^{SP}(\cdot),\ z_{t+1}^{SP}(\cdot)\right\}_{t=0}^{\infty}$ *denote, respectively, the labor allocation and knowledge formation for the laissez-faire and social planners allocations. If* $0 \leq \gamma < 1$ *and* $-\infty < \rho < \infty$,

$$\frac{n_t^{LF}(z_1)}{n_t^{LF}(z_0)} < \frac{n_t^{SP}(z_1)}{n_t^{SP}(z_0)} \text{ and } \frac{z_t^{LF}(z_1)}{z_t^{LF}(z_0)} < \frac{z_t^{SP}(z_1)}{z_t^{SP}(z_0)}$$

for any $z_0 < z_1$ *and* $t \geq 0$ *for which the ratios are well defined.*

Both of these forces implies that in any point in time, the efficient allocations leads to a more dispersion and therefore, to a faster convergence to homogeneity than in the laissez-faire allocation.

If (when) initially the old cohort of managers is homogeneous, the planning problem is fairly simple. Assume that all the current crop of old managers have the same expertise $Z_t > 0$. The planner must decide the units of labor to assign to each manager and the skills Z_{t+1} to invest in each of the young workers. Because learning is the same in all firms, the decreasing returns in production implies that all managers must command the same amount of labor, n_t. Aggregating over firms, aggregate output of goods is Z_t. It is evident also that it is optimal to invest the same knowledge Z_{t+1} in each of the future managers. The aggregate cost of learning formation is $Z_t\phi\left(Z_{t+1}/Z_t\right)$.

In recursive form, the value function $S(Z)$ for the planner is defined by the Bellman Equation (BE):

$$S(Z) = \max_{\{Z' \geq 0\}} \left\{ Z\left[1 - \phi\left(\frac{Z'}{Z}\right)\right] + \beta S(Z') \right\}. \tag{14}$$

Notice that the period return function $Z\left[1 - \phi\left(Z'/Z\right)\right]$ is linearly homogeneous and jointly concave in (Z, Z') and that the feasible set for Z' does not depend on Z. These properties lead to the following result:

Proposition 4 *Assume that parameter conditions in Proposition 1 hold for* $\gamma = 1$. *Then, the unique solution to (14) has the form* $S(Z_n) = S_0 Z_n$ *for* $0 < S_0 < \infty$ *given by*

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

Moreover, the value G *that solves this maximization coincides with the laissez-faire* G *for* $\gamma = 1$.

Let G^{SP} and G^{LF} denote the growth rate in the social planner's and in the laissez-faire allocations, respectively. When $\gamma < 1$, $G^{SP} > G^{LF}$, because the individual entrepreneur only captures the returns on his knowledge accumulation that accrued in his profits and not on the aggregate stock of ideas circulating for future generations. However, for the case of homogeneous managers, the implementation of the socially efficient accumulation of knowledge is fairly simple. It involves simple proportional Pigouvian taxes. The following result is straightforward to verify:

Proposition 5 *Assume* $0 \le \gamma < 1$. *If there is a tax rate* $-\alpha/(1-\alpha) < \tau^E < 1$ *such that*

$$\tau^E = 1 - \frac{v_0 \left(G^{SP}\right)^v}{\beta \left[1 + \frac{(1-\tau^W)\gamma v v_0}{1+v} \left(G^{SP}\right)^{1+v}\right]}, \text{ and } \tau^W = -\frac{\tau^E (1-\alpha)}{\alpha} < 1, \tag{15}$$

then the allocation of labor and formation of knowledge in a competitive equilibrium with constant taxes $\left(\tau^E, \tau^W\right)$ *coincide with the socially efficient ones.*

When $\gamma < 1$, a subsidy, i.e. $\tau^E < 0$, is required to induce young entrepreneurs to accumulate more knowledge and internalize the social benefits for the knowledge formation of subsequent generations. To finance these subsidies, a labor tax $\tau^W > 0$ is required. Even if labor taxes are non-distortionary in this environment, the parameter values in this economy can make it possible that the efficient allocation cannot be implemented. On the other hand, the equation for τ^E defines a quadratic expression, so it might be possible that two different tax rates pairs $\left(\tau^E, \tau^W\right)$ implement the efficient allocation.

5 An Open Economy

Assume now that the home country allows foreign managers to set up firms and hire domestic labor.[14] In our model, the entry of foreign skills and ideas can impact the domestic accumulation of knowledge in three ways. First, foreign managers directly expose their ideas to the domestic workers under their control. Second, their productive ideas are included in Z_t^O, in the form of externalities that benefit all young workers, including those working for domestic firms. Third, the entry of foreign firms bids up $\{w_t(\cdot)\}_{t=0}^{\infty}$, the cost of domestic labor. The balance between the first two effects, which are positive, and the third effect, which is negative, will be determined by equilibrium forces and policy decisions.

