International Migration of Skilled Workers with Endogenous Policies

Slobodan Djajić*
and
Michael S. Michael†

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Abstract

We study the interaction between the optimal immigration policy of a host country and education policy of a source country in a model of international migration where acquisition of human capital by agents is driven by the academic and career opportunities at home and abroad. Greater opportunities to migrate are found to increase the source country’s net stock of human capital only under stringent conditions concerning the shape of the utility function of students and of the production function for human capital, the international wage differential, and the country’s emigration rate.

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*Corresponding Author: Slobodan Djajić, Graduate Institute, 11A, Avenue de la Paix, CH-1202 Geneva, Switzerland, Tel: (41) 22 908 5934, Fax: (41) 22 733 3049, e-mail: slobodandjajic@yahoo.com. This paper was initiated when Djajić was visiting the Department of Economics of the University of Cyprus. I wish to thank the Department for its hospitality and support.
†Department of Economics, University of Cyprus, email: m.s.michael@ucy.ac.cy
1 Introduction

Migration of skilled labor from the developing to the advanced countries has been the subject of extensive research over the last four decades. Efforts to measure these flows, including the works of Carrington and Detragiache (1998) and Docquier and Marfouk (2006), indicate that skilled emigration, as a proportion of the economy’s skilled population, is particularly large in the case of relatively poor and small developing countries. Island economies as well as countries in Central America, Sub-Saharan Africa, and South-East Asia are found to have the highest skilled-emigration rates. Rates of over 80% are reported for several Caribbean nations and they exceed 50% in many African countries (Docquier and Rapoport, 2012).\(^1\) Given that the cost of education and training represents a disproportionate financial burden for such economies (Lucas, 2005), the exodus of skilled workers can be expected to have an impact on their education policies (see Justman and Thisse, 1997, and Djajić, Michael, and Vinogradova, 2012). A strong confirmation of this is provided by Docquier, Faye, and Pestieau, (2008), who find a negative relationship between public spending on education and skilled emigration rates based on the data covering 108 middle-income and low-income countries. Still, incentives for human capital accumulation in a source country depend not only on public subsidies to education, but also on other factors including migration opportunities. This is one of the key points to emerge from the extensive literature on migration of skilled workers and its implications for the source countries.\(^2\) There is by now ample evidence that migration opportunities help stimulate human capital formation. Using data on 127 developing countries, Beine, Docquier and Rapoport (2008) estimate that a doubling of

\(^1\)See Commander et al. (2004) and Docquier and Rapoport (2012) for very useful surveys of the various issues and evidence related to the brain drain.

a country’s emigration rate of highly-skilled workers is associated with a 5% increase in the short run and 20% increase in the long run in the stock of human capital possessed by its nationals, including emigrants. Their findings suggest that under certain conditions the stimulus to skill formation may be strong enough to bring the economy’s stock of human capital to a higher level in the post-migration equilibrium. Studies by Chand and Clemens (2008) and Gibson and McKenzies (2011) provide micro-level evidence of a positive impact of emigration on the net stock of human capital in a source country.

The present study contributes to this literature on the brain drain by analyzing the interaction between the optimal immigration policy of the host country and the optimal education policy of the source country in the context of a two-country model where the effort of students to accumulate human capital is driven by optimizing behavior with an eye on career opportunities at home and abroad. An important distinction between our framework of analysis and that of the earlier studies focusing on the optimal education policy of a source country is with respect to the conditions under which a potential migrant accumulates human capital. Previous contributions address the problem under the assumption that education is privately funded, with agents having access to credit markets (as in Mountford, 1997, Docquier, Faye, and Pestieau, 2008, and Bertoli and Brucker, 2011), or facing liquidity constraints (as in Beine, Docquier and Rapoport, 2008 and Docquier and Rapoport, 2012), while the role of the authorities is to set the level at which they subsidize the optimally-chosen private expenditures on education. We assume instead that only fully subsidized public education is available, as in Wong and Yip (1999). This framework can be particularly useful when considering the problem of investment in education in poor developing countries, where credit markets for the purpose of funding private education are underdeveloped and, as noted by the World Bank (2000, p.54), higher education systems are heavily dominated by public universities
with the costs falling predominantly on the state. Instead of deciding on how much money to invest in the acquisition of human capital, students in our model optimally choose their study effort as a function of their academic and occupational opportunities, while the authorities choose the level of expenditures on education so as to maximize net national income.

Our investigation proceeds in three steps. We begin by solving for the equilibrium levels of educational spending and students’ effort in the "source" country under autarky. We subsequently open the economy to international migration. With higher wages per unit of skill abroad, this induces students to exert greater effort to acquire human capital. An expansion of migration opportunities is found to increase the source country’s net stock of human capital only under certain conditions. These conditions are met, loosely speaking, if in the initial equilibrium (i) the emigration rate is low, (ii) the elasticity of the human-capital production function with respect to a student’s effort is high, (iii) the degree of concavity of the utility function is low, and (iv) the international earnings differential is sufficiently large. Under such conditions an increase in recruitment of skilled workers by the host country has a large impact on the effort of students in school, as well as a large impact on their subsequent productivity at the workplace. The stock of human capital remaining in the source country and net output can then increase in spite of the fact that more skilled workers exit the economy. In this type of an environment, referred to as a "low-migration" (LM) equilibrium, it also pays for the authorities of the source country to raise educational expenditures in response to an increase in migration opportunities that are available to its citizens in the host country.

After setting up the model in Section 2, we examine in Section 3 the implications

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3The financing of higher education in developing countries has been largely borne by the government through tax financing with very little or zero costs borne by students. Concerning private funding of education, it is true that even in sub-Saharan Africa, we observe some household financing of schooling. The contribution at the household level for higher education is, however, relatively low when compared to household contribution to primary education and especially lower-secondary education (World Bank, 2010, p.5). Teferra (2007) notes that in virtually all sub-Saharan countries, the state provides over 90% of the support for higher education.
of (i) a reduction in the cost of providing educational services in the source country, (ii) a shift in preferences on immigration in the host country, and (iii) a change in the degree of international transferability of human capital. In conducting these exercises, our focus is on the amount of effort exerted by students in school, the optimal level of source-country spending on education, and the optimal immigration quota of the host country in the Nash equilibrium. One of our findings is that in an LM equilibrium, an increase in the international transferability of human capital entails an expansion of the immigration quota of the host country and an increase in spending on education in the source country. By contrast, in a "high-migration" (HM) equilibrium, defined as an environment in which a higher emigration rate reduces the economy’s net stock of human capital, an increase in the transferability of human capital may entail a reduction in spending on education by the source country. We conclude the paper in Section 4 by highlighting its principal contributions.

2 The Analytic Framework

We consider a small developing country, $S$, producing a single commodity with the aid of skilled labor. It provides education to its citizens with the view of maximizing its GNP, net of expenditures on education. After completing studies, some of the graduates may be able to migrate to $F$, depending on the regime governing international migration. Before considering the implications of labor mobility, however, let us begin by defining the environment facing individuals and the authorities in $S$ under autarky.

