Journal of Development Economics
Vol. 64 (2001) 275–289

JOURNAL OF Development ECONOMICS

www.elsevier.com/locate/econbase

Brain drain and economic growth: theory and evidence

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Abstract

We focus on the impact of migration prospects on human capital formation and growth in a small, open developing economy. We assume that agents are heterogeneous in skills and take their educational decisions in a context of uncertainty regarding future migrations. We distinguish two growth effects: an ex ante "brain effect" (migration prospects foster investments in education because of higher returns abroad), and an ex post "drain effect" (because of actual migration flows). The case for a beneficial brain drain (BBD) emerges when the first effect dominates, i.e., when the average level of human capital is higher in the economy opened to migrations than in the closed economy. We derive the theoretical conditions required for such a possibility to be observed. Using cross-section data for 37 developing countries, we find that the possibility of a BBD could be more than a theoretical curiosity.

JEL classification: F22; J24; O15
Keywords: Brain drain; Migration; Growth; Human capital formation

1. Introduction

Modern theories of endogenous growth have considerably renewed the analysis of the relations between education, migration and growth. Since education has

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0304-3878/01/$ - see front matter
PII: S0304-3878(00)00133-4

been pointed out as a major determinant of long-term growth (Lucas, 1988), common wisdom suggests that the migration of people endowed with a high level of human capital—the so-called "brain drain"—is detrimental for the country of emigration. The brain drain can indeed be seen as a negative externality on the population left in the source country (Bhagwati and Hamada, 1974), due for example, to imperfect substitution between skilled and unskilled labor (Piketty, 1997). The negative impact of the brain drain has also been stressed in the New Growth literature (Miyagiwa, 1991; Haque and Kim, 1995; Galor and Tsiddon, 1997). Most studies underline the positive impact of migrations on human capital formation, but when turning to the issue of the brain drain, conclude that there is a detrimental growth effect.[1]

This view, however, has recently been challenged in a range of theoretical papers which all examine the impact of migration prospects on human capital formation within a context of uncertainty. The rationale is roughly the following: in a poor economy with an inadequate growth potential, the return to human capital is likely to be low and hence, would lead to limited incentive to acquire education, which is the engine of growth. However, the world at large does value education and hence, allowing migration to take place from this economy would increase the educated fraction of its population. Given that only a proportion of the educated residents would emigrate, it could well be that *in fine*, the average level of education of the remaining population would increase. This result is obtained in models of brain drain,[2] i.e., when labor is heterogeneous and when only the most skilled residents emigrate (Mountford, 1997; Docquier and Rapoport, 1997), in models with homogenous labor (Stark et al., 1998; Vidal, 1998), and in models with imperfect information and return migrations (Stark et al., 1997).

The aim of the present paper is both theoretical and empirical. In the model presented in Section 2, we refer mainly to Haque and Kim (1995) and to Mountford (1997). As distinct from Haque and Kim (1995), education is a discrete rather than a continuous variable. Moreover, we assume that uncertainty regarding future migration opportunities prevails. Consequently, some agents do invest in education for the purpose of a migration opportunity which may not materialize. As distinct from Mountford (1997), we introduce a change in the source of the intergenerational growth externality. Instead of considering a growth factor depending on the proportion of the educated in the remaining population, we make it

[1] For example, Haque and Kim (1995) find that "brain drain reduces the growth rate of the effective human capital that remains in the economy and hence, generates a permanent reduction of per capita growth in the home country". See also Miyagiwa (1991), who finds that "contrary to the presumption that brain drain hurts the unskilled individuals left in a source country (it is actually those professionals possessing intermediate-level abilities who are hurt by brain drain".

