Human capital acquisition and international migration in a model of local interactions

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Abstract

I propose a model of learning centered on the idea that acquisition of skill is only possible through personal interaction with an individual already possessing such skill. In this environment, the fact that unskilled individuals learn from skilled individuals increases the income of the latter, which increases the willingness of the unskilled to acquire skill. The steady-state income of skilled individuals (teachers) is thus very sensitive to the ability of unskilled individuals (students) to fund their education. Cross-country differences in such ability have a multiplicative effect on the skill premium, which becomes a cause of international migration of the skilled from less developed countries (i.e. those with poorer access to educational credit) to more developed countries. Additionally, I study the welfare implications of such brain drain for a less developed country. Although brain drain reduces the number of skilled individuals in the country and thus makes acquisition of skill more difficult, unskilled individuals may still be better off: the increased difficulty of skill acquisition is offset by a higher skill premium once the skill has been acquired. Also, I find that increased openness of less developed countries to migration and the resultant accelerated brain drain increase the incentives for national governments to improve access of unskilled individuals to education.

Keywords: human capital formation; skill acquisition; compensated knowledge spillovers; brain drain; institutional improvement

JEL codes: F22, J61, O15

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1 Introduction

Despite the unprecedented development of long-distance communication technologies, knowledge continues to diffuse from one person to another mainly by means of personal interaction. One can become a scientist only through a continuous interaction with other scientists. In stable political environments, virtually all successful politicians have an experience of interaction with politicians from previous cohorts. In most jobs, young workers learn from old workers. Teaching services continue to be local in nature, and university professors in the United States do not fear that their jobs will ever be exported to India. Even the acquisition of skills that are labeled by economists as "low" such as taxi driving, require frequent personal interaction with people who have been in the business for some time. Numerous studies find that the first destination of immigrant workers is usually a location where many immigrants from the same country live,[1] despite the fact that the new immigrants, whose skills are usually similar to that of incumbent immigrants, would face less competition on the job market in other locations.

Although there exists an extensive literature on the diffusion of knowledge[2] and on positive externalities of human capital,[3] virtually all of this literature assumes that all the welfare gains of knowledge spillovers accrue only to those who absorb these spillovers; those who generate them earn nothing beyond what they would earn in the absence of such spillovers. But if diffusion of knowledge is local in nature, part of the welfare gain may be shifted from the learners (young, unskilled workers) to the teachers (old, skilled workers) through a bargaining process, pushing current earnings of the learners below their current marginal product of labor, and vice versa, raising the income of the teachers. I define this phenomenon as *compensated* knowledge spillovers. Park [1997] is, to my knowledge, the only account of compensated knowledge spillovers in existing literature.[4] The main focus of Park [1997] is to study the effects of the fact that unskilled workers learn from the skilled on the age-earnings profile, while the main focus of the current research is quite different and is elaborated below.

In this paper, I argue that a compensation for knowledge spillovers may have a multiplicative effect on the willingness to acquire skill and on the return to skill. When skilled

[1] E.g. Winters et al. [2001], Bauer et al. [2007], Munshi [2003]; Vergalli [2006] provides a theoretical analysis of the location choice of migrants.

[2] Jovanovic and Rob [1989] is an example of theoretical analysis; Keller [2002] is an empirical account of geographic localization; Keller [2004] contains a review of literature on knowledge spillovers.

[3] This literature starts with Lucas [1988]; applications of this concept to migration include Stark et al. [1997], Mountford [1997], Stark and Wang [2002], and Stark and Zakharenko [2010].

[4] Although Park [1997] does not use the term "compensated knowledge spillovers" to define the phenomenon.

individuals increase their earnings by receiving a compensation for generating knowledge spillovers, unskilled individuals have an increased willingness to acquire skill. Since the only way for them to acquire skill is to learn from existing skilled individuals, the latter get a further increase in earnings, further increasing the willingness of the unskilled to acquire skill. This multiplicative positive effect of compensated knowledge spillovers on demand for education offsets the traditional law of demand and makes the demand for education highly inelastic. In the model that I develop, I show that own-price elasticity of demand for education may approach zero under fairly mild restrictions on model parameters.

With highly inelastic demand, even small exogenous cross-country differences in the ability of the unskilled to acquire skills (for example, due to differences in their access to educational credit) may lead to large differences in the return to skill and create a basis for brain drain from a country with a poor access to educational credit (a country with "poor institutions" henceforth). Thus, I identify a new potential cause of brain drain: while the existing literature explains international migration of skilled workers by the differences in how much *current* output they can produce in different countries, I argue that brain drain may arise even between countries with identical fundamental parameters (productivity of skilled and unskilled, the learning technology), due to heterogeneous institutions that facilitate the transfer of wealth from the unskilled to the skilled in compensation for knowledge spillovers.

Further, I study the welfare implications of reduced costs of migration between countries. To obtain sharp results, I assume that countries differ only in one parameter – institutions that govern the access of the unskilled individuals to credit – and study how increased openness of a country with poorer institutions (less developed country) and a resulting accelerated brain drain from that country to a country with better institutions (more developed country) affects the unskilled individuals left behind in the less developed country. On the one hand, the departure of a fraction of skilled workers reduces the number of potential teachers and makes it more difficult to acquire skill (the negative effect of openness). On the other hand, increased country openness increases the return to skill, which makes unskilled individuals, who expect to acquire skill in the future better off (the positive effect of openness). I find that when institutions in the less developed country are sufficiently good, the positive welfare effect of openness overwhelms the negative effect, and the unskilled are better off: openness brings a large increase in the return to skill and a small decrease in the number of potential teachers. On the contrary, when home country institutions are sufficiently poor, the opposite happens: openness sharply reduces the number of potential teachers and thus makes it impossible for the unskilled individuals to acquire skill, making them worse off.