2.1 The Autarky Case

Consider the problem of an individual in a closed economy. Her lifetime consists of two phases of given durations. In the first phase she is supported by her parents and has to
decide on how to optimally divide her time, normalized to unity, between leisure, \( l \), and study effort, \( z \). The skills acquired in the first phase affect her income and consumption in the second phase. Utility is derived from leisure, \( l \), in this first (formative) phase and consumption of commodities, \( C \), in the second (career) phase according to a separable utility function \( U(l, C) = v(l) + u(C) \). We adopt the standard assumptions: \( v'(l) > 0, \ v''(l) \leq 0, \ u'(C) > 0, \) and \( u''(C) < 0 \). By investing more of her time in education, a student can acquire more skills, \( H \), which allows for a higher income and consumption, \( C \), in the second phase. More precisely,

\[
C(w, z, \varepsilon) = wH(z, \varepsilon), \tag{1}
\]

where \( w \) is the real wage in \( S \) per unit of skill (or efficiency labor) acquired by the student and \( \varepsilon \) is the level of educational services dispensed by the authorities of the source country. Only public education is available and it is provided to students free of charge. We assume that \( H_z > 0, \ H_\varepsilon > 0, \ H_{zz} < 0, \ H_{z\varepsilon} < 0, \) and \( H_{\varepsilon\varepsilon} > 0 \). The labor market is perfectly competitive and there is full employment.

The optimization problem of a student is to

\[
\max_z \ v(1 - z) + u(wH(z, \varepsilon)), \tag{2}
\]

taking \( w \) and \( \varepsilon \) as given. The first-order condition reads:

\[
-v'(1 - z) + u'(C)wH_z(z, \varepsilon) = 0, \tag{3}
\]

which provides an implicit solution for the optimal study effort, \( z \), as a function of \( \varepsilon \) and the real market wage, \( w \), per unit of skill. This relationship implies that the effect of the wage on study effort is positive, assuming that the elasticity of marginal utility of consumption, \( \theta = -u''(C)/[C/u'(C)] \), defined to be positive, is less than unity.
\[
\frac{\partial z}{\partial w} = \frac{u'(C)}{w} \frac{(\theta - 1) \frac{\partial C}{\partial z}}{v''(1 - z) + u''(C) \left( \frac{\partial C}{\partial z} \right)^2 + u'(C) \frac{\partial^2 C}{\partial z^2}} > 0,
\]
as both the denominator and the numerator are then negative. Only if \( \theta < 1 \), does the substitution effect dominate the income effect, so that an increase in \( w \) (or any other exogenous change that generates a higher level of future income) induces students to exert more effort in acquiring human capital. On the basis of evidence documented in the literature on risk aversion and labor supply behavior, we consider this to be the relevant case.\(^4\) As for the effect of \( \varepsilon \) on student effort, we have

\[
\frac{\partial z}{\partial \varepsilon} = -\frac{u''(C) \frac{\partial C}{\partial z} + u'(C) \frac{\partial^2 C}{\partial z \partial \varepsilon}}{v''(1 - z) + u''(C) \left( \frac{\partial C}{\partial z} \right)^2 + u'(C) \frac{\partial^2 C}{\partial z^2}},
\]
where the denominator is unambiguously negative, while the two terms in the numerator have conflicting signs: both \( \frac{\partial C}{\partial z} \) and \( \frac{\partial^2 C}{\partial z \partial \varepsilon} \) are positive, while \( u''(C) < 0 \) and \( u'(C) > 0 \). Let us consider the case of iso-elastic utility functions

\[
v(z) = \frac{(1 - z)^{(1 - \chi)}}{(1 - \chi)}, \quad u(C) = \frac{C^{(1 - \theta)}}{(1 - \theta)}
\]
and assume that

\[
H(z, \varepsilon) = \mu \varepsilon^\beta z^\gamma,
\]
where \( \mu > 0 \) is a parameter reflecting the efficiency of the skill-formation technology,

\(^4\)Estimates of \( \theta \) vary significantly, depending on the data used and the empirical strategy. Chetty (2006) examines some of the factors that explain this wide range of estimates. He reports that the mean estimate in the literature is \( \theta = 0.71 \), while noting that studies which combine the benefits of exogenous variation with the structural lifecycle approach, such as Blundell, Duncan, and Meghir (1998), with its estimate of \( \theta = 0.93 \), provide perhaps the most credible microeconomic estimates.
We can then write

\[ \frac{\partial z}{\partial \varepsilon} = \frac{z(1 - \theta)\beta}{\varepsilon[1 - \gamma(1 - \theta) + \chi\frac{z}{1-z^2}] > 0,} \]

indicating that if the authorities choose to provide a higher $\varepsilon$, this triggers more effort on the part of students. As one would expect, the elasticity of $z$ with respect to $\varepsilon$ is positively related to the elasticity of $H(z, \varepsilon)$ with respect to both $z$ and $\varepsilon$, but negatively related to the degrees of concavity, $\chi$ and $\theta$, of the utility functions in the first and second phases of the planning horizon, respectively. Higher degrees of concavity of the utility functions make students less responsive to educational and occupational opportunities under autarky and, as we shall see in the next section, to migration opportunities in an open economy. This is an important point as most of the literature on the impact of migration opportunities on skill formation in a developing country with an endogenous educational policy is based on the assumption that the utility function is either logarithmic or linear.\(^5\)

\(^5\)There is an extensive literature on the positive relationship between educational inputs that correspond to $\varepsilon$ (such as teacher quality and class size) and the skill level of students (reflected in their test scores and even subsequent earnings). By contrast, we have not been able to find documented evidence on the relationship between study effort of students taking part in a given educational program and their productivity or earnings after graduation, which would provide us with information regarding $\gamma$. The impact of study effort is obviously difficult to measure in a student population as it consists of inputs such as time and the degree of mental concentration, while its effectiveness depends on a range of other parameters and personal characteristics of a student. Also note that we are assuming that the skill-formation technology exhibits decreasing returns to scale. We consider this to be the most reasonable assumption in the context of our analysis that deals with the effects of policy variations around an equilibrium. It may well be the case that for certain values of $\varepsilon$ (and the implied $z$), there could be increasing returns to scale, but such values of $\varepsilon$ would not be optimal, as can be seen below by looking at the optimization problem of the education authorities.

\(^6\)Changes in the stock of human capital in response to greater migration opportunities arise in this literature through a very different mechanism. Students are assumed to be heterogeneous in terms of ability, with higher ability students facing a lower price when purchasing the one unit of human capital that they can potentially possess (as in Beine, Docquier and Rapoport, 2008 and Docquier and Rapoport, 2012) or, more generally, face a lower cost of acquiring human capital (as in Mountford, 1997). A higher probability of migration in that context raises the expected payoff from owning human capital, inducing a larger number of individuals (including those with a marginally lower level of ability) to acquire it. Inmate ability and its distribution within a population, however, is not measurable. This makes existing models difficult to evaluate in relation to the evidence, a characteristic also shared by our model, where student effort is a key variable. Our focus on effort in the analysis of human capital accumulation is motivated by the observation that the input expected
In sum, in the context of our model with endogenous study effort, the skill level of an agent depends positively on $\varepsilon$ through two channels: one direct and another indirect, through the interaction between the education policy of the authorities and the study effort, $z$, optimally chosen by each student. We thus have $H(\varepsilon, z(w, \varepsilon))$, with $dH/d\varepsilon = \partial H/\partial \varepsilon + (\partial H/\partial z)(\partial z/\partial \varepsilon)$, where the first term is the direct effect and the second term corresponds to the indirect "effort" effect, both being positive.

In a closed economy, the objective of the authorities is to maximize GNP, net of official expenditures on education. We assume that the marginal product of a unit of efficiency labor is constant at the level determined by the technology of production and institutional arrangements in $S$. Each of the country's $N$ citizens is assumed to go through the educational system, receiving $\varepsilon$ units of training. From the perspective of the authorities, we take the per-student cost of providing an extra unit of training to be a constant $\alpha$. Education is assumed to be funded by collecting taxes in a way that does not distort the decision of students with respect to the optimal study effort, $z$. An example might be a tax on land, real-estate, or a tax on royalties in the mining industry or other resource-based activities.