[2] By "brain drain", we do not mean the migration of engineers, physicians, scientists or other very highly skilled professionals, but simply, the emigration of a fraction of the population that is relatively highly educated as compared to the average.

depend on the average level of human capital of a generation of remaining adults. This allows us, in Section 3, to distinguish two effects of the brain drain on growth: an ex ante "brain effect" (migration prospects foster investments in education because of higher returns to education abroad), and an ex post "drain effect" (some, if not all, educated agents actually migrate). The case for a "beneficial brain drain" (henceforth, BBD) emerges when the first effect dominates, i.e., when the average level of human capital is higher in the economy opened to migrations than in the economy without migration possibilities. Last, in the empirical section (Section 4), we test the direct effect of migrations on education and its indirect effect on growth. To the best of our knowledge, this is the first attempt proposing an empirical validation of the conjecture of a possible BBD. Using cross-section data on 37 developing countries, we show that surprisingly enough, the possibility of a BBD cannot be rejected on the base of the available data. Section 5 concludes and draws some policy implications.

2. The model

Our model depicts a small open economy with overlapping generations of two period-lived individuals. In the first period, agents have the possibility to allocate a share of their time to education. In the second period, they supply a fixed quantity of labor, and their productivity when adult depends on their investments in human capital when young. Heterogeneity is introduced by considering that, at each period of time, young individuals exhibit different abilities to learn. Economic growth is due to the intergenerational transmission of human capital: adults' average level of human capital is integrally transmitted to the young of the next generation and constitutes the latters' inherited human capital.

2.1. The production sector

At each period of time, a representative firm uses capital K_t and labor H_t (measured in perfectly substitutable efficient units) to produce a composite good in quantity Y_t. The production function exhibits constant returns to scale. Output per efficient unit of labor $(y_t = Y_t/H_t)$ may thus be expressed as a function of capital per efficient hour worked $(k_t = K_t/H_t)$. We write: $Y_t = F(K_t, H_t);\ y_t = f(k_t)$.

The representative firm behaves competitively, so that factors' prices are given by their marginal productivity. The interest rate r is determined on the international capital market and the economy is assumed to be small enough to take the interest rate as given. The exogenous interest rate fixes the capital stock per efficient unit of labor and the wage rate. Without loss of generality, we assume a constant interest rate and normalize the wage rate to unity.

2.2. Individual behavior

Each young agent i from generation t is endowed with an identical inherited level of human capital h_t. During the first period, he or she has the possibility to invest a given fraction of time in education ($e_t^i = \bar{e}$, which we also interpret as the educational threshold required for prospective migrants), or not to invest ($e_t^i = 0$). The individual's level of human capital in the second period of life (h_{t+1}^i) is an increasing function of the time spent in education and of the individual's ability to learn, i.e., to transform a given time spent in education into productive skills:

$$h_{t+1}^i = \left[1 + a^i e_t^{i\beta}\right] h_t, \tag{1}$$

with $0 < \beta < 1$ and a^i, a parameter of individual ability uniformly distributed on the probability space $[\underline{a}, \bar{a}]$.

In an economy opened to migrations, individuals compare foreign and domestic returns to human capital when taking their education decisions. Since our main concern is the brain drain, we assume that human capital acquired through education is transferable and is rewarded a higher return abroad. We denote by w, $w > 1$, the relative return to education net from any migration costs (whether monetary or not), and assume it as given. This means that there is no room for convergence in productivity levels, a result that could be obtained by assuming persistent technological differences.[3] Moreover, this also means that migration flows are sufficiently small and do not affect wages in the destination country.

Under these assumptions, prospective migrants' productivity during the second period in the foreign country will thus be given by:

$$h_{t+1}^i = \left[1 + w a^i e_t^{i\beta}\right] h_t. \tag{1$'$}$$

One crucial point is that the achievement of the educational requirement is a necessary, but not sufficient, condition to be allowed to immigrate. Educated agents face uncertainty in the sense that they have a probability p to be allowed to migrate and a probability $(1 - p)$ to stay home. This could be due to both internal and external factors. Internal factors of uncertainty include emigration policies set by source countries, or simply the time lag between the two decisions on education and on migration. In between, even if people's preferences do not evolve, their relevant personal environment may have changed dramatically so that they could be willing to catch unforeseen domestic (professional or familial) opportunities. But the most obvious justification for the context of uncertainty is an external one. Indeed, international mobility is restricted by immigration authorities in the destination countries through measures like quotas, temporary visas, etc., whose criteria are at least partially arbitrary. To account for that, we assume that the probability of migration depends solely on the achievement of the educational requirement and not on individuals' productivity. Because educational attainments are perfectly observable, while individual skills are not, the probability of receiv-