Additionally, I study the welfare gains of the less developed country from a marginal increase in the quality of institutions governing the access to credit. I find that such gain is always higher in a more open country: the welfare of the unskilled is more sensitive to the quality of institutions when the skilled have a better opportunity to leave. Thus, the increased openness and the resultant increased brain drain help “discipline”a home country government to improve institutions facilitating education. In the remainder of the paper, I develop and analyze a model of skill acquisition and brain drain. I begin with a description of a one-country (“closed economy”) steady-state, and then proceed to a two-country setting to model migration between the two countries.

2 Closed Economy

2.1 Overview

This is a general equilibrium dynamic model. Time is discrete; at each moment of time τ, there is a continuum of a unitary mass of individuals that are endogenously divided into two types – skilled and unskilled. I denote the fraction of skilled individuals in the economy in period τ by m_τ.[5] Between any two time periods, a randomly selected fraction $1-\delta$ of all individuals dies. The same mass of new individuals is born; therefore, the total population remains constant. Every newly-born individual is unskilled.

There is one consumption good, which is produced using the only input – skill – in a manner specified below. The price of the good is normalized to unity. All individuals maximize their discounted stream of consumption by:

$$U_i = \sum_{\tau=\tau_i \ldots \infty} \beta^{\tau-\tau_i} c_{i,\tau} \tag{1}$$

where i is the index of an individual, τ_i is the birth date of individual i, τ is the index of time, $c_{i,\tau} \geq 0$ is consumption of individual i at time τ, and $\beta < 1$ is the discount factor. Given that death is a random occurrence, individuals do not know the moment of their death and calculate their utility on an infinite time horizon. I assumed that the death probability is already built into the discount factor (thus $\beta \leq \delta < 1$), and therefore the parameter δ does not explicitly enter the decision-making process. In each period of time, each skilled

[5]For convenience, I have denoted all exogenously given parameters and functions either by uppercase Latin or lowercase Greek letters and all endogenous variables by lowercase Latin letters.

individual produces two types of output: one unit of consumption good and one unit of teaching services. Both outputs are supplied inelastically.

The productivity of unskilled individuals is normalized to zero.[6] The only way for unskilled individuals (students) to become skilled is through personal interaction with existing skilled individuals (teachers). The process of learning is stochastic and depends on the *learning intensity* of students $x \geq 0$, which has two possible interpretations. First, it could be viewed as a fraction of time a student has spent learning within each time period. Alternatively, we can assume that all students learn full time, but in classes of variable sizes: low intensity x implies learning in a large class, while high intensity x implies learning in a small class, or individually, or even individually with several teachers. In this stylized model x must be equal to the ratio of teachers to students in equilibrium; empirically, x can be measured as a ratio of skilled to unskilled people in the group of interest (country, firm etc.).

If an unskilled individual learns with intensity x, his probability of becoming skilled at that point in time is $P(x)$ where $P : R_+ \to [0, 1]$ is a smooth, strictly increasing, and strictly concave "learning" function.

The instantaneous income of individuals may differ from their instantaneous consumption, which calls us to model savings decisions of an individual. To reduce dimensionality, however, I avoid introducing an explicit model of savings, and make the following additional assumptions. First, I assume that the savings rate is equal to the discount rate, which, combined with the linear utility, makes individuals indifferent between current and future consumption unless the non-negativity of consumption constraint binds or is expected to bind in the future. Second, I assume that the borrowing rate is higher than the discount rate, such that the net present cost of one borrowed dollar is $K \geq 1$ dollars. The wedge between the savings and the borrowing rate reflects the quality of financial institutions in that country: $K = 1$ means that the quality of institutions is "perfect", while a higher value of K means the existence of transaction costs due to poor institutions. In an open economy version of the model, the value of K will be the only exogenous difference across countries, and one of our main parameters of interest.

2.2 Skilled individuals

Skilled individuals have reached their terminal state of knowledge, and supply both their outputs, consumption good and teaching services, inelastically. As a result, there are no

[6]Generalizing the unskilled productivity to a positive value would reduce the incentive to acquire skill, which would entail a lower return to skill, but it would not qualitatively change the results that follow.

decisions that they have to make in a closed economy: each period of their remaining life, they earn one unit of income from production, and w_τ units of income from teaching, where w_τ is the compensation for knowledge spillovers generated by teachers, or "teachers' compensation". Therefore, the value of being skilled at time τ_0 is given by:

$$v_1(w_{\tau_0}, w_{\tau_0+1}, ...) = \sum_{\tau=\tau_0}^{\infty} \beta^{\tau-\tau_0}(1 + w_\tau)$$