In an autarky regime, signified by the superscript $a$, we can write the objective function of the authorities as

$$V^a = \hat{w}L - Nx\varepsilon,$$

where $\hat{w}$ is the exogenously-given marginal productivity of a unit of efficiency labor and

of a student in the higher-education systems of the poor developing countries tends to be predominantly study effort rather than a monetary payment. An alternative formulation would be to use Becker's classic model focussing on the work-study tradeoff, where students choose the optimal length of schooling to maximize lifetime income. We view such a model as being relatively more suitable when analyzing human capital formation in the advanced countries than it is in the case of developing countries. Liquidity constraints and the dominant role of public universities in the latter set of countries can effectively restrict a student's choice of educational program and duration of schooling at the tertiary level. For this reason we consider it more meaningful to take a student's effort in school rather than duration of schooling as the appropriate choice variable.
$L$ is the stock of skilled labor, measured in efficiency units:

$$L = NH(\varepsilon, z(\bar{w}, \varepsilon)). \quad (7)$$

Maximizing $V^a$ with respect to $\varepsilon$ requires that

$$\bar{w} \frac{dL}{d\varepsilon} = Nx. \quad (8)$$

On the basis of eq. (7), we have

$$\frac{dL}{d\varepsilon} = N(H_\varepsilon + H_z \frac{\partial z}{\partial \varepsilon}) > 0. \quad (9)$$

Thus maximization of $V^a$ with respect to $\varepsilon$ implies that

$$\bar{w}(H_\varepsilon + H_z \frac{\partial z}{\partial \varepsilon}) = x, \quad (10)$$

so that $x$, the marginal resource cost of an extra unit of training is equal to the marginal contribution of a unit of training, taking into account both its direct effect on skill formation and the indirect effect through its influence on students’ effort.

### 2.2 International Migration Under a Quota

Let us now open our economy to international migration. The advanced foreign country, $F$, is assumed to differ, when compared with $S$, in terms of the technology of production and institutional structures that render the marginal productivity of labor in $F$ higher than that in $S$.

Although migration from $S$ to $F$ is now possible, it is not unrestricted. We shall assume that $F$ sets its optimal immigration quota that allows only $M$ workers to immi-
grate and become permanent residents.\textsuperscript{7} Since all workers in S are identical, they are all equally productive. We can then think of the migrants as being selected on the basis of a lottery and allocated to employers in F also on the basis of a lottery. Let us assume, in addition, that skills are not perfectly transferable from S to F, so that a migrant with the skill level \( H \) gets credit for only \( \phi H \) units of skill in the labor market of F, where \( \phi \leq 1 \). Moreover, the immigration policy of F is designed to benefit the country's employers. In some countries, including the rapidly-growing East-Asian economies, as well as in many of the labor-importing countries in the Middle East, the regulations allow foreign workers to be systematically underpaid in relation to native workers.\textsuperscript{8} In other economies, such as the U.S.A., the underpayment is more subtle, although it can be quite substantial. As noted by the former Secretary of Labor, Robert B. Reich, in the early days of the H1-B

\textsuperscript{7}Djajić, Michael and Vinogradova (2012) also consider a two-country model where the source country sets its optimal education policy and the host country sets its immigration policy. The focus of that article, however, is on temporary migration of skilled workers: the host-country chooses the optimal duration of the work permit, with a view of how this duration affects the profitability of the employers (workers are assumed to become more productive with experience) and how it affects the use of public services by immigrant households (with a longer work-permit duration, workers are more likely to bring family members who absorb disproportionately more public services). The source country provides education to its citizens, taking into account that those who migrate temporarily will also improve their skills abroad and contribute to an increase in the domestic stock of human capital from the date of their return until retirement. The longer migrants stay abroad, the more human capital they bring back, but this human capital benefits the source country over a shorter, pre-retirement phase of each migrant’s planning horizon. Thus the host-country policy of setting the duration of a migrant’s stay abroad has a fundamental influence over the optimal education policy of the source country. These elements do not play a role in the present study as we are considering here the problem of permanent migration with the policy instrument being the number of migrants, \( M \), admitted to the economy rather than the duration of each migrant’s stay. Djajić, Michael and Vinogradova (2012) take \( M \) to be exogenously given. Another important difference between the two models is that the present study has a more solid micro foundation. It considers explicitly the optimization problem of a potential migrant, allowing us to focus on the link between migration opportunities and the process of human capital accumulation in the source country, a key element that drives the main results of this paper. Djajić, Michael and Vinogradova (2012) assume that student effort is exogenous, rather than a function of educational and migration opportunities.

\textsuperscript{8}Migration programs in these countries are often negotiated at the bilateral level between the host and source counties, with compensation of foreign workers set to generate benefits for both the migrants and their employers. Bilateral agreements between Japan and the Philippines, Japan and Vietnam and Japan and Indonesia governing migration of nurses or bilateral agreements between Saudi Arabia and the Philippines, Singapore and Indonesia or Singapore and the Philippines in the domain of domestic helpers are examples of such arrangements.
program, "We have seen numerous instances in which American businesses have brought in foreign skilled workers after having laid off skilled American workers, simply because they can get the foreign workers more cheaply" (Branigin, 1995). In what follows, we shall assume that while the natives earn $w^*$, foreign workers earn only $(1 - \sigma)w^*$ per unit of transferable skills, where $\sigma < 1$ is an exogenous parameter of the model.

Within this framework, the expected period-two utility of consumption of a representative student in $S$ at the beginning of the planning horizon is given by

$$E_0(u(C)) = \frac{p}{1 - \theta} \left[ w^*(1 - \sigma)\phi H(\varepsilon, z, \bar{w}, \varepsilon, p, w^*, \sigma, \phi) \right]^{(1 - \theta)} + \frac{1 - p}{1 - \theta} \left[ \bar{w} H(\varepsilon, z, \bar{w}, \varepsilon, p, w^*, \sigma, \phi) \right]^{1 - \theta},$$

where $p \equiv M/N$ is the probability that a skilled graduate in $S$ will be able to migrate to $F$ and earn $w^*(1 - \sigma)\phi H(\varepsilon, z, \bar{w}, \varepsilon, M/N, w^*, \sigma, \phi)$ instead of $\bar{w} H(\varepsilon, z, \bar{w}, \varepsilon, M/N, w^*, \sigma, \phi)$, where we naturally assume that $w^*(1 - \sigma)\phi > \bar{w}$. Note that once we allow for the possibility of working in $F$, $z$ becomes a function of not only $\bar{w}$ and $\varepsilon$, as under autarky, but it also depends on the probability of ending up abroad, $M/N$, and on the conditions

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9U.S. employers apply for H-1B visas even though they pay a fee to the U.S. government in order to obtain a visa. This suggests that H-1B workers are paid lower wages than native workers with the same productivity level. Hira (2010, p.11) reports that "...paying H-1Bs below-market wages is quite common. According to the U.S. Citizenship and Immigration Services (USCIS)...the median wage in FY2008 for new H-1B computing professionals was $60,000, a whopping 25% discount on the $79,782 median for U.S. computing professionals. The median wage for new H-1Bs was even lower than the 25th percentile for computing professionals, and roughly equivalent to the salary of an entry-level bachelor's degree graduate in computer science commands. So, approximately half of the 58,074 H-1B computing professionals admitted in FY2008 earned less than entry-level wages for computer scientists." (See also Usher, 2001). As noted by Martin, Chen and Madamba (2000), "...many H-1B foreign workers want to find a United States employer to "sponsor" them for a permanent immigration EB visa; thus, as H-1B workers they are more willing to work long hours for lower pay than United States workers." Although the underpayment of any given foreign skilled worker is likely to be over just a limited period of time, it nonetheless generates a rent for the employer. To simplify our analysis, we do not model explicitly the wage-assimilation process of foreign workers. Instead, the employer's rent component is simply assumed to be a fraction of a foreign worker's lifetime earnings. One can think of this fraction as being smaller, the lower the degree of dependency (under the regulations) of foreign workers in relation to their host-country employers and the greater the degree of mobility of foreign workers within the labor market of $F$.
in the foreign labor market, as reflected in \( w^*, \sigma, \) and \( \phi \).