[3] This could be justified through assuming some thresholds in the returns to human capital, depending for example on the average level of schooling (Lucas, 1988), or on time lags observed in the sequence of innovations (Galor and Tsiddon, 1997).

ing an immigration visa is assumed to be the same for all the educated whatever their individual productivity.[4] Consequently, migrants are assumed to be randomly selected among the educated (rather than self-selected), through relative quotas set by immigration authorities.

For the sake of simplicity, we assume that agents are risk neutral and maximize expected lifetime income, $E[h_t(1-e_t^i)+(h_{t+1}^i/1+r)]$, where r is used as a discount rate.[5] For each agent i, the condition under which an investment in education is observed is given by:

$$h_t(1-\bar{e}) + \frac{p[1+wa^i\bar{e}^{\beta}]h_t}{1+r} + \frac{(1-p)[1+a^i\bar{e}^{\beta}]h_t}{1+r} \geq h_t + \frac{h_t}{1+r}. \tag{2}$$

The share of the population that chooses to engage in human capital formation can easily be determined by characterizing the agent who is indifferent between investing or not. More precisely, agents who decide to invest are such that:

$$a_i \geq a_{\mathrm{E}} \equiv \frac{\bar{e}^{1-\beta}(1+r)}{\phi(p,w)}, \tag{3}$$

where $\phi(p,w) \equiv 1+p(w-1)$ is comprised between 1 and w, and a_{E} is the ability of the critical agent, i.e., of the agent who is indifferent between investing or not.

In the absence of any migration possibility (when $p=0$), the ability of the critical agent is given by $a_{\mathrm{F}} \equiv \bar{e}^{1-\beta}(1+r)$. By analogy with Mountford (1997), the proportion of educated in the remaining population would be given by $P_{\mathrm{F}} = \max\{0;(\bar{a}-a_{\mathrm{F}})/(\bar{a}-\underline{a})\}$. If migration would be a certainty for the educated $(p=1)$, more people would invest in education (the critical ability would be decreased up to $a_{\mathrm{M}} \equiv a_{\mathrm{F}}/w$) but the proportion of educated in the remaining population would clearly be zero $(P_{\mathrm{M}}=0)$. Finally, in the case where the migration probability is comprised between 0 and 1, the critical agent is defined by $a_{\mathrm{M}} < a_{\mathrm{E}} < a_{\mathrm{F}}$ and the proportion of educated in the remaining population is given by

$$P_{\mathrm{E}} = \max\left\{0; \frac{(1-p)(\bar{a}-a_{\mathrm{E}})}{a_{\mathrm{E}}-\underline{a}+(1-p)(\bar{a}-a_{\mathrm{E}})}\right\},$$

which may be either higher or lower than P_{F}.

[4] As pointed out by one referee, another possibility would have been to assume that education is a continuous variable and does make it easier to obtain an immigration visa. In that case, p would have been a function of e (with $p'>0$). However, education is not a perfect signal of individual skills and a certain degree of asymmetric information undoubtedly prevails. To mix the two features, we could assume different educational thresholds, each one associated to a different probability of migration, but this would just split the same qualitative results into different subgroups.

[5] The introduction of risk aversion would obviously mitigate the results but would not change their essence.