I focus on the case when the home country is *less developed* than the rest of the world. I made other ancillary assumptions to simplify and clarify the analysis. First, both home and foreign are initially populated by homogeneous managers. That is, at time $t = 0$, $Z_0^h < Z_t^f$, where, as with all other variables, the super-indexes h and f stand for "home" and "foreign." Second, the home country is "small," i.e. its policies do not affect the aggregate dynamics of the foreign country. Third, the rest of the world is in a BGP with growth G_f, and foreign entrepreneurs face a constant tax (subsidy) rate τ_f^E if they remain operating in the foreign country. As special cases, I will either consider $\tau_f^E = 0$ or τ_f^E to be equal to the (lowest) rate that decentralizes the efficient allocation

[14] I will assume that individuals from the home country cannot move. This is without loss of generality for workers and old entrepreneurs, since, in equilibrium they will be indifferent between moving to foreign or remaining in home. However, ruling out the possibility for domestic young potential entrepreneurs to move and "grow up" in the developed country is crucial. I will discuss further below the factual and analytical relevance of this assumption.

$G_f = G^{SP}$. Finally, for the rest of the paper I restrict attention to $\gamma = 0$, when the exposure to ideas is external to the firm. Such a case captures the literature's emphasis on externalities and analytically is very tractable.[15]

As knowledge levels in home and foreign grow over time, in what follows it will be useful to define the ratio of domestic-to-foreign knowledge, $R_t \equiv Z_t^h / Z_t^f$.

5.1 Laissez-Faire

First, consider the case in which both home and foreign country are in a *laissez-faire* equilibrium, where all taxes are zero. Foreign entrepreneurs can freely enter the home country. The mass that enters is determined by an indifference condition between staying at foreign or entering home. Specifically, with no mobility frictions or taxes, foreign entrepreneurs at home must earn $\pi_f = (1 - \alpha) Z_f$, their profits at foreign.[16] This can only happen if

$$w_t^h = w_t^f = \alpha Z_t^f, \tag{16}$$

i.e., the cost of labor (in efficiency units) is the same in both countries.[17]

Facing the same effective wages, each foreign firm hires the same amount of labor units, $n_t^f = 1$, as if they had remained in the foreign country. Facing wages $w^t = \alpha Z_f^t$, domestic firms with knowledge $Z_h^t = R_t Z_f^t$ hire $n_t^h = (R_t)^{\frac{1}{1-\alpha}}$ workers. Denoting by m_t the *fraction of domestic labor hired by foreign workers*, clearing in the domestic labor market requires

$$m_t = 1 - (R_t)^{\frac{1}{1-\alpha}}, \tag{17}$$

which is strictly decreasing in the relative knowledge R_t of the local entrepreneurs. If $R_t = 1$, foreign entrepreneurs will not enter because home firms are at par with them and dissipate any differences in the cost of labor. On the contrary if $R_t = 0$, the entire domestic labor force would be under the control of foreign management.[18]

With m_t and $1 - m_t$ as the shares of labor controlled by foreign and domestic foreign firms, young domestic entrepreneurs are exposed to ideas in the level

$$Z_t^E = Z_t^O = \left[(1 - m_t) \left(Z_t^h \right)^\rho + m_t \left(Z_t^f \right)^\rho \right]^{\frac{1}{\rho}}. \tag{18}$$

[15] Monge-Naranjo (2011) studies the general case $0 \le \gamma \le 1$ and compares laissez-faire openness ($\tau^F = 1$) with complete closedness ($\tau^F = 0$).

[16] I am abstracting from differences in 'country-embedded productivities' (Burstein and Monge-Naranjo 2009). Adding those differences would add extra notation but not much substance to the results in this paper.

[17] The key is that the cost of each efficiency unit and not physical unit of labor be the same in the two countries. The model can easily accomodate cross-country differences in workers earnings by introducing differences in the ratio of effective-to-physical units across countries.

[18] As explained in Section 6, with occupation choices $m_t = 1$.if R_t falls below a positive threshold.

Relative to the ideas Z_t^f to which foreign youth are exposed to, the ratio $R_t^E \equiv Z_t^E/Z_t^f$ can be written as

$$R_t^E = \left[1 + (R_t)^{\rho+\frac{1}{1-\alpha}} - (R_t)^{\frac{1}{1-\alpha}}\right]^{\frac{1}{\rho}}, \tag{19}$$

which obtains from using (17) in (18) and then simplifying.

As long as $R_t \leq 1$, domestic exposure R_t^E for the young is always above domestic knowledge R_t of the old. Openness always improves the exposure to ideas of youth of a developing country. Notice however that R_t^E may not be always increasing in R_t. On the one hand, a higher R_t increases R_t^E because domestic firms are a better source of ideas. But, on the other hand, a higher ratio R_t reduces the entry of foreign firms m_t and the country's exposure to to foreign ideas. When $\rho \leq -1/(1-\alpha)$ a strong complementarity between the domestic and foreign sources of ideas makes R_t^E to be always increasing in R_t. If the complementarity is weaker, i.e. if $\rho > -1/(1-\alpha)$, the negative effect dominates but only at low values of R_t. In those cases, R_t^E exhibits an initial decreasing region and then a strictly increasing region.