In a steady state where the teachers' compensation w_τ is constant over time and is equal to w, the above expression can be simplified to:

$$v_1(w) = \frac{1+w}{1-\beta} \tag{2}$$

2.3 Unskilled individuals and demand for education

Since the productivity of unskilled individuals is zero, there is no opportunity cost associated with obtaining education, and low-skilled individuals spend all their time learning. I assume that unskilled individuals do not have personal savings to fund their own education, and thus have to borrow. An individual i who chooses a learning intensity $x_{i,\tau}$ at time τ has to borrow $w_\tau x_{i,\tau}$ dollars, the net present cost of which, as specified above, is equal to $K w_\tau x_{i,\tau}$. Given the learning intensity $x_{i,\tau}$, the probability of becoming skilled is $P(x_{i,\tau})$; therefore, the value of being unskilled is:

$$v_0^\tau(w_\tau, w_{\tau+1}, ..., K) = \max_{z\geq 0}\left(-Kw_\tau z + \beta\left[P(z)v_1(w_{\tau+1}, w_{\tau+2}, ...) + (1-P(z))v_0^{\tau+1}(w_{\tau+1}, w_{\tau+2}, ..., K)\right]\right) \tag{3}$$

The steady-state version of (3) is:

$$v_0(w, K) = \max_{z\geq 0}\left(-Kw_\tau z + \beta\left[P(z)v_1(w) + (1-P(z))v_0(w, K)\right]\right) \tag{4}$$

Using (2) and solving (4), we derive the (inverse) steady-state demand for education as:

$$w = \frac{G(x(w, K))}{K - G(x(w, K))} \tag{5}$$

where x is the optimal steady-state learning intensity of the unskilled, and:

$$G(x) \equiv \frac{P'(x)}{\frac{1-\beta}{\beta} + s(x)} \tag{6}$$

$$s(x) \equiv P(x) - P'(x)x \tag{7}$$

Refer to the Appendix for proof.

From the properties of $P(x)$, it follows that $s(x)$ is increasing from zero to one, while $G(x)$ is decreasing from $G(0) = \frac{\beta}{1-\beta}P'(0)$ to zero.

Define by $\underline{x}(K)$ the lower bound of demand:

$$\underline{x}(K) \equiv \min_w x(w, K) = x(\infty, K)$$

The following property of the steady-state demand for education can now be established.

Proposition 1 **(a)** *When institutions are sufficiently poor, $K > G(0)$, demand for education $x(w, K)$ is positive when $w < \frac{G(0)}{K - G(0)}$, and is zero otherwise. Thus, $\underline{x}(K) = 0$.*

(b) *When $K = G(0)$, demand for education is positive for all $w > 0$, and approaches zero as w approaches infinity. Thus, $\underline{x}(K) = 0$ again.*

(c) *When $K < G(0)$, demand for education is always positive and is bounded away from zero: $x(w, K) \geq \underline{x}(K) > 0$, where $\underline{x}(K)$ satisfies the condition $K = G(\underline{x}(K))$.*

The proof follows directly from the formula for the inverse demand (5), and the fact that $G'(\cdot) < 0$. ■

This finding can be interpreted as follows. A marginal increase of the compensation w has two effects. First, w can be seen as a tuition, and the law of demand prescribes unskilled individuals to demand less of teaching services when tuition increases. Second, an increased w means an increased return to skill (since education is provided by skilled individuals), which means an increased willingness to acquire skill, implying an increased demand for education. With poor institutions (high transaction costs K) the former effect overwhelms the latter, and demand for education is a standard textbook demand function with negative and bounded away from zero own-price elasticity. When transaction costs K are sufficiently low, the two effects offset each other, and the learning intensity approaches its lower bound $\underline{x}$, while demand elasticity approaches zero, as the compensation w approaches infinity. The two types of the demand curve for education are illustrated on figure 1.

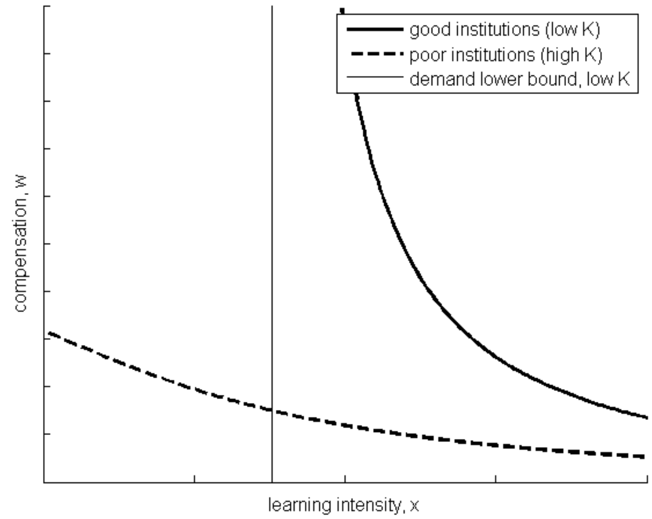

Figure 1: Demand for education: an illustration

2.4 Supply of teachers and equilibrium

We denote the steady-state fraction of skilled individuals in the economy by m; thus, the teacher-student ratio, and the learning intensity of the unskilled in the closed economy is $\overline{x} = \frac{m}{1-m}$. The steady-state fraction of skilled people is determined by the fact that in every period, the number of skilled that perish, $(1-\delta)m$, must be equal to the number of newly produced skilled individuals, which in turn equals the number of the unskilled, $1-m$, times the probability that they acquire skill, $P(\overline{x})$, times the probability that they survive until the next period, δ:

$$(1-\delta)m = \delta P(\overline{x})(1-m) \tag{8}$$

$$\frac{P(\overline{x})}{\overline{x}} = \frac{1-\delta}{\delta} \tag{9}$$

Formula (9) uniquely determines the steady-state supply of teaching services. Note that due to our assumption of inelastic supply of teaching services, the equilibrium number of teachers in the closed economy does not depend on the compensation w, and the supply is therefore vertical.[7]