3. The case for a BBD

We now turn to the effects of migration opportunities on growth in the source country of migrants. We consider the growth of income per capita and do not consider size effects due to demographic changes. The source of long-run growth here is the intergenerational externality linked to the transmission of human capital. It is assumed that the average level of human capital of those adults who remain home is integrally and equally transmitted to each young of the next generation and constitutes the next generation's inherited human capital. As already mentioned above, migrants are randomly selected among the educated at a given probability. An important consequence is that the skill composition of the migrant fraction of the educated is identical to that of the remaining fraction of the educated. Consequently, the average level of human capital of the remaining population can simply be computed as follows:

$$h_{t+1} = \frac{\bar{a} - \underline{a}}{a_{\mathrm{E}} - \underline{a} + (1-p)(\bar{a} - a_{\mathrm{E}})} \left[\int_{\underline{a}}^{a_{\mathrm{E}}} h_t U(a)\, da + (1-p) \int_{a_{\mathrm{E}}}^{\bar{a}} (1 + a\bar{e}^{\beta}) h_t U(a)\, da \right], \tag{4}$$

where $U(a)$ is the uniform distribution on $[\underline{a}, \bar{a}]$.

From Eq. (4) we can derive the equilibrium growth factor in our economy:

$$g_{t+1} = \frac{h_{t+1} - h_t}{h_t} = \frac{(1-p)\bar{e}^{\beta}\left(\bar{a}^2 - a_{\mathrm{E}}^2\right)}{2\left[a_{\mathrm{E}} - \underline{a} + (1-p)(\bar{a} - a_{\mathrm{E}})\right]}. \tag{5}$$

Eq. (5) clearly highlights the two opposite growth effects of the brain drain. On the one hand, the equilibrium growth rate is directly proportional to $(1-p)$, the proportion of educated agents who remain home: this is the "drain effect", which slows down growth (indeed, $\partial g / \partial p < 0$ for a_{E} constant). On the other hand, the equilibrium growth rate is a decreasing function of a_{E}, the ability of the critical agent, which is itself a negative function of p: this is the "brain effect", which fosters growth. Obviously, the case for a BBD emerges when the brain effect dominates.

In the following, we derive the general conditions required for a BBD to be observed. As a benchmark case, we consider the case of an economy without migration possibilities, which is obtained by setting $p = 0$ in Eq. (5); without any loss of generality, we set $\underline{a} = 0$ so that we can write:

$$g_{\mathrm{F}} = \frac{\bar{e}^{\beta}\left(\bar{a}^2 - a_{\mathrm{F}}^2\right)}{2\bar{a}}; \qquad a_{\mathrm{F}} = \bar{e}^{1-\beta}(1+r), \tag{6}$$

where g_{F} is the growth rate of the economy without migration possibilities, and a_{F}, the ability of the critical agent in that economy.

Our main concern here is the comparison of growth rates with and without migration possibilities. The general condition for a BBD to be observed is therefore

$$\frac{(1-p)\,\bar{e}^{\beta}\left(\bar{a}^2-a_{\mathrm{E}}^2\right)}{2\,a_{\mathrm{E}}+2(1-p)(\bar{a}-a_{\mathrm{E}})} > \frac{\bar{e}^{\beta}\left(\bar{a}^2-a_F^2\right)}{2\,\bar{a}}, \tag{7}$$

where $a_{\mathrm{E}} = a_{\mathrm{F}}/\phi(p,w)$.

Obviously, if there is no growth in the autarkic economy ($a_{\mathrm{F}} = \bar{a}$), openness can never be detrimental. In the following, we exclude such an extreme case and focus on interior solutions for the autarkic economy which we define as follows:

Definition. An interior solution in the autarkic economy is an equilibrium with a strictly positive proportion of educated in the economy ($a_{\mathrm{F}} < \bar{a}$).

Under the interior solution assumption, condition (7) yields the following result:

Proposition 1. *A brain drain is beneficial for the source country if and only if the probability of migration verifies the following condition:*

$$p \times Z(p) = p\left(Ap^2 + Bp + C\right) < 0, \tag{7'}$$

with $A = (w-1)^2$, $B = (w-1)\left(\dfrac{\bar{a}^2-a_{\mathrm{F}}^2}{\bar{a}a_{\mathrm{F}}} + 3 - w\right)$ *and* $C = \dfrac{\bar{a}^2-a_{\mathrm{F}}^2}{\bar{a}a_{\mathrm{F}}} - 2(w-1)$.