The dynamic behavior of the country can be fully characterized analytically. Taking Z_t^E and $w_{t+1}^h = \alpha Z_{t+1}^f$ as given, expressions (4) and (6) imply that the optimal investment in knowledge by domestic youth is

$$\begin{aligned} Z_{t+1}^h &= \arg\max_{z'} \left\{\beta (1-\alpha) (z')^{\frac{1}{1-\alpha}} \left[Z_{t+1}^f\right]^{\frac{-\alpha}{1-\alpha}} - Z_t^E \phi\left(\frac{z'}{Z_t^E}\right)\right\} \\ &= \left[\frac{\beta}{v_0} \left(Z_t^E\right)^v (Z_{t+1})^{-\frac{\alpha}{1-\alpha}}\right]^{\frac{1}{v-\frac{\alpha}{1-\alpha}}}, \end{aligned} \tag{20}$$

which is increasing in Z_t^E but decreasing in Z_{t+1}^f because of the requirement that $v > \alpha/(1-\alpha)$. In relative terms, using $Z_{t+1}^f = G_f Z_t^f$, $Z_t^E = R_t^E Z_t$ and (19), equation (20) implies

$$R_{t+1} = \left(R_t^E\right)^\theta = \left[1 + (R_t)^{\rho+\frac{1}{1-\alpha}} - (R_t)^{\frac{1}{1-\alpha}}\right]^{\frac{\theta}{\rho}}, \tag{21}$$

where $\theta \equiv v/[v-\alpha/(1-\alpha)] > 1$.

Therefore, the country's relative knowledge for the next period R_{t+1} is strictly increasing and convex in the current relative exposure R_t^E to ideas. However, the relationship of R_{t+1} with R_t is more complex; it is concave for levels of R_t close to 0, but it is always convex near $R_t = 1$. Furthermore, it is non-monotone whenever R_t^E is non-monotone.

As illustrated by Figure 1, $R = R^E = 1$ is always a fixed point. If the home country starts at par with the rest of the world it will stay at par. But, as long as $-\infty < \rho < +\infty$, another fixed point $R^{\text{int}} < 1$ exists. Such a interior fixed point is unique and globally stable. See the related discussion in Monge-Naranjo (2011), which also contains the proof of the following result:

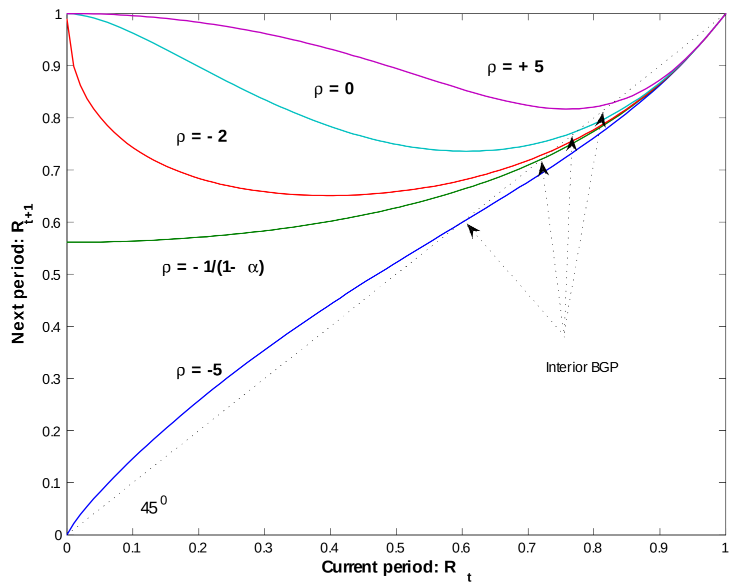

Figure 1: **Transition Function: Laissez-Faire**

Proposition 6 (BGPs open economy) $R = 1$ *is an equilibrium BGP. If* $-\infty < \rho < \infty$*, then there exists a unique interior equilibrium* $R^{int} \in (0, 1)$ *and an open, laissez-faire country converges to it from any initial* $R_0 \in (0, 1)$*.*

This is a simple yet crucial result. It shows that laissez-faire openness does not push developing countries all the way to catch up with the rest of the world, even if their technologies, preferences and inherent capacity to learn are the same. In the presence of externalities, initial differences in the exposure to ideas across countries will be preserved over time, even if barriers to knowledge are absent. As a matter of fact, openness can lead countries that are initially close to the frontier, i.e. $R_0 \in \left(R^{\text{int}}, 1\right)$, to end up lagging further behind. For those countries, opening up leads to a slowing down, not to an acceleration, in the domestic accumulation of skills.

The model can be also used to explore the implications of laissez-faire openness on the country's overall welfare. It is straightforward to show that with openness the geographic per-capita output $Y_t^{D,\text{ open}}$ must be equal to that of the foreign country, $Y_t^{D,\text{ open}} = Z_t^f$, because the marginal product of labor is equalized between the two countries. However, home's national income is only $Y_t^{N,\text{ open}} = Z_f^t[\alpha + (1-\alpha) R_t^{\frac{1}{1-\alpha}}]$ because it does not include the profits of foreign managers. Subtracting the costs of knowledge formation, aggregate domestic consumption is $C_t^{\text{open}} = Y_t^{N,\text{ open}} - Z_t^E \phi \left(Z_{t+1}/Z_t^E\right)$ or