### 2.2.1 Optimal Educational Policy of the Source Country

When \( S \) is open to emigration, let us assume that the aim of the authorities is to maximize the contribution of skilled labor to the economy’s output, net of educational expenditures, not taking into account the earnings or welfare of those who work abroad.\(^{10}\)

\[
V = \bar{w}(N - M)H(\varepsilon, z(\bar{w}, \varepsilon, M/N, w^*, \sigma, \phi)) - Nx \varepsilon. \tag{12}
\]

For a given \( M \), the optimal education policy of \( S \) must satisfy the following condition.

\[
\frac{\partial V}{\partial \varepsilon} = V_\varepsilon = \bar{w}(N - M)(H_\varepsilon + H_z \frac{\partial z}{\partial \varepsilon}) - N x \varepsilon = 0. \tag{13}
\]

In comparing eq. (13) with (10), we immediately notice that \( (N - M) < N \), which implies that the optimal provision of educational services must be such that \( (H_\varepsilon + H_z \frac{\partial z}{\partial \varepsilon}) \) is larger when migration is permitted. This, however, does not necessarily call for a lower \( \varepsilon \). As we shall see below, an increase in the educational efforts of students following the opening of the economy to emigration will, for a given \( \varepsilon \), result in an increase in \( (H_\varepsilon + H_z \frac{\partial z}{\partial \varepsilon}) \).\(^{11}\)

This can more than offset the difference between \( N - M \) and \( N \), in which case a larger \( \varepsilon \) is required to maximize the welfare of \( S \) when migration is permitted.

Using eqs. (4)-(5) along with the assumption that the marginal utility of leisure is constant (i.e., \( \chi = 0 \)),\(^{12}\) we can write \( V_\varepsilon = \frac{\bar{w}(N-M)\beta H}{\gamma(1-\theta)} - Nx \). Thus the second-order

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\(^{10}\)In making this assumption, we follow the mainstream of the literature on the brain drain. A notable exception is Bertoli and Brückner (2011), where the weight attached by the authorities of the source country to the utility of migrants is a parameter of the model.

\(^{11}\)By using (4) and (5), we can write \( \partial(H_\varepsilon + H_z \frac{\partial z}{\partial \varepsilon})/\partial z = \beta \gamma \mu z^{\gamma-1} \varepsilon^\beta - 1 + \frac{\beta \gamma \mu z^{\gamma-1} \varepsilon^\beta (1-\theta)}{\varepsilon^{(1-\gamma)(1-\theta)}} + \frac{\beta \gamma \mu z^{\gamma-1} \varepsilon^\beta}{\varepsilon^{(1-\gamma)(1-\theta)}} = 0 \).

\(^{12}\)This assumption makes the algebra more tractable in the analysis below. Note that the larger is \( \chi \), the smaller is the effort response of students to incentives for human capital accumulation. This is because a larger \( \chi \) makes it more difficult to give up leisure in exchange for future expected utility of consumption as
condition is satisfied as
\[ \frac{\partial V_{\varepsilon}}{\partial \varepsilon} = V_{\varepsilon\varepsilon} = \bar{w}(N-M)(H_{\varepsilon\varepsilon} + H_{\varepsilon} \frac{\partial z}{\partial \varepsilon} + H_z \frac{\partial^2 z}{\partial \varepsilon^2}) = \frac{\bar{w}(N-M)H\beta[\beta + \gamma(1-\theta) - 1]}{\varepsilon^2(1 - \gamma(1 - \theta))^2} < 0. \] (14)

Moreover,
\[ \frac{\partial V_{\varepsilon}}{\partial M} = V_{\varepsilon M} = \bar{w} \left[ (N-M) \frac{\partial (H_{\varepsilon} + H_z \frac{\partial z}{\partial \varepsilon})}{\partial M} \right] = \frac{\bar{w}\beta H}{\varepsilon(1 - \gamma(1 - \theta))} \left[ \frac{(N-M)\Delta}{M(1 - \gamma(1 - \theta))} - 1 \right] \geq 0, \] (15)

where \( 0 < \Delta < 1 \) is the the expected period-two gain in utility of a skilled worker stemming from being born in S when S is open rather than closed to international migration, divided by the expected period-two utility of a skilled worker when S is an open economy:
\[ \Delta \equiv \frac{M}{N} \left[ \frac{|w^*(1-\sigma)|^{1-\theta} - \bar{w}^{1-\theta}}{1-\theta} \right] \left[ \frac{(1 - \gamma(1 - \theta))}{M(1 - \gamma(1 - \theta))} \right] < 1. \] (16)

In what follows, we shall refer to \( \Delta \) as a skilled worker’s "normalized" utility gain of being in an open economy rather than in one closed to international migration.

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the level of study effort increases. Thus, by assuming that \( \chi = 0 \), the effect of a change in \( \varepsilon \) or expected future earnings on \( z \) (and therefore \( H(\varepsilon, z) \)) is larger than in the case where the marginal utility of leisure is diminishing. In what follows, we shall assume that \( \chi = 0 \), while noting that this stacks the cards in favor of the outcome that an increase in migration opportunities results in an increase in the net stock of human capital of the source country. At the same time our assumption that the marginal product of skilled labor is constant in the source country stacks the cards in the opposite direction. It keeps the source-country wage constant, rather than allowing it to rise (see Mishra, 2007) with an increase in emigration and hence provide greater incentives for human capital accumulation. Moreover, we follow the approach in the mainstream of the brain-drain literature by assuming that migration is permanent. If we were to consider the possibility of return migration, with skilled workers accumulating additional human capital abroad à la Domingues Dos Santos and Postel-Vinay (2003) or Djajić, Michael and Vinogradov (2012), one might argue that a net gain in the stock of human capital of the source country may be a more likely outcome, as documented by Gibson and McKenzie (2011) for the case of Tonga and Papua New Guinea. We should note, however, that temporary migration is a double-edged sword in relation to the net stock. On the one hand, returning migrants augment the stock of human capital of the source country. On the other hand, migration opportunities have a weaker effect on student effort, the shorter the expected duration of stay abroad.
Thus, according to (15), in response to an increase in $M$ it may be optimal for the authorities of $S$ to spend either more or less on education, depending on the parameters of the model. An increase in $\varepsilon$ is the optimal response if

$$\Gamma = \frac{(N - M)\gamma \Delta}{M[1 - \gamma(1 - \theta)]} > 1. \quad (17)$$

Alternatively, if $\Gamma < 1$, it is optimal for $S$ to spend less on education following an increase in $M$.