For each $p > 0$, condition (7′) depends on the sign of $Z(p)$. It comes out that $Z(\varepsilon) \cong C$ (for ε sufficiently small) might be either positive or negative (that is, a developing country may or may not benefit from a small opening of its frontiers to the migration of educated people). On the opposite, $Z(1) = w(\bar{a}^2 - a_{\mathrm{F}}^2)/(\bar{a}a_{\mathrm{F}})$ is always non-negative (that is, a unitary probability to migrate is obviously detrimental for the country).

Between these two extreme cases, the total effect depends on the signs and values of B and C. One can see that C is positive if investment in human capital is relatively high in the economy closed to migrations (i.e., if a_{F} is small enough). In this case, a brain drain is expected to be either, always detrimental for the home country if ($B > 0$), or beneficial on a reduced migration probability space (if $B < 0$). The intuition for the first case is that migrants are mostly picked up among educated people that would have engaged in human capital formation even in the absence of migration opportunities.

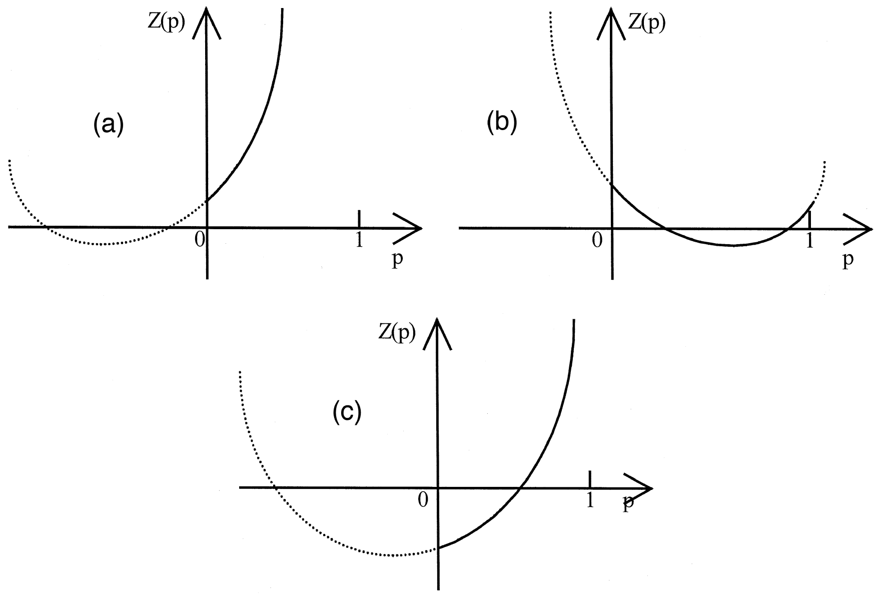

Fig. 1. General conditions for a beneficial brain drain. (a) Brain drain is always detrimental ($C > 0$ and $B > 0$: two negative roots). (b) Beneficial brain drain for intermediate values of p ($C > 0$ and $B < 0$: two positive roots). (c) Beneficial brain drain for low values of p ($C < 0$: one positive and one negative root).

In the second case, the probability of migration must be high enough (since $Bp < 0$) to induce a significant brain effect, but low enough (since $Ap^2 > 0$) to avoid a strong drain effect. As a result, in that second type of economy, a small opening to migrations may then be insufficient to induce a higher growth rate since the brain effect dominates only for intermediate values of the migration probability. These two cases are illustrated in Fig. 1(a) and (b), while Fig. 1(c) illustrates the case where C is negative. This corresponds to an economy with a low growth rate in the absence of migrations (that is, a situation which could approximate an underdevelopment trap). In that third case, a brain drain is expected to be beneficial, as long as the migration probability is not too high.