$$C_t^{\text{open}} = Z_t^f \left[\alpha + (1-\alpha) R_t^{\frac{1}{1-\alpha}} - \phi(G) \left(R_t^E\right)^{\theta + (\theta-1)v}\right].$$

where R_t^E is given by (19). Under the counter-factual of remaining closed, at time t aggregate consumption would have been $C_t^{\text{closed}} = Z_h^t\left[1-\phi\left(G\right)\right]$. As reported below, it is straightforward to compute transition paths and the implied net (present value) aggregate gains of openness, $\left(\sum_{t=0}^{\infty}\beta^t C_t^{\text{open}}\right)/\left(\sum_{t=0}^{\infty}\beta^t C_t^{\text{closed}}\right)-1$. A simpler calculation is the cross-BGP or *steady state* consumption gains between the interior BGP and the closed economy BGP with initial ratio R_0,

$$\frac{C_{\text{open}}^{\text{int}}}{C_{\text{closed}}^{0}} = \frac{\alpha + \left[1-\alpha-\phi\left(G\right)\right]\left(R^{\text{int}}\right)^{\frac{1}{1-\alpha}}}{R^0\left[1-\phi\left(G\right)\right]},$$

an expression derived using the definition of θ and then simplifying. The following result is immediate:

Corollary 7 *Let $R_L \equiv [\alpha + (1-\alpha-\phi(G))(R^{int})^{\frac{1}{1-\alpha}}]/[1-\phi(G)]$. Then laissez-faire openness lead to a (steady state) reduction in the aggregate consumption of countries with initial knowledge $R_0 \in (R_L, 1)$.*

How can a country lose domestic knowledge when it is exposed to superior knowledge from abroad? Because the *future* inflow of foreign skills reduces the incentives of each individual in the current generation to build up skills. Collectively, the resulting reduction in the value of Z^O can more than offset inflow of ideas from abroad. How can it reduce aggregate consumption? Because the increase in domestic aggregate wages could be smaller than the reduction in the domestic aggregate profits.

These results apply for laissez-faire equilibria, which, in the presence of externalities are inefficient. It is interesting to explore the implications of openness when taxes may reduce or exacerbate the inefficiencies.

5.2 Exogenous Taxes

For the rest of this section, assume that the foreign country follows a constant tax regime, $\tau_{f,t}^E = \tau_f^E$, but the home country follows an arbitrarily tax regime $\left\{\tau_t^W, \tau_t^E, \tau_t^F\right\}$. As before, I focus in the case in which only old managers from the foreign country are mobile.

Foreign managers can earn net-of-tax profits equal to $(1-\tau_f^E)\pi(Z_t^f, w_t^f)$ in the foreign country or $\left(1-\tau_t^F\right)\pi(Z_t^f, w_t^h)$ in the home country. For these managers to be indifferent, the equilibrium wages must satisfy $w_t^h = \left[\left(1-\tau_t^F\right)/\left(1-\tau_f^E\right)\right]^{\frac{1-\alpha}{\alpha}} w_t^f$. It may be possible that home taxes on foreign firms are too high and/or that the domestic firms are too productive. Because in in foreign country $w_t^f = \alpha Z_t^f$, domestic wages satisfy

$$w_t^h = \begin{cases} \alpha Z_t^h & \text{if } R_t \geq \left(\frac{1-\tau_t^F}{1-\tau_f^E}\right)^{\frac{1-\alpha}{\alpha}} \\ \alpha Z_t^f\left(\frac{1-\tau_t^F}{1-\tau_f^E}\right)^{\frac{1-\alpha}{\alpha}} & \text{otherwise,} \end{cases} \tag{22}$$

where the first branch indicates zero entry and $w_t^h = \alpha Z_t^h$; in the second branch the entry foreign firms pin down the wages. Likewise, clearing of the home labor market implies

$$m_t = \begin{cases} 0 & \text{if } R_t \geq \left(\frac{1-\tau_t^F}{1-\tau_f^E}\right)^{\frac{1-\alpha}{\alpha}} \\ 1 - (R_t)^{\frac{1}{1-\alpha}} \left(\frac{1-\tau_f^E}{1-\tau_t^F}\right)^{\frac{1}{\alpha}} & \text{otherwise.} \end{cases} \tag{23}$$

Obviously, this expression implies the relative exposure to be

$$R_t^O = \begin{cases} R_t & \text{if } R_t \geq \left(\frac{1-\tau_t^F}{1-\tau_f^E}\right)^{\frac{1-\alpha}{\alpha}} \\ \left\{1 + [(R_t)^\rho - 1] (R_t)^{\frac{1}{1-\alpha}} \left(\frac{1-\tau_f^E}{1-\tau_t^F}\right)^{\frac{1}{\alpha}}\right\}^{\frac{1}{\rho}} & \text{otherwise.} \end{cases}$$