[7]One can develop a model in which skilled individuals have a tradeoff between production and teaching, which would result in a traditional upward-sloping supply of teaching services. This would, however,

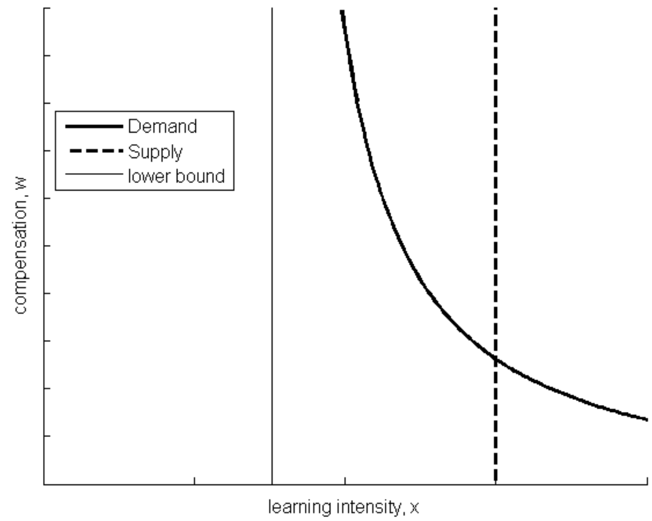

Figure 2: An illustration of the steady-state

Next, we establish the existence of the closed economy steady state.

Proposition 2 *In the closed economy, steady state exists and is unique.*

Proof. The uniqueness follows from the fact that the steady-state supply of teaching services is vertical, while the steady-state demand is downward sloping. To prove existence, given that the amount of demanded educational services ranges from $\underline{x}(K)$ to infinity, it is sufficient to show that the steady-state supply $\overline{x}$ is greater than the lower bound of demand $\underline{x}(K)$ for any K. Indeed, when $\underline{x}(K) = 0$, the proof is trivial since $\overline{x} > 0$. Otherwise,

$$\begin{aligned} P'(\underline{x}(K)) \quad & \underbrace{>}_{\text{cf.(7)}} \quad \frac{P'(\underline{x}(K))}{1 + \frac{\beta}{1+\beta} s(\underline{x}(K))} \underbrace{=}_{\text{cf.(6)}} \frac{1-\beta}{\beta} G(\underline{x}(K)) \\ & \underbrace{=}_{\text{definition of } \underline{\text{x}}} \quad \frac{1-\beta}{\beta} K \geq \frac{1-\beta}{\beta} \underbrace{\geq}_{\beta \leq \delta} \frac{1-\delta}{\delta} \underbrace{=}_{\text{cf.(9)}} \frac{P(\overline{x})}{\overline{x}} \geq P'(\overline{x}) \end{aligned}$$

The fact that P' is decreasing in its argument ensures $\overline{x} > \underline{x}(K)$ ■

Figure 2 illustrates the steady state.

We can also calculate the effect of poorer institutions (higher K) on a closed-economy GDP. As noted earlier, due to inelastic nature of the supply of teaching services, the share

complicate the analysis that follows, without adding new insights to the migration part of the model.

of high-skilled individuals in the population, and thus the total amount of the consumption good produced, does not depend on the quality of institutions. Nevertheless, inefficient institutions lower social welfare as they result in a borrowing deadweight loss. In a more general model with an upward-sloping supply of teaching services, inefficient institutions would additionally cause a decline in the learning intensity, which would additionally result in a smaller steady-state share of skilled individuals in the population, and thus even lower GDP.

Proposition 3 *With weaker institutions (higher K), steady-state country GDP decreases.*

Proof.

The GDP of the country is the aggregate income of all individuals. Skilled individuals earn $1 + w$, while the unskilled pay $Kw\overline{x} = Kw\frac{m}{1-m}$:

$$\begin{aligned} Y &\equiv m(1+w) + (1-m)(-Kw\overline{x}) = m(1+w) - (1-m)Kw\frac{m}{1-m} = m - m(K-1)w \\ &= m - m(K-1)\frac{G(\overline{x})}{K - G(\overline{x})} \end{aligned} \tag{10}$$

From (8) and (9), it follows that the steady-state values of m and $\overline{x}$ do not change as the quality of institutions K changes. Further, the fact that $\overline{x} > \underline{x}(K)$ for *any* value of K (cf. Proposition 2) ensures $G(\overline{x}) < G(\underline{x}(1)) \equiv 1$. Therefore, the value of GDP (10) strictly diminishes from m to $m(1 - G(\overline{x}))$ as the value of K increases from unity to infinity. Thus, weaker institutions, manifested in the form of a borrowing deadweight loss, reduce GDP despite the fact that the amount of borrowing decreases with weaker institutions, and the fact that the share of skilled individuals in the population does not change. ■

3 International migration

3.1 Brain drain

In this paper, I identify a new cause of the brain drain from less developed to more developed countries. I argue that even if the origin and destination countries have identical "real-sector" parameters such as marginal product of labor of both skilled and unskilled workers, fertility, life expectancy, and learning technology, brain drain may still exist due to differences in the technology of transferring wealth from those who are willing to acquire skill to those who provide teaching services. Such differences, manifested in the form of costs of transactions between teachers and students, lead to differences in return to skill across countries. Moreover, lower return to skill in a less developed country decreases the willingness to acquire such skill, which leads to further decrease in return to skill. This multiplicative effect of institutional differences creates an incentive for skilled individuals to migrate from less developed to more developed countries. In this section, I conduct a formal analysis of this effect and study its welfare implications.