The six schedules in Figure 1 illustrate combinations of the emigration rate $M/N$ and the international earnings differential, $w^*(1 - \sigma)\phi/\bar{w}$, such that $\Gamma$ takes on the threshold value of unity. These schedules correspond to several combinations of $\theta$ and $\gamma$ ($\theta = 0.6$ and 0.7 and $\gamma = 0.6$, 0.7, and 0.8), chosen merely to illustrate the relationship, with the source-country wage $\bar{w}$ normalized to 1 unit of output. For any emigration rate above (below) a given threshold schedule, $\Gamma$ is smaller (greater) than unity, implying that an increase in $M$ makes it optimal for $S$ to reduce (raise) educational expenditures. As we shall see later, (17) is also the critical condition that determines if a larger $M$ chosen by the host country entails an increase or a decrease in the net stock of human capital in $S$ when $\varepsilon$ is held constant. The net stock increases if $\Gamma > 1$ and diminishes otherwise.

What Figure 1 shows very clearly is that the critical value of $M/N$ is positively related to the international earnings differential $w^*(1 - \sigma)\phi/\bar{w}$ and the elasticity, $\gamma$, of the human-capital production function with respect to the amount of study effort expended by a student. Both a larger wage differential and a bigger $\gamma$ provide students with a stronger incentive to accumulate human capital in response to an increase in migration opportunities. On the other hand, the critical value of $M/N$ is inversely related to $\theta$, the degree of concavity of the utility function. A larger $\theta$ makes students’ effort in school less sensitive to occupational opportunities later on in life.

In sum, an increase in official spending on education in $S$ is more likely to be the
optimal response to an expansion of an immigration quota in F, (i) the smaller the skilled emigration rate, (ii) the greater the international earnings differential, \( w^*(1 - \sigma) \phi / \tilde{w} \), (iii) the greater is \( \gamma \), and (iv) the lower is \( \theta \). An expansion of migration opportunities can then have a large impact on the effort of students in school, as well as a large impact on their subsequent productivity at the workplace. It then pays for the authorities of S to raise \( \varepsilon \), considering the fact that when \( M/N \) is small, the vast majority of students will end up in the labor market at home. We shall refer to an environment in which \( \Gamma > 1 \) and hence \( V_{\varepsilon M} > 0 \), as a "low-migration" (LM) equilibrium and the opposite case in which \( \Gamma < 1 \) and \( V_{\varepsilon M} < 0 \) as a "high-migration" (HM) equilibrium.

**Proposition 1.** If \( \Gamma \) is greater (less) than unity, then the optimal expenditure on education in S increases (decreases) with an expansion of immigration opportunities in F.

Figure 1 also plots the data on the skilled emigration rates and international earnings differentials between the U.S.A. and a set of developing source countries covered by the study of Clemens, Montenegro and Pritchett (2009), CMP hereafter. The skilled emigration rates are for the year 2000 and come directly from Table A.1-2, column 3 of Docquier and Marfouk (2006). The data on wage differentials between the U.S.A. and each source country are for observably identical workers, as reported in column 6, Table 1 of CMP.

Let us suppose that the degree of concavity of the utility function is at least \( \theta = 0.7 \) and that the elasticity of an individual’s earnings with respect to effort in school is no greater than \( \gamma = 0.8 \) (in which case a 1% increase in study effort in a given educational program results in a 0.8% increase in earnings), then at most three of the 42 developing countries covered by the CMP study, namely Yemen (YA), Nigeria (NG), and Egypt (EG) are possible candidates for being classified as countries in an LM equilibrium.
Alternatively, let us extend the relevant range of \( \theta \) to include values as low as 0.6.\(^\text{13}\) In that case Indonesia (ID), Venezuela (VE), India (IN), Jordan (JO), and Pakistan (PK) can also be added to Yemen (YA), Nigeria (NG), and Egypt (EG) on the list of possible LM countries, having assumed that \( \gamma \) does not exceed 0.8. The remaining 34 economies covered by the CMP study may then be classified as being in an HM equilibrium, with some of them (Haiti, Sierra Leone, Ghana, Guyana, Jamaica, and Belize) not even appearing in Figure 1 because their skilled emigration rates exceed 0.40 (see Table 1 for the complete list of countries and the data). Note, however, that the CMP study covers only 42 developing countries. This leaves a large number of other potential candidates that may be characterized as being in an LM equilibrium. As illustrated in Figure 1, given the country’s skilled emigration rate and the international wage differential, this hinges on the values of \( \theta \) and \( \gamma \) pertaining to the economy.

If we compare these findings with those reported in the key contributions to the literature, such as the seminal work of Beine, Docquier and Rapoport (2008), we find strong similarities with respect to the role of the emigration rate and the international wage differential in determining whether a country enjoys a net increase in its stock of human capital. Beine, Docquier and Rapoport (2008) assume, however, that education is privately funded, with the cost of acquiring a standard unit of human capital dependent on an agent’s innate ability. This brings into the analysis the distribution of ability within the population and the question of whether or not a person interested in acquiring human capital is liquidity constrained. In our model with publicly-funded education and students of identical abilities, these factors don’t play a role. The question is, instead, how do education authorities and students react to an expansion of migration opportunities, which in turn depends in our model on \( \theta \) and \( \gamma \). What we are suggesting

\(^{13}\) It is important to emphasize that the value of \( \theta \) can be expected to differ across countries, as cultural differences can result in differences in the shape of an individual’s utility function. For this reason we would hesitate to rule out a particularly low value of \( \theta \), such as 0.6 or even 0.5 as being irrelevant in the present context.
is that the analysis of the brain-drain/gain problem across economies with different education systems and at different stages of economic development may well require different model structures.

2.2.2 Optimal Immigration Policy of the Host Country

Turning to the host country, admission of immigrants is for the purpose of enabling the employers to benefit from the opportunity to hire foreign labor. Expansion of immigration programs for the admission of skilled migrants is typically driven by employer lobbies, as recently documented by Facchini, Mayda and Mishra (2015). In examining the data on lobbying expenditures of organizations trying to influence immigration policy in the U.S.A. over the period 1998-2005, they find that Microsoft was the single largest spender ($3,564,231) followed by Motorola ($2,660,473). Noting that the national cap on H-1B visas was 115,000 in the year 2000 and then raised to 195,000 in the years 2001-2003, it would be difficult to argue that these firms have not benefitted from the increase in the quota.\footnote{A recent paper by Doran, Gelber and Isen (2016) estimates the causal impact of extra H-1B visas on the receiving firm, using randomized variation from the Fiscal Year 2006 and Fiscal Year 2007 H-1B lotteries. They find evidence that "...H-1B workers at least partially crowd out other workers, with the estimates typically indicating substantial crowdout of other workers" (p.32). They also note: "Consistent with firm profit maximization, we find some evidence that extra H-1B visas increase median firm profits. We also find some evidence that extra H-1B visas lead to a decrease in median earnings per employee... Overall, our results are more supportive of the narrative about the effects of H-1Bs on firms in which H-1Bs crowd out alternative workers, are paid less than the alternative workers whom they crowd out, and thus increase the firm’s profits despite no measurable effect on innovation" (pp.32-33).}