In the presence of taxes changes, the domestic accumulation of knowledge is given by the maximization $Z_{t+1}^h = \arg\max_{z'} \left\{\beta\left(1-\tau_{t+1}^E\right)\pi\left(z', w_{t+1}^h\right) - R_t^O Z_t^f \phi\left(\frac{z'}{R_t^O Z_t^f}\right)\right\}$. Given the behavior of w_{t+1}^h there are two candidate solutions. The first is

$$Z_{t+1}^h = \left[\frac{\beta\left(1-\tau_{t+1}^E\right)}{v_0}\right]^{1/v} R_t^O Z_t^f,$$

which is the solution of that maximization under the hypothesis that $w_{t+1}^h = \alpha Z_{t+1}^h$; is only valid if $\left[\beta\left(1-\tau_{t+1}^E\right)/v_0\right]^{1/v} R_t^E/G_f \geq \left[\left(1-\tau_{t+1}^F\right)/\left(1-\tau_f^E\right)\right]^{\frac{1-\alpha}{\alpha}}$. The second candidate is

$$Z_{t+1}^h = \left[\frac{\beta\left(1-\tau_{t+1}^E\right)}{v_0}\left(\frac{1-\tau_f^E}{1-\tau_{t+1}^F}\right)\right]^{\theta/v} \frac{\left(R_t^O\right)^\theta}{\left(G_f\right)^{\theta-1}} Z_t^f,$$

the maximand under the hypothesis that $w_{t+1}^h = \alpha Z_t^f\left[\left(1-\tau_{t+1}^F\right)/\left(1-\tau_f^E\right)\right]^{\frac{1-\alpha}{\alpha}}$; such candidate is only valid if $\left[\frac{\beta\left(1-\tau_{t+1}^E\right)}{v_0\left(G_f\right)^v}\right]^{\theta/v}\left(R_t^O\right)^\theta < \left(\frac{1-\tau_{t+1}^F}{1-\tau_f^E}\right)^{\frac{(1-\alpha)}{\alpha}\theta}$. Given R_t, τ_t^E, τ_{t+1}^E, and τ_f^E, at least one of these two are valid. If both are valid, the relevant one is the first one, i.e. the one that implies the highest wages w_{t+1}^h. Multiplicity issues do not arise in this environment because investments in knowledge are strategic substitutes across domestic entrepreneurs.

An important implication is that current taxes τ_t^F reduce the formation of domestic knowledge by impairing the exposure R_t^O to ideas for the current young. On the contrary, a higher future tax on foreign firms τ_{t+1}^F can increase the formation of domestic knowledge by increasing the marginal returns to investing in entrepreneurial skills.

From these formulas, one can easily compute domestic and national output levels and aggregate consumption levels. Computationally, it is easy to check whether different tax regimes satisfy the government budget constraint. But before illustrating the growth and welfare implications of different tax regimes, I now examine the taxes that maximize the overall welfare of the country.

5.3 The Ramsey Program

Following the Ramsey tradition, let us now assume that the objective of the home government is to maximize the average welfare of the country, but that the tools available are restricted to some proportional taxes $\left\{\tau_t^W, \tau_t^E, \tau_t^F\right\}$, taking as given the tax τ_f^E and growth rate G_f in the foreign country. Specifically, I take maximizing $\sum_{t=0}^{\infty} \beta^t C_t$ as the objective of the government, which, given the OLG structure, implicitly weights the welfare of different generations on the basis of the individuals' discount factor β.

To solve for the Ramsey program, I use the *primal approach*, i.e. instead of maximizing over the different taxes $\left\{\tau_t^W, \tau_t^E, \tau_t^F\right\}$, I solve for a social planner's problems in terms of allocations that correspond to competitive equilibria for feasible taxation programs, taking as given the initial level of knowledge of both countries Z_0^h and Z_0^f and the tax rate τ_f^E and growth path G_f in the foreign country. In any period, the aggregate consumption equals the domestic wages and domestic profits, the taxes collected from (or the subsidies pay to) foreign profits minus the cost of acquiring skills, i.e.

$$C_t = w_t^h + \pi_t^h + \tau_t^F \pi_t^f q_t^f - Z_t^O \phi\left(\frac{Z_{t+1}^h}{Z_t^E}\right), \tag{24}$$

where q_t^f is the mass of foreign firms in the home country at time t.

Ramsey allocations can be solved as follows: given the state R_t, the planner chooses the mass m_t of labor controlled by foreign firms and the country's next period knowledge level relative to foreign, R_{t+1}. From (23) a value of $m_t > 0$ implies

$$\tau_t^F = 1 - \frac{\left(1-\tau_f^E\right)}{\left(1-m_t\right)^{\alpha}} \left(R_t\right)^{\frac{\alpha}{1-\alpha}};$$

$m_t = 0$ is compatible with any $\tau_t^F \geq \bar{\tau}^F\left(R_t\right) \equiv 1 - \left(1-\tau_f^E\right)\left(R_t\right)^{\frac{\alpha}{1-\alpha}}$. On the other hand, there is a highest attainable $\bar{m}\left(R_t\right) < 1$ which corresponds to the highest feasible subsidy $-\underline{\tau}^F\left(R_t\right) > 0$ financed with taxes levied domestic workers and domestic firms.[19] Thus, we can restrict attention to $m_t \in \Gamma\left(R_t\right) = \left[0, \bar{m}\left(R_t\right)\right]$. In those cases:

$$w_t^h = Z_t^f \frac{\alpha R_t}{\left(1-m_t\right)^{1-\alpha}},$$

which, plugged into (4) implies

$$\begin{aligned}
\pi_t^h &= (1-\alpha) Z_t^f \left(1-m_t\right)^{\alpha} R_t, \text{ and} \\
\pi_t^f &= (1-\alpha) Z_t^f \left(1-m_t\right)^{\alpha} \left(R_t\right)^{\frac{-\alpha}{1-\alpha}},
\end{aligned}$$