Unlike the existing literature on international migration which explains migration patterns by differences in productivities, or differences in exchange rates, or "psychic costs" of living at home or abroad, this paper assumes that all these parameters are equal across countries; the only difference among countries is the ease of borrowing for students. If students have limited access to credit, they offer lower rewards to their teachers which makes the latter emigrate; students' access to education thus becomes limited.

Suppose there are two countries, North, whose quality of institutions is $K_N = 1$, and South, with $K_S \equiv K > 1$. Thus, South is less developed, with higher costs of transactions. Since the main focus of this paper is to study the effects of migration on the Southern economy, we assume that North is a large country, so its steady-state does not depend on international migration, and the Northern reward for teaching services is fixed at $w = w_N$. Southern autarky wage is lower, due to higher costs of transaction, and is equal to $w = w_S^A$. I assume that there exist a fixed sunk costs of emigration of M; free arbitrage condition imposes the following restriction on the Southern reward for teaching services:[8][9]

$$w = \max\{w_S^A, w_N - (1-\beta)M\} \tag{11}$$

where $(1-\beta)M$ is the annuity value of the migration cost M. I assume that M is sufficiently low, so that $w = w_N - (1-\beta)M > w_S^A$.

I assume that only skilled individuals can migrate; this is consistent with the selective immigration policy exercised by most developed recipient countries. I also assume that the number of individuals born each period in the South, and thus the total number of Southern-born individuals, is constant and does not depend on migration flows. With exogenous

[8] All endogenous variables without subscripts refer to the Southern economy henceforth, unless otherwise specified.

[9] One important phenomenon not captured in this paper is that limited access to credit negatively affects not only the acquisition of skill, but also the ability of individuals to migrate. In this paper, the cost of migration M is assumed to be independent of institutions K: skilled individuals that consider migration are assumed to have enough funds for such migration.

inflow of newly-born into the Southern economy, definition and calculation of the steady state becomes straightforward even when there is an endogenous outflow of migrants from the economy.

With the above assumptions, the following properties of an open Southern economy can be established. The fraction of skilled Southerners that migrate to the North is denoted by r.

Proposition 4 *The lowered migration cost M and associated increased Southern return to skill w have the following steady-state effects on the Southern economy:*

(a) *reduced learning intensity of the unskilled, x;*

(b) *reduced total (at home and abroad) number of skilled Southerners, m;*

(c) *increased r, the fraction of skilled Southerners that live abroad.*

Proof. Since the learning decisions of the Southern unskilled are described by the (inverse) downward-sloping demand function (5), the proof of (a) is straightforward: higher tuition w results in a lower demanded learning intensity x.

The proof of (b) follows from (8) that equates the number of newly created skilled individuals with the number of skilled that perish, whether at home or abroad. The increased openness of the South and the associated lower x must lead to a reduction of m.

The proof of (c) follows from the fact that the equilibrium learning intensity must equal the ratio of skilled Southerners that remain at home to the unskilled Southerners: $x = \frac{(1-r)m}{1-m}$. Upon combining this expression with (8), we obtain

$$\frac{1-\delta}{\delta} = \frac{P(x)}{x}(1-r) \tag{12}$$

Concavity of $P(\cdot)$ implies that $\frac{d}{dx}\frac{P(x)}{x} < 0$; using this fact and the implicit function theorem, we obtain from (12) that $\frac{dr}{dx} < 0$. Therefore, increased openness, by reducing x, increases the emigration rate r. ■

Figure 3 illustrates the steady state with emigration.

3.2 Welfare effects of brain drain

The main focus of this paper is to study the welfare implications of the brain drain. To fix ideas, I assume by "welfare" the expected utility of newly-born individuals. In other words,

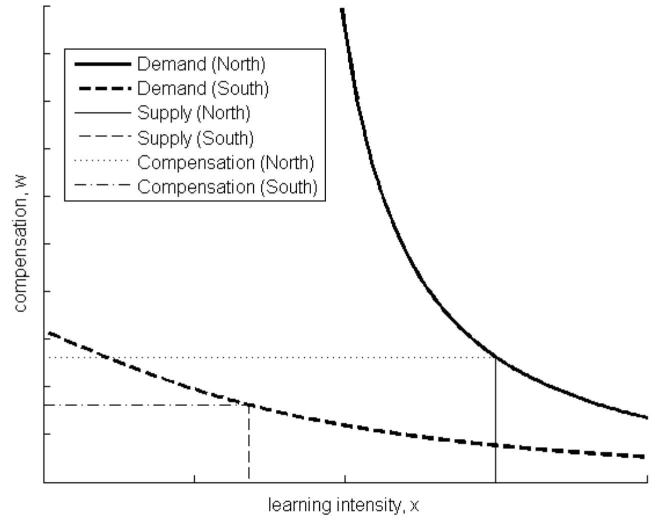

Figure 3: Steady-state with brain drain

does emigration of the skilled individuals make, on average, happier those Southerners who have just entered this world? Since all newly-born are unskilled, it is sufficient to study the effects of the brain drain on the value of being unskilled, $v_0(w, K)$. Prior to the analysis, it is helpful to introduce the following short form of v_0:

Lemma 1

$$v_0(w, K) = \frac{w+1}{1-\beta} S(x(w, K)) \tag{13}$$

$$S(x) \equiv \frac{s(x)}{\frac{1-\beta}{\beta} + s(x)} \tag{14}$$

The proof is contained in Appendix.