To capture the notion that the inflow of migrants is expected to generate rents for their employers, we assume that the objective of F is to choose M that maximizes

$$V^* = w^* \sigma \phi MH(\varepsilon, z, w, \varepsilon, p, w^*, \sigma, \phi) - Q(M),$$  \hspace{1cm} (18)

where the first term on the right represents total employers' rents generated by F's immi-
igration policy and $Q(M)$ is the perceived cost for the society, including the costs imposed on skilled native workers, of hosting $M$ immigrants. In most of the host countries, the attitude of the native population (in contrast with that of employers) is negative when asked if more immigration is preferable. Facchini and Mayda (2008) find that in over twenty high- and middle-income economies, less than 10 percent of respondents who gave an opinion about migration were in favor of increasing the number of immigrants to their country. Moreover, regions with a higher percentage of immigrants tend to have a higher probability of natives expressing negative attitudes to immigration.\footnote{See, for example, Schlueter and Wagner (2008) and Marfaki and Longhi (2012). Ortega and Polevieja (2012) is of related interest. There is a growing literature on the political economy of immigration policy, starting with the pioneering work of Benhabib (1996) and extensions within a dynamic framework, such as Ortega (2005) and Facchini and Testa (2015).} Although in Western countries, these negative attitudes pertain primarily to unskilled migrants, asylum seekers and undocumented foreign workers, there is also resistance to skilled migration in countries where university graduates feel that they are unable to find their first job because they are obliged to compete with foreign skilled workers or, as in the U.S., where native skilled workers have been laid off while their employer is adding hundreds of new H-1B workers to the payroll (see Hira, 2010, p.9). In some countries there is resistance to skilled migration even in the presence of a severe shortage in some occupations. One example is Japan, which has bilateral migration agreements with the Philippines, Indonesia and Vietnam, allowing for immigration of nurses under country-specific quotas. There is considerable resistance throughout their health services sector to employment of foreign nurses as patients have a very strong preference to be treated by Japanese nurses (Kobayashi, 2014).

In what follows, we shall assume that $Q'(M) > 0$ and $Q''(M) > 0$. Maximization of $V^*$ with respect to $M$ requires that

$$
\frac{\partial V^*}{\partial M} = V_1 = R(1 + \gamma \eta_{M}) - Q'(M) = 0,
$$

(19)
where \( R = w^* \sigma \phi H(\varepsilon, z(\bar{w}, \varepsilon, M/N, w^*, \sigma, \phi)) \) is the per-worker rent enjoyed by the employers of skilled immigrants, \( \gamma \) is the elasticity of \( H(., .) \) with respect to \( z \) (see eq. (5)) and \( \eta_{zM} \) is the elasticity of \( z \) with respect to \( M \):

\[
\eta_{zM} = \frac{\Delta}{1 - \gamma(1 - \theta)} > 0.
\]  

(20)

An expansion of the immigration quota stimulates students’ effort in \( S \) by increasing the probability of being able to migrate. The optimal immigration policy implied by eq. (19) therefore requires admission of skilled workers beyond the point where the rent, \( R \), generated per migrant is equal to the marginal cost, \( Q'(M) \), of admitting an extra worker. This is because a more generous admissions policy implies a higher level of skill in possession of each immigrant and hence larger rents enjoyed by F’s employers on the entire stock of foreign labor employed in the economy. In terms of the parameters of the model, a lower degree of concavity of the utility function (\( \theta \)), a higher elasticity of \( H(., .) \) with respect to a student’s effort in school (\( \gamma \)) and, recalling the definition of \( \Delta \), a larger international wage differential, all work in the same direction to provide F with a stronger incentive to admit immigrants beyond the point where \( R = Q'(M) \).

If the degree of convexity of \( Q(M) \) is sufficiently high, which we assume to be the case,\(^{16}\) the second-order condition for the maximization of \( V^* \) is satisfied.

\[
\frac{\partial V^*_M}{\partial M} = V^*_{MM} = \frac{R \gamma \Delta}{[1 - \gamma(1 - \theta)]M[1 + \gamma \eta_{zM} + (1 - \Delta)]} - Q''(M) < 0.
\]  

(21)

Also note that

\(^{16}\)The degree of convexity of the \( Q(M) \) function must be such that \( \frac{Q''(M)/M}{Q'(M)} > [1 + \frac{(1 - \Delta)}{1 + \gamma \eta_{zM}[1 - \gamma(1 - \theta)]}] \). If we consider, for example, the case in which \( \gamma = 0.8, \theta = 0.6, M/N = 0.05 \), and the international earnings differential, \( w^*(1 - \sigma)\phi/\bar{w} = 4 \), with \( \bar{w} \) normalized to unity, a value of \( \frac{Q''(M)/M}{Q'(M)} > 0.079 \) is required to satisfy the second order condition. It can be shown that this critical value is decreasing in \( \theta \) and increasing in \( \gamma, M/N \), and the international earnings differential.

20
\[
\frac{\partial V^*_M}{\partial \varepsilon} = V^*_{M\varepsilon} = \frac{R\beta}{\varepsilon[1 - \gamma(1 - \theta)]}(1 + \gamma \eta z M) > 0,
\]

which states that the higher the provision of educational services in S, the stronger the incentive for F to admit more immigrants. This completes the presentation of our model’s structure.

3 Nash Equilibrium

We consider the case of both countries simultaneously choosing their policies in a non-cooperative manner so as to maximize their individual welfare. For the source country, the optimal provision of education (\(\varepsilon\)) is implicitly given by eq. (13), which is its reaction function, \(V^*_\varepsilon = 0\), while the host country sets its optimal immigration quota (\(M\)) on the basis of its own reaction function, \(V^*_M = 0\), as given by eq. (19). The slope of \(V^*_\varepsilon = 0\) is

\[
\left. \frac{d\varepsilon}{dM} \right|_{V^*_\varepsilon=0} = -\frac{V^*_{\varepsilon M}}{V^*_\varepsilon\varepsilon} = \frac{\varepsilon[1 - \gamma(1 - \theta)](\Gamma - 1)}{(N - M)[1 - \beta - \gamma(1 - \theta)]} \geq 0. 
\]

Noting that \(\beta + \gamma(1 - \theta) < 1\) in the denominator, the slope of \(V^*_\varepsilon\) is positive for parameter values corresponding to an LM equilibrium (i.e., \(\Gamma > 1\)) and negative in an HM equilibrium (i.e., \(\Gamma < 1\)).

The slope of F’s reaction function is unambiguously positive.

\[
\left. \frac{d\varepsilon}{dM} \right|_{V^*_M=0} = -\frac{V^*_{MM}}{V^*_{M\varepsilon}} = \frac{\gamma \varepsilon \Delta(1 + \gamma \eta z M + 1 - \Delta) - Q''(M)}{M \beta(1 + \gamma \eta z M)} > 0,
\]

as \(V^*_{MM} < 0\) and \(V^*_M > 0\). Note that \(1 - \Delta\) is a positive fraction representing the ratio of the period-two utility of working at home for the real wage \(\bar{w}\), to the expected period-two utility when the probability of migration is \(M/N\).
3.1 Comparative statics