[19] With occupation choices, any $m_t = 1$ is attainable, a jump in the occupation choices as a response to taxes can imply that some $m \in [0,1]$ are not attainable.

and plugged into (5) implies $n_t^h = 1 - m_t$ and $n_t^f = (1 - m_t) / (R_t)^{\frac{1}{1-\alpha}}$. Then, labor market-clearing requires a mass of foreign firms equal to $q_t^f = (R_t)^{\frac{1}{1-\alpha}} m_t / (1 - m_t)$, and the country's total collection of taxes from (disbursement of subsidies to) foreign firms is

$$\tau_t^F q_t^f \pi_t^f = (1-\alpha) Z_t^f \frac{m_t}{1-m_t} R_t \left[(1-m_t)^\alpha - \left(1 - \tau_f^E\right) (R_t)^{\frac{\alpha}{1-\alpha}} \right],$$

which, given R_t and τ_f^E, is a non-montone (Laffer) curve; it is zero for $m_t = 0$ and $m_t = m_t^{LF} \equiv 1 - (1 - \tau_f^E)^{\frac{1}{\alpha}} (R_t)^{\frac{1}{1-\alpha}}$; positive inside these two points and negative for $m_t > m_t^{LF}$, where m_t^{LF} indicates the level that would take place if the government imposes zero taxes at time t.

Finally, as a function of m_t, the relative exposure to ideas in the country is $R_t^E = [m_t + (1 - m_t)(R_t)^\rho]^{\frac{1}{\rho}}$ and the cost of acquiring a relative knowledge R_{t+1} for the next generation is $Z_t^f R_t^E \phi\left(\frac{R_{t+1}}{R_t^E} G_f\right)$. Adding the elements in (24) and simplifying, we obtain $C_t = Z_t^f \varrho(R_t, m_t, R_{t+1})$ where

$$\varrho(R_t, m_t, R_{t+1}) \equiv \frac{R_t \left[(1-m_t)^\alpha - (1-\alpha) m_t \left(1 - \tau_f^E\right) (R_t)^{\frac{\alpha}{1-\alpha}} \right]}{1 - m_t} - \frac{v_0 (G_f)^{1+v}}{(1+v)} \frac{(R_{t+1})^{1+v}}{[m_t + (1-m_t)(R_t)^\rho]^{\frac{v}{\rho}}}.$$

As a fraction of Z_t^f, the first term indicates the amount of resources available to consume or to invest in the period. These resources are single-picked in m_t; initially they increase in m_t but eventually they decrease and become negative as m_t approaches 1. The second term is the cost of knowledge accumulation. It is always decreasing in m_t and strictly increasing in R_{t+1}. There is an important complementarity between m_t and R_{t+1}, as the marginal cost of investing in skills R_{t+1} is decreasing in m_t.[20] As a practical matter, this property will imply a complementarity between openness (and even subsidies) to foreign firms and government incentives for domestic investment in knowledge.

To solve for the Ramsey program, we can eliminate Z_t^f, and leave R_t as the only state. The value function $\vartheta(R)$ associated with the Ramsey program solves the Bellman equation

$$\vartheta(R) = \max_{m \in [0, \bar{m}(R)],\ R' \geq 0} \left\{ \varrho(R, m, R') + \beta G_f \vartheta(R') \right\}. \tag{25}$$

In the appendix, standard recursive methods are used to prove the following proposition.

Proposition 8 *Assume that the foreign government tax rate τ_f^E is such that $G_f < \beta^{-1}$. Then, there exists a unique $\vartheta(\cdot)$ that solves (25); $\vartheta(\cdot)$ is continuous and strictly increasing. Let $\{m_t^{Ramsey}, R_{t+1}^{Ramsey}\}_{t=0}^\infty$ denote the optimal Ramsey allocation. From any initial R_0: (a) a country would subsidize foreign firms, $m_t^{Ramsey} > m_t^{LaissezFaire} \equiv 1 - (R_t)^{\frac{1}{1-\alpha}} \left(1 - \tau_f^E\right)^{\frac{1}{\alpha}}$, if and only if $R_{t+1}^{Ramsey} > R_{t+1}^{LaissezFaire}$; moreover, (b) if $G_f \leq G^{SP}$, then, the home country converges, i.e. $\lim_{t\to\infty} R_{t+1}^{Ramsey} \geq 1$ and $\lim_{t\to\infty} m_t^{Ramsey} = 0$.*