The main result can now be established.

Proposition 5 *When institutions are sufficiently poor, $K \geq \frac{\beta}{1-\beta} P'(0)$, the increasing openness of the South and the resultant increase in the compensation for knowledge spillovers w reduce welfare: $\frac{dv_0(w,K)}{dw} < 0$. Otherwise, the welfare effect of openness is non-monotone: it is negative when the initial compensation w is below a threshold, and is positive otherwise.*

Intuitively, there are two opposite effects of increased openness and the resulting increase of w on the welfare. First, the negative effect is that a higher compensation for knowledge spillovers w means that the unskilled have to pay more for education, and therefore have a lower chance of skill acquisition. Second, the positive effect is that a higher w means a higher return to skill and therefore higher welfare once the skill has been acquired. With sufficiently good institutions and sufficiently high initial w, the own-price elasticity of demand for education is close to zero, hence a further increase in w does not lead to a significant reduction of the learning intensity x. Thus, the probability that the unskilled acquire skill is not significantly reduced and the first (negative) effect on welfare is small, while the second (positive) effect is still large.

Proof. Using (13), we have that

$$
\begin{aligned}
(1-\beta)\frac{dv_0}{dw} &= S(x) + (w+1)\frac{dS(x)}{dx}\left(\frac{dw}{dx}\right)^{-1} \\
&\underbrace{=}_{\text{cf.}(5)} S(x) + \frac{K}{K-G(x)}\frac{dS(x)}{dx}\frac{(K-G(x))^2}{K}\left(\frac{dG(x)}{dx}\right)^{-1} \\
&= S(x) + (K-G(x))\frac{dS(x)}{dx}\left(\frac{dG(x)}{dx}\right)^{-1} \qquad (15)
\end{aligned}
$$

The Appendix proves that (15) is equal to

$$
(1-\beta)\frac{dv_0}{dw} = \frac{P(x) - \frac{1-\beta}{\beta}Kx}{\left(\frac{1-\beta}{\beta} + P(x)\right)}
$$

which is positive if and only if

$$
\frac{\beta}{1-\beta}\frac{P(x)}{x} \geq K \qquad (16)
$$

Define $x^*(K)$ as the value of the learning intensity that equates (16): $\frac{\beta}{1-\beta}\frac{P(x^*(K))}{x^*(K)} \equiv K$. Since $\frac{P(x)}{x}$ is decreasing, $\frac{dv_0}{dw}$ is positive when the equilibrium learning intensity is sufficiently small: $x(w) \leq x^*$, that is, the return to skill w is sufficiently large; $\frac{dv_0}{dw}$ is negative otherwise. Note that since $\frac{1-\beta}{\beta}\frac{P(x^*(K))}{x^*(K)} < \frac{1-\beta}{\beta}\lim_{z\to 0}\frac{P(z)}{z} = \frac{1-\beta}{\beta}P'(0)$, $x^*(K)$ exists only when institutions are sufficiently good, $K < \frac{\beta}{1-\beta}P'(0)$. Otherwise, $\frac{dv_0}{dw}$ is negative for all values of w.

To complete the proof, we need to verify that the value of $x^*(K)$ is meaningful, that is, it exceeds the lower bound of the learning intensity $\underline{x}(K)$. Indeed,

$$
\frac{\beta}{1-\beta}P'(x^*(K)) < \frac{\beta}{1-\beta}\frac{P(x^*(K))}{x^*(K)} \equiv K \equiv G(\underline{x}(K)) \equiv \frac{P'(\underline{x}(K))}{\frac{1-\beta}{\beta} + s(\underline{x}(K))} < \frac{\beta}{1-\beta}P'(\underline{x}(K))
$$

By assumption, $P'(x)$ is strictly decreasing in x, which ensures $x^*(K) > \underline{x}(K)$. ■

3.3 Improvement of institutions

It is intuitively obvious and straightforward to verify that better institutions would lead to increased welfare. Improvement of institutions, however, usually comes at a social cost, and it is therefore useful to know by *how much* better institutions increase welfare, and whether greater openness of a country to migration increases or decreases the social gain from better institutions. The following proposition states that greater openness increases this gain: in more open countries, governments have a higher incentive to make their institutions better.