Let us examine the implications of changes in the key exogenous variables on the Nash equilibrium values of the policy instruments of the two countries. By totally differentiating the reaction functions (13) and (19), we obtain

\[
\begin{bmatrix}
V_{\varepsilon} & V_{\varepsilon M} \\
V_{M \varepsilon} & V_{M M}^*
\end{bmatrix}
\begin{bmatrix}
d\varepsilon \\
dM
\end{bmatrix}
= 
\begin{bmatrix}
-V_{\varepsilon x} & -V_{\varepsilon \phi} \\
0 & -V_{M \phi}^*
\end{bmatrix}
\begin{bmatrix}
dx \\
d\phi
\end{bmatrix}
+ 
\begin{bmatrix}
0 \\
0
\end{bmatrix}
dQ'(M),
\]

where \( V_{\varepsilon x} = -N, V_{\varepsilon \phi} = (N - M)\bar{w}\beta \gamma H[\Delta + \frac{M}{\gamma}(1 - \Delta)]/\varepsilon \phi[1 - \gamma(1 - \theta)]^2 > 0, V_{M \phi}^* = R[\gamma(1 - \theta)(1 - \Delta)(\Delta + \frac{M}{\gamma}(1 - \Delta))] + (1 + \gamma \eta_M)[1 - \gamma(1 - \theta) + \gamma(1 - \theta)((1 - \Delta)(\Delta + \frac{M}{\gamma}(1 - \Delta)))]/\phi[1 - \gamma(1 - \theta)] > 0, \) and \( V_{M Q'(M)}^* = -1. \)

The system (25) enables us to solve for the impact of changes in the exogenous variables, including \( x, \phi, \) and the perceived marginal cost of admitting immigrants into \( F, Q'(M), \) on the equilibrium values of \( M \) and \( \varepsilon. \) Stability of the Nash equilibrium requires that the determinant \( \Omega = V_{\varepsilon \varepsilon} V_{M M}^* - V_{M \varepsilon}^* V_{\varepsilon M} > 0. \) This implies that in an LM equilibrium, depicted in Figure 2(b), the positively sloped \( V_{M} = 0 \) schedule must be steeper than the \( V_{\varepsilon} = 0 \) schedule. In an HM equilibrium, depicted in Figure 2(a), the \( V_{\varepsilon} = 0 \) schedule is negatively sloped.

3.2 Change in the cost of providing education

It is interesting in the present context to examine the implications of technological innovations that lower the cost of educating students. Recent improvements in communications and information technologies have lowered the cost of transmitting information through the educational system, giving both teachers and students much quicker, more efficient, and lower-cost access to knowledge and educational tools. We can think of these new technologies as being instrumental in lowering the cost, \( x, \) that the authorities face in...
providing a unit of educational services to students in $S$.

Using the system of eqs. (25) the effects of a change in $x$ on the Nash-equilibrium values of $\varepsilon$ and $M$ are as follows.

$$\Omega \frac{d\varepsilon}{dx} = -V_{MM}^* V_{ex} = NV_{MM}^* < 0, \quad (26)$$

$$\Omega \frac{dM}{dx} = V_{Mx}^* V_{ex} = -NV_{Mx}^* < 0. \quad (27)$$

The best response of $S$ to a decline in the cost of education is to provide more $\varepsilon$ to its students. With the now higher level of education in $S$ and a correspondingly greater effort on the part of students to acquire skills, the best response of $F$ is to admit more immigrants. In Figures 2(a) and 2(b) a reduction in $x$ gives rise to an upward shift of the reaction function of $S$ from $(V_\varepsilon = 0)$ to $(V_\varepsilon = 0)'$, while leaving the $V_M^* = 0$ schedule unaffected. The Nash equilibrium therefore moves from point A to point B. In both panels this entails an increase in the equilibrium levels of $\varepsilon$ and $M$, but more so in an LM equilibrium of Figure 2(b), as the vertical shift of the $V_\varepsilon = 0$ schedule is of the same magnitude in both panels (i.e., $V_{ex} = -N$).

Improvements in education technology can therefore be expected to have a positive impact on the provision of educational services in $S$ and on the level of skills possessed by its graduates. This effect is reinforced by the endogenous immigration-policy response of $F$ in an LM equilibrium of Figure 2(b) and mitigated in an HM equilibrium of Figure 2(a). Since the conditions in the relatively poorer developing countries, with low wages, are more likely to meet the criteria for a "low-migration" equilibrium (when compared with the conditions in the relatively more prosperous developing economies, other things being equal), our model suggests that technological improvements in the education industry are likely to have a greater positive impact on human capital formation in such economies. This follows from the model's implication that for a country in an LM equilibrium, the
interaction between education and immigration policies of S and F helps to stimulate educational spending and study effort of students, while for one in an HM equilibrium this interaction has a negative impact that offsets to some extent the positive direct effects on $\varepsilon$ and $z$.

3.3 Drop in the marginal cost of hosting immigrants

Suppose that the population of F undergoes an exogenous shift in it’s attitude towards immigration. To be more concrete, let us assume that the perceived cost of hosting immigrants is given by $Q(M) = q_0 + q_1 M^2$, where $q_0$ and $q_1$ are positive, exogenously given parameters and $Q'(M) = 2q_1 M$. A change in the perceived marginal cost of hosting immigrants in that case corresponds to a change in $q_1$.

On the basis of eqs. (25) we can solve for the effects of a change in $Q'(M)$ on $\varepsilon$ and $M$. Noting that $V_{MQ'} = -1$, we have

$$\Omega \frac{d\varepsilon}{dQ'(M)} = -V_{\varepsilon M} \geq 0, \text{ as } \Gamma \leq 1,$$

(28)

$$\Omega \frac{dM}{dQ'(M)} = V_{\varepsilon \varepsilon} < 0.$$

(29)

Eq. (29) shows that when the perceived marginal cost of hosting immigrants decreases, the Nash equilibrium level of F’s immigration quota increases. The effect on the provision of educational services in S is ambiguous, however, as indicated in eq. (28).

In an HM scenario, with a negatively sloped $V_\varepsilon = 0$ schedule, the source country’s best response to an expansion of the immigration quota in F is to lower $\varepsilon$. This can be seen in Figure 2(a), where starting from an initial HM equilibrium at point A, a reduction in $Q'(M)$ shifts the $(V_M^* = 0)$ schedule to the right so that the new $(V_M^* = 0)'$ schedule intersects the unaffected $V_\varepsilon = 0$ locus at point C. This results in a higher Nash-equilibrium value of $M$ and a lower $\varepsilon$. Alternatively, in an LM equilibrium, an increase in $M$ raises
the level of education provided in S. This is illustrated in Figure 2(b), where the Nash equilibrium moves from point A to C in response to a rightward shift of the $V_{M}^{*} = 0$ locus.

### 3.4 Change in $\phi$

The improvements in the information and communications technologies are also contributing to the globalization of the education industry. What students and trainees are learning across countries in any given field of study or occupation is becoming increasingly more similar. This is also driven to a significant extent by the expansion of trade in goods and services and the spread of technological knowledge across the globe. In terms of our model, this phenomenon can be captured by an exogenous increase in $\phi$, which measures the degree to which skills possessed by a migrant are transferable from S to F. Using the system of eqs. (27), we find that the effects on the Nash equilibrium values of $\varepsilon$ and $M$ are as follows:

\[
\frac{\Omega}{d\phi} \frac{d\varepsilon}{d\phi} = V_{M\phi}^* V_{\varepsilon M} - V_{M\varepsilon}^* V_{\varepsilon \phi} \geq 0, \tag{30}
\]

\[
\frac{\Omega}{d\phi} \frac{dM}{d\phi} = V_{\phi \varepsilon}^* V_{M \varepsilon} - V_{M \phi}^* V_{\varepsilon \varepsilon} > 0, \tag{31}
\]