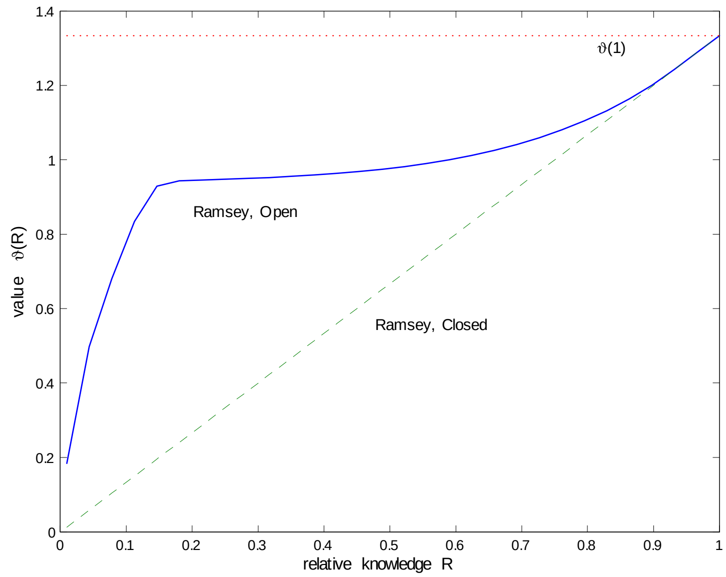

Figure 2: **Value Function of the Ramsey Program: Open and Closed Economies**

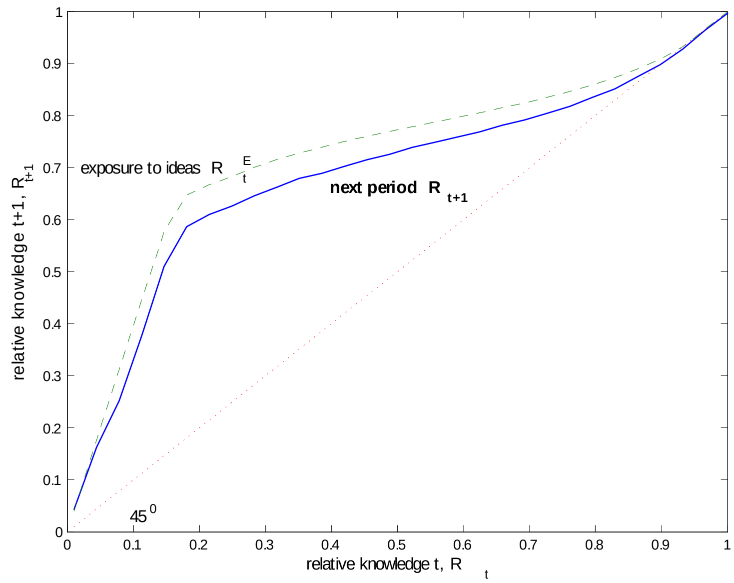

Figure 3: **Transition Function under the Ramsey Program.**

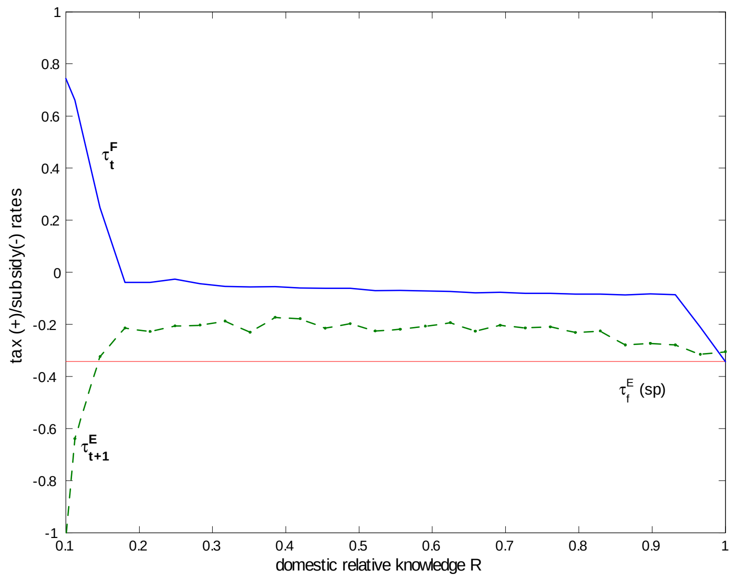

Figure 4: **Inferred Taxes from the the Ramsey Allocation**

Figures 3 and 4 illustrate the solution of the Ramsey program under the assumption that the foreign country follows also the (closed economy) Ramsey policies, i.e. τ_f^E is given by (**??**) and $G_f = G^{SP}$. Figure 2 shows that for any R_t, the value of an open economy is *always* above the value of a closed economy (the straight line in the diagonal). The gains from openness are always positive, except when $R = 1$, when the home country has nothing to learn from the rest of the world. Notice that the gains from openness are initially very steep: not only the learning opportunities are huge for laggard countries (low R) but they can also impose taxes from foreign firms that would still enter motivated by the low wages. For more advanced countries (high R), the learning opportunities may come at a fiscal cost. Furthermore Figure 3 shows that the transition function of an open country is always above the 45^0 line except when $R = 1$; therefore, the open country always catches up.

Figure 4 shows the implied taxes $\left\{\tau_{t+1}^E, \tau_t^F\right\}$. From the figure, it is clear that more than subsidizing foreign knowledge (which could occur but only temporarily), the key of the optimal program is to incentivize the formation of domestic knowledge, given the enhanced learning opportunities from the exposure to foreign ideas.