Proposition 6 *Greater openness of a country to migration and resulting increased compensation for knowledge spillovers, w, lead to a higher marginal gain from better institutions:*

$$\frac{d}{dw}\left|\frac{dv_0(w,K)}{dK}\right| = -\frac{d^2 v_0}{dwdK} > 0$$

Proof. $\frac{d^2v_0}{dwdK} = \frac{d}{dK}\frac{dv_0}{dw}$ can be obtained by differentiating (15) with respect to K. We get:

$$\begin{aligned}
&\frac{d}{dK}\left(S(x(w,K)) + (K - G(x(w,K)))\frac{dS(x(w,K))}{dx}\left(\frac{dG(x(w,K))}{dx}\right)^{-1}\right) \\
&= (K-G(x))\frac{d}{dx}\left(\frac{dS(x)}{dx}\left(\frac{dG(x)}{dx}\right)^{-1}\right)\frac{dx}{dK} + \frac{dS(x)}{dx}\left(\frac{dG(x)}{dx}\right)^{-1} \qquad (17)
\end{aligned}$$

To prove that (17) is negative, it is sufficient to show that each of its two components is negative. Indeed, in the first component that consists of three multipliers, two multipliers are positive while the third is negative:

$$\begin{aligned}
K - G(x) &> 0 \\
\frac{d}{dx}\left(\frac{dS(x)}{dx}\left(\frac{dG(x)}{dx}\right)^{-1}\right) &= \frac{d}{dx}\left(\frac{\frac{1-\beta}{\beta}x}{\frac{1-\beta}{\beta}+P(x)}\right) = \left(\frac{1-\beta}{\beta}\right)\frac{\frac{1-\beta}{\beta}+P(x)-P'(x)x}{\left(\frac{1-\beta}{\beta}+P(x)\right)^2} > 0
\end{aligned}$$

We can compute $\frac{dx}{dK}$ from (5), using the implicit function theorem and holding w fixed: $\frac{dx}{dK} = \frac{G(x)}{K}\left(\frac{dG(x)}{dx}\right)^{-1} < 0$ due to $\frac{dG(x)}{dx} < 0$.

The second component of (17) is also negative because $\frac{dS(x)}{dx} > 0$ while $\frac{dG(x)}{dx} < 0$. ■

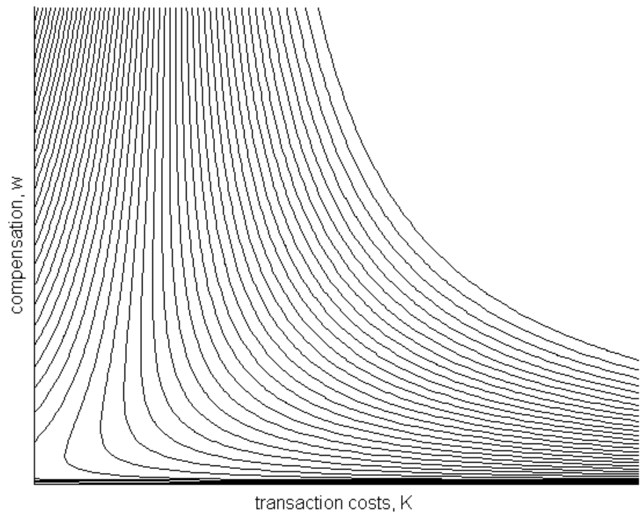

Figure 4: Welfare isolines of newly born, as functions of institutions and compensation for knowledge spillovers

Figure 4 plots the welfare isolines of the newly born, as functions of institutions (transaction costs) and compensation for knowledge spillovers. The highest welfare is attained in the NorthWest corner of the graph, with the lowest transaction costs (best institutions) and the highest compensation for knowledge spillovers. The lowest welfare (that is, zero) is attained in the NorthEast corner, with the highest transaction costs and the highest compensation. This means that, with high cost of education and high borrowing constraints, education is virtually unattainable, and hence there is no skill production in the economy. Without skilled individuals, there is no one from which unskilled individuals could learn from; even if skilled individuals did exogenously appear, they would all immediately emigrate.

With poor institutions/high transaction costs, a rise in the compensation w is decreasing welfare, while for low transaction costs, such a rise first decreases and then increases welfare, as predicted by Proposition 5. Also, the horizontal distance between isowelfare curves diminishes as the compensation for knowledge spillovers rises, which illustrates Proposition 6: with higher compensation due to greater openness, an equivalent improvement in institutions leads to a greater welfare gain (more isowelfare lines are crossed).

4 Conclusion

Modern civilization is only possible because people acquire knowledge from those who already possess the knowledge rather than acquiring it by themselves. While this phenomenon is well-studied at both theoretical and empirical levels, its logical extension that knowledge spillovers from skilled to unskilled may be compensated by the latter, and that this compensation may positively affect the willingness to acquire skill, is not discussed in the literature. In the present paper, I elaborate on this idea by developing a general equilibrium model of skill acquisition, in which the unskilled individuals acquire skill only by interacting with the skilled, and by compensating the latter for knowledge spillovers they generate. An exogenous increase in the demand for education, for example, due to lower costs of transaction between learners and teachers, has a multiplicative effect: it leads to an increase in the return to skill, which encourages the unskilled to acquire even more skill and boosts the demand for education even further.

I apply this idea to a model of international migration between countries with exogenously different ability of the unskilled to pay for their education, which leads to large differences in the return to skill and creates a basis for skilled migration from a less developed country to a more developed country. I find that an increased openness of the less developed country to such emigration may lead to an increase of welfare of the unskilled, despite the fact that they lose potential teachers, when institutions in the less developed country are sufficiently good. I also find that such increased openness increases economic payoffs to improvement of institutions.