where we recall that $V_{M\phi}^* > 0, V_{\varepsilon \phi}^* > 0, V_{M \varepsilon}^* > 0, V_{M M}^* < 0, V_{\varepsilon \varepsilon} < 0$, and the sign of $V_{\varepsilon M}$ is the same as that of $\Gamma - 1$. The effect of an increase in $\phi$ on the Nash-equilibrium level of spending on education is ambiguous and depends on the slope of the reaction function of S. Figure 3(a) illustrates the case of an HM equilibrium with a negatively sloped $V_{\varepsilon} = 0$ locus. An increase in $\phi$ shifts the $V_{\varepsilon} = 0$ schedule up and to the right and the $V_{M}^* = 0$ schedule down and to the right. In relation to the original equilibrium at A, we find that the immigration quota of F is unambiguously higher. Depending on the
relative magnitudes of the two shifts, however, the new equilibrium can feature either
a higher or a lower $\varepsilon$. The rightward shift of the $V_M^* = 0$ schedule is greater than that
of the $V_\varepsilon = 0$ locus if $-V_{M\phi}^*/V_{MM}^* > -V_{\varepsilon\phi}/V_{\varepsilon M}$. The Nash-equilibrium then moves to
$D^a$, where the level of $\varepsilon$ is lower. This would be the case, for instance, if the size of the
immigration quota of $F$ is highly sensitive to the amount of (marketable) human capital
in possession of potential immigrants, which makes $V_{M\phi}^*$ relatively large. Alternatively,
if the sensitivity of $F$’s quota to the stock of human capital that immigrants bring into
the economy is sufficiently low, the rightward shift of the $V_M^* = 0$ schedule is smaller
than that of $V_\varepsilon = 0$. The new equilibrium is then at $D'$, where it is optimal for $S$ to raise
$\varepsilon$ in response to an increase in $\phi$ triggered by the globalization of the education industry.

The implications of such an increase in $\phi$ in an LM equilibrium are illustrated in
Figure 3(b) by a shift of the Nash equilibrium from point $A$ to $D$. More spending on
education is then optimal for $S$ and more immigration is optimal for $F$. A higher $\varepsilon$ and
a higher $M$, as well as the increase in $\phi$ that triggered the changes in policies, all serve
to provide students in $S$ with stronger incentives to study, contributing to a more skilled
and more productive labor force both at home and abroad.

Proposition 2.

• A decline in the cost of education in $S$, increases the Nash equilibrium levels of both
educational spending and immigration quota.

• A decrease in the marginal cost of hosting immigrants in $F$, increases the Nash-
equilibrium level of the immigration quota and increases (decreases) educational
spending in a low- (high-) migration equilibrium.

• In a high-migration equilibrium an increase in the international transferability of
skills from $S$ to $F$ raises the Nash-equilibrium level of the immigration quota and
has an ambiguous effect on educational spending.
• In a low-migration equilibrium an increase in the transferability of skills from $S$ to $F$ has a positive effect on the level of spending on education as well as on the immigration quota.

4 Conclusions

Instead of repeating the principal findings of this study, which are conveniently summarized in the form of Propositions 1 and 2, we conclude the paper by discussing its main contributions at a more general level. There are two key elements and both of them flow directly from the model’s structure. First, we examine the interaction between the host-country’s immigration policy and the source-country’s education policy when both are endogenous and where students optimally choose how much effort to apply in the process of human capital accumulation. While we are aware that the two-country structure has its limitations in the present context, it enables us to investigate the impact of exogenous shocks, such as a technological improvement that lowers the cost of providing educational services in the source country, a shift in preferences on immigration in the host country, and a change in the degree of international transferability of human capital, on the amount of effort expended by students in school, the optimal level of source-country spending on education, and the optimal immigration quota of the host country. With a growing number of bilateral migration agreements covering skilled workers, particularly in the health services sector (e.g., bilateral Economic Partnership Agreements (EPA) between Japan and Indonesia (2008), Japan and the Philippines (2008), Japan and Vietnam (2009) or Venezuela and Cuba), a two-country model of migration of skilled workers becomes increasingly relevant.

The second key contribution relates to the way we model skill formation. Instead of having to purchase human capital, as is typically assumed in the earlier contributions
to the literature on education policies and the brain drain, we assume that students in
the source country have free access to public education, while the authorities choose the
optimal provision of training. Students then maximize their utility from consumption
and leisure by choosing the optimal amount of effort they apply in the process of human-
capital accumulation. Within this framework, the concavity of the utility function ($\theta$)
plays an important role in terms of how students respond to educational and occupational
opportunities at home and abroad. Expansion of migration opportunities increases the
source-country’s gross stock of human capital in the empirically relevant case of $\theta < 1$.
Whether or not it increases the net stock, depends on the magnitude of $\theta$, as well as that
of the elasticity, $\gamma$, of the human capital production function with respect to a student’s
effort, the international wage differential, and the emigration rate, $M/N$, in the initial
equilibrium. Our model implies that there is a net brain gain in a "low-migration"
equilibrium, characterized by a large $\gamma$, a low $\theta$, a low $M/N$, and a sufficiently large gap
between earnings of a skilled worker at home and abroad.
References


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International earnings differential: $w^*(1-\sigma)\phi/w$

Emigration rate: $M/N$

$\theta = 0.6$ (solid), $0.7$ (dashed)
with $\gamma = 0.8$ (blue), $0.7$ (red), $0.6$ (black)

Figure 1: Threshold schedules
Fig. 2(a) shows the case where $V_{\varepsilon M} < 0$ and the slope of the reaction function for $S$ is negative. Fig. 2(b) shows the case where $V_{\varepsilon M} > 0$ and the slope of the reaction function for $S$ is positive. In both cases i) a decrease in the cost of education moves the Nash equilibrium from point A to point B and ii) a decrease in the perceived marginal cost of hosting immigrants moves the Nash equilibrium from point A to point C.
Fig. 3(a) shows the case where $V_{\epsilon M}<0$ and the slope of the reaction function for $S$ is negative. An increase in $\phi$ moves the Nash equilibrium from point A to points such as $D'$ or $D''$, depending on the relative magnitudes of the rightward shifts of the $V^*_M=0$ and the $V_\epsilon=0$ schedules. Fig. 3(b) shows the case where $V_{\epsilon M}>0$ and the slope of the reaction function for $S$ is positive. An increase in $\phi$ moves the Nash equilibrium from point A to point D.
Table 1. Emigration rates and wage differentials between the U.S.A. and the 42 developing countries covered by Clemens, Montenegro and Pritchett (2009).

<table>
<thead>
<tr>
<th>Country</th>
<th>Country code</th>
<th>Emigration rate for high-skilled workers based on Docquier and Marfouk (2006)</th>
<th>USA wage differential relative to the other countries: $\omega^*(1 - \sigma_{p/\bar{w}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yemen</td>
<td>YA</td>
<td>6.0</td>
<td>15.45</td>
</tr>
<tr>
<td>Nigeria</td>
<td>NG</td>
<td>10.7</td>
<td>14.85</td>
</tr>
<tr>
<td>Egypt</td>
<td>EG</td>
<td>4.6</td>
<td>11.92</td>
</tr>
<tr>
<td>Haiti</td>
<td>HT</td>
<td>83.6</td>
<td>10.31</td>
</tr>
<tr>
<td>Cambodia</td>
<td>KH</td>
<td>18.3</td>
<td>7.45</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>SL</td>
<td>52.5</td>
<td>7.43</td>
</tr>
<tr>
<td>Ghana</td>
<td>GH</td>
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Source: The data on skilled emigration rates are for the year 2000 and come directly from Table A.1-2, column 3 of Docquier and Marfouk (2006). The data on wage differentials between the U.S.A. and each of the listed countries are obtained from Table 1, column 6, of Clemens, Montenegro and Pritchett (2009).