Need to complete this section. (1) Discussion of these results, e.g. for any R<1, Ramsey program implies $m > 0$ and $R' > R$. *(2) add of extensions including: (i) restrictions in the tax program, e.g.* $\tau_t^W = \tau_t^E$ or $\tau_t^F = \tau_t^E$ *; (ii) non-optimal foreign policies,* $G_f \lesseqgtr G^{SP}$. *Sequel to this paper: large country issues, including the analysis of strategic interactions.*

[20] $\frac{\partial^2 \varrho(R_t, m_t, R_{t+1})}{\partial R_{t+1} \partial m_t} < 0$, when $R_t < 1$, i.e.the marginal cost of R_{t+1} is reduced with a higher m_t.

6 Occupation Choices

Entrepreneurship choices have a prominent presence in the development literature (e.g. Banerjee and Newman 1993). Sorting individuals between managerial and labor occupations can enhance the static gains of openness as shown by Antras, Garicano and Rossi-Hansberg (2006), Burstein and Monge-Naranjo (2009) and more forcefully by Eeckhout and Jovanovic (2009). In this section I will argue that occupation choices can also determine whether –and how quickly– a developing country can catch up with the rest of the world. Specifically, I will show that occupation choices: (a) can change the form of the BGPs; (b) can push an open economy away from the interior BGP and instead to fully catch up; and (c) can accelerate the convergence.

In the model, an old person carrying a skill level z would only become an active entrepreneur if his rents $\pi[z, w(z)]$ are above the maximum wage as a worker, i.e. only if

$$\left(1-\tau_t^E\right)\pi\left[z, w_t(z)\right] \geq \left(1-\tau_t^W\right) \sup_{\zeta \in \text{ support}(t)} w_t(\zeta), \tag{26}$$

where 'support' refers to the entire set of entrepreneurial knowledge –domestic or foreign– active in the country.

The option of choosing occupation when old can change the investment in skills for a young person. For a given exposure to ideas z^E, a young person would only invest in skills if:

$$V\left[z^E, w_{t+1}(\cdot)\right] \geq \beta \sup_{\zeta \in \text{ support } (t+1)} w_{t+1}(\zeta). \tag{27}$$

This lower bound in the career value of a job $V[\cdot,\cdot]$ can reduce the equilibrium gap between the wages paid by active entrepreneurs with different skills. Specifically, consider two entrepreneurs with skill levels $z_0 < z_1$. If the two of them fall below a certain threshold z_t^*, they will both pay the same wage; if the two fall above the threshold, the wage difference will be given by (8) of the previous section, reflecting the difference in the learning opportunities of the two jobs. Finally, if the two skill levels fall on different sides of the threshold, i.e. $z_0 < z_t^* < z_1$, the two wages paid satisfy:

$$w_t(z_1) = w_t(z_0) + \beta \sup_{\zeta \in \text{ support } (t+1)} w_{t+1}(\zeta) - V\left[z_1^E, w_{t+1}(\cdot)\right] < w_t(z_0) = w_t(z_t^*).$$

Obviously, $w_t(\cdot)$ is flat up to the threshold z_t^*, after which it becomes strictly decreasing.

6.1 The Ramsey Program with Endogenous Occupation Choices

To be added.

7 Concluding Remarks

Does the allure of technology spillovers make it optimal for poor and often cash-strapped countries to provide those costly incentives? That is, can these subsidies be justified in terms of the growth and overall welfare of the country? How should other tax policies in those countries be designed to maximize the gains from openness? To address these issues, this paper deviated from the usual practice of comparing extreme openness vs. closedness, and instead characterize the output and welfare gains under a Ramsey program, where tax policies are set to maximize the welfare of recipient countries, subject to the equilibrium behavior of national and foreign agents. The paper argues that optimal taxation can change the gains from openness to foreign knowledge in a small developing country. Contrary to simple laissez-faire, openness to foreign knowledge is always optimal when the country follows a Ramsey program. More interestingly, the paper shows that the optimal tax program always lead developing countries to catch-up with the productive knowledge in developed countries.

Ongoing work extends the analysis along a number of dimensions. A first extension is to solve numerically for the optimal policies for the general case $0 < \gamma < 1$, allowing for the vintage structure described in Section 3. The second extension considers the optimal policies for home when foreign is not following the optimal Ramsey program. I find that if $G_f > G^{SP}$ it is not optimal for home to catch up with foreign; instead, the country will be better off reaching a BGP in which the (excessive) growth of foreign knowledge pulls up the country via a positive presence of foreign firms. On the other hand, if $G_f < G^{SP}$, the optimal policies for home country is to surpassing the foreign country; in this case, the ratio R will grow without bound at the rate $G^{SP}/G_f > 1$. A third extension considers a two-country world in which the policies of home affect foreign and viceversa. In equilibrium, the tax program of one country must be the best response of the tax program of the other. Standard game theoretic constructs will be applied to this setting and the equilibrium outcomes will be contrasted with recent policies in the OECD and large emerging market countries.

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