4. Empirical evidence

Two fundamental relationships emerge from the theoretical sections. The first relationship, implied by Eq. (3), establishes a positive link between migration opportunities and the proportion of young individuals who decide to invest in education. The second relationship that can be estimated is derived from Eq. (5) and states that the growth rate is positively linked to the share of educated people and negatively affected by migration flows. Eqs. (3′) and (5′) summarize these two theoretical results in their testable form:

$$\frac{\bar{a}-a_{\mathrm{E}}}{\bar{a}-\underline{a}}=\frac{1}{\bar{a}-\underline{a}}\left(\bar{a}-\frac{\bar{e}^{1-\beta}(1+r)}{1+p(w-1)}\right), \tag{3′}$$

$$g_{t+1}=\frac{(1-p)\bar{e}^{\beta}\left(\bar{a}^{2}-a_{\mathrm{E}}^{2}\right)}{2\left[a_{\mathrm{E}}-\underline{a}+(1-p)(\bar{a}-a_{\mathrm{E}})\right]}. \tag{5′}$$

In this section, we assess the empirical relevancy of the theoretical results, as well as of some of the underlying mechanisms at work in the model. It is important to note, however, that our empirical analysis does not aim at estimating the structural theoretical model.[6] On the basis of cross-country data relative to developing countries, we estimate a reduced linear form of Eqs. (3′) and (5′). In order to control for omitted variables, we introduce additional variables in these two equations: public expenditures in education are introduced in both, while workers' remittances are included in relationship (5′). Before we turn to the estimation results (Section 4.3), two important methodological issues must be discussed. The first problem concerns the data (Section 4.1), and the second one deals with the specification of the estimated equations (Section 4.2).

4.1. Data issues[7]

There is no data harmonized across countries on the skill characteristics of international migrants. Many source countries do not collect any qualitative data on their emigrants, and the data collected by destination countries on their immigrants display a large heterogeneity, especially when dealing with migrants' educational attainments. Because data on migration flows by educational level do not exist in a suitable form, we use gross migration rates as a proxy variable for data on the brain drain. In turn, the choice of this proxy leads to statistical problems which have to be addressed.

The main problem concerning the data used is the measurement of migration flows. On the one hand, migration flows can be measured by the number of emigrants reported by developing countries. This is for instance the case for the

[6] Such an estimation would of course require much more information. As emphasized in Section 4.1., we face a hard constraint with respect to the available data set on developing countries. Besides, the estimation of a structural model would imply the use of more elaborate techniques. A natural candidate would then be the Generalized Method of Moments, which is quite appropriate for the estimation of equations derived from maximization programs. This would allow to test for possible misspecifications, due for example, to an incorrect structural form. Nevertheless, these techniques would require the use of instrumental variables, which would in turn require an increase in the number of variables used.

[7] Table 1 reports how the theoretical variables are matched by empirical counterparts and indicates the sources used.

data provided by the United Nations, which are mainly based on records reported by the authorities of the source countries. On the other hand, one may rely on immigration data recorded in the host countries. This is the case, for instance in the data provided by the OECD (OECD, 1997). A comparison makes clear that important differences arise between these two sources. We have chosen to base our computations on data reported by OECD countries. Indeed, as pointed out by OECD (1997), emigration data are less reliable than immigration data since emigration declarations are usually not compulsory. Moreover, the former generally include all the people leaving the country, including tourists, for example. It is therefore important to use statistics reported by well-defined categories. In our case, one should ideally measure migration flows by long-term emigrants. Unfortunately, the definitions of the main categories often change over time and are not harmonized across countries. This, in turn, introduces significant breaks in the series and artificial heterogeneity between countries. All these features definitely stand in favor of the data collected by receiving countries.