The framework developed in this paper can also be applied to model another important phenomenon – return migration. Theoretical literature on human capital acquisition and return migration is scarce; to my knowledge, the only two theories are Santos and Postel-Vinay [2003] and Mayr and Peri [2008]. Both of these are based on a conventional model of migration in which accumulation of knowledge depends only on the effort of the learners, and migration is induced by differences in productivity of the consumption good(s) in different countries. To explain why an individual first migrates to a more developed country, and then returns back, both of these models introduce an ad hoc assumption of a skill premium of returnees: people who have lived abroad and returned become more productive than others. The skill premium is applied *only* to returnees; it does not apply to those who never emigrated, or those who emigrated but not returned. Within the framework of the current paper, return migration can be explained without such an artificial assumption: return migration emerges when financial institutions at home suddenly improve. With better institutions, unskilled Southerners can borrow (and thus study) more, which creates a temporary deficit of skill in the South. Such a deficit makes Southern emigrants return if the cost of doing so is sufficiently low.

Appendix

Derivation of demand for education Maximization of (4) with respect to learning intensity z results in the following first-order condition:

$$-Kw + \beta P'(x(w,K))(v_1(w) - v_0(w,K)) \leq 0 \tag{18}$$

where $x(w,K)$ is the arg max of (4). Note that (18) holds with strict equality if $x(w,K) > 0$. Solving for $v_1 - v_0$, we get

$$(v_1(w) - v_0(w,K)) \leq \frac{Kw}{\beta P'(x(w,K))} \tag{19}$$

Substituting the inequality for $v_1 - v_0$ back into (4) yields, after some rearrangement,

$$(1-\beta)v_0(w,K) \leq -Kwx(w,K) + Kw\frac{P(x(w,K))}{P'(x(w,K))}$$

Given that (cf.(2)) $v_0(w,K) = v_1(w) - (v_1(w) - v_0(w,K)) \geq \frac{1+w}{1-\beta} - \frac{Kw}{\beta P'(x(w,K))}$, we have that

$$(1+w) - Kw\frac{1-\beta}{\beta P'(x(w,K))} \leq (1-\beta)v_0(w,K) \leq Kw\left(\frac{P(x(w,K))}{P'(x(w,K))} - x(w,K)\right)$$

Rearranging, we get

$$\begin{aligned}\frac{1+w}{Kw} \quad &\geq \quad \frac{P(x(w,K))}{P'(x(w,K))} - z + \frac{1-\beta}{\beta}\frac{1}{P'(x(w,K))} \\ &= \quad \frac{\frac{1-\beta}{\beta} + P(x(w,K)) - P'(x(w,K))x(w,K)}{P'(x(w,K))} = \frac{1}{G(x(w,K))}\end{aligned}$$

where G is defined in (6). Solving for w, we get (5). ■

Proof of Lemma 1 From (18), we have that

$$v_0(w,x) = v_1(w) - \frac{Kw}{\beta P'(x)} \tag{20}$$

From (2), we know that $v_1(w) = \frac{1+w}{1-\beta}$. From (5), we have that $Kw = (w+1)\frac{P'(x)}{\frac{1-\beta}{\beta}+P(x)-P'(x)x}$, which allows us to rewrite (20) as follows:

$$\begin{aligned}
v_0(w,x) &= (w+1)\left[\frac{1}{1-\beta} - \frac{1}{(1-\beta)+\beta(P(x)-P'(x)x)}\right] \\
&= (w+1)\frac{1}{1-\beta}\frac{\beta(P(x)-P'(x)x)}{(1-\beta)+\beta(P(x)-P'(x)x)} \\
&= v_1(w)\frac{P(x)-P'(x)x}{\frac{1-\beta}{\beta}+P(x)-P'(x)x} \\
&= v_1(w)\frac{s(x)}{\frac{1-\beta}{\beta}+s(x)}
\end{aligned}$$

■

Proof of Proposition 5 continued

$$\begin{aligned}
& S(x) + (K - G(x))\frac{dS(x)}{dx}\left(\frac{dG(x)}{dx}\right)^{-1} \\
\underbrace{=}_{\text{cf.}(6),(7),(14)} & \frac{s(x)}{\frac{1-\beta}{\beta}+s(x)} + \left(K - \frac{P'(x)}{\frac{1-\beta}{\beta}+s(x)}\right)\frac{\frac{1-\beta}{\beta}x}{\frac{1-\beta}{\beta}+P(x)} \\
= & \frac{\left(\frac{1-\beta}{\beta}+P(x)\right)(P(x)-P'(x)x) - \left(K\frac{1-\beta}{\beta}+Ks(x)-P'(x)\right)\frac{1-\beta}{\beta}x}{\left(\frac{1-\beta}{\beta}+s(x)\right)\left(\frac{1-\beta}{\beta}+P(x)\right)} \\
= & \frac{P\left(\frac{1-\beta}{\beta}+P(x)-P'(x)x\right) - \frac{1-\beta}{\beta}Kx\left(\frac{1-\beta}{\beta}+P(x)-P'(x)x\right)}{\left(\frac{1-\beta}{\beta}+s(x)\right)\left(\frac{1-\beta}{\beta}+P(x)\right)} \\
= & \frac{P(x) - \frac{1-\beta}{\beta}Kx}{\left(\frac{1-\beta}{\beta}+P(x)\right)}
\end{aligned}$$

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