The second problem lies in the use of raw emigration rates rather than of data relative to the most educated migrants. As a result, it is likely that additional effects to the incentive one on human capital are captured in Eq. (5′). For example, one possible effect is the direct contribution of workers' remittances to the national income and to human capital formation.[8] Workers' remittances indeed turn out to be substantial in some countries of the sample, like Turkey, Bangladesh, the Dominican Republic, or Pakistan. In order to control for this effect, we have introduced remittances as a share of GDP in the growth equation.[9]

4.2. Specification issues

The first specification problem is related to the question of the endogeneity of migration in the empirical analysis. Since the theoretical framework considers migration as a key variable, we need to estimate an additional migration equation. This question is an important one in the growth literature, and recent studies have been particularly concerned with generating exogenous instruments to cope with that issue (see for example Hall and Jones, 1999). For internal migrations within industrialized countries or regions, Barro and Sala-I-Martin (1995) rely, for instance, on climate indicators or on population densities. Regarding international migrations from developing to developed countries, our theoretical analysis has emphasized two important determinants: wage differentials, that create the incentive to migrate, and the presence of binding immigration quotas which restrict

[8] Indeed, it has been argued that workers' remittances could contribute to human capital formation through the alleviation of liquidity constraints when financial markets are imperfect.

[9] Workers' remittances have also been introduced in the human capital equation (Eq. 10) but did not turn out to be significant and have therefore been removed.

effective migrations. As a proxy for immigration quotas, one may use countries' population sizes (denoted by pop_i). This choice stems from a basic feature of immigration policies in many developed countries. For example, immigration policy in the US is based on both individual skills and on a quota system, with a common quota for all countries, regardless of their size. Practically, this means that these quotas are less binding for small countries than for large ones, so that a country's population may be appropriately used as a determinant in the empirical migration equation.

The second specification issue is related to the non-linear form of Eq. (3′). Our theoretical framework predicts a non-linear relation between human capital accumulation and migration prospects or probabilities. This implies the choice of a non-linear form (in the variables) of the human capital regression equation. Therefore, we post-multiply migration rates (denoted mig_i) by a dummy variable $plev_i$ that involves a threshold for being in the "underdevelopment trap". As a matter of choice, $plev_i$ takes the value 1 if country i displays a value of GDP per head that is less than 15% of the average GDP per head in the G7 countries.[10] We also introduce public education expenditures as a control variable.

4.3. Estimation results

Our sample includes 37 developing countries (see Table 1). We use cross-section data and do not pay attention to possible dynamic effects. The examination of the dynamic effects would require the use of panel data, i.e., data with both time and cross-section dimensions (see Hsiao, 1986, or Baltagi, 1995). The absence of harmonized time series on human capital levels makes such an analysis impossible; besides, some variables (such as education levels or migration rates) exhibit very high inertia from year to year, further justifying our use of average data. Eqs. (9) and (10) are estimated in logs by ordinary least squares, and Eq. (11) is estimated in levels due to negative values for some growth rates.

The results relative to the three-equations system are given by:[11]

$$mig_i = \underset{(1.804)}{0.336}\, diff_i - \underset{(-4.158)}{0.554}\, pop_i - \underset{(-0.489)}{0.144}\, \underset{R^2=0.484}{epub_i}, \tag{9}$$

$$hum_i = \underset{(-3.868)}{-0.444} - \underset{(-0.502)}{0.016}\, mig_i + \underset{(2.495)}{0.075}\, mig_i^{*}\, plev_i + \underset{(2.207)}{0.161}\, \underset{R^2=0.355}{epub_i}, \tag{10}$$

$$grw_i = \underset{(-1.539)}{-0.050} - \underset{(-0.184)}{0.004}\, mig_i + \underset{(1.855)}{0.084}\, hum_i + \underset{(0.784)}{0.134}\, \underset{R^2=0.108}{rem_i}, \tag{11}$$

[10] This leads to the exclusion from the sample of the following countries: Brazil, Cyprus, Hong Kong, Mexico, South Africa, South Korea, and Trinidad and Tobago.

[11] Between brackets, t-ratios. Since this system is a recursive one (no simultaneity bias), we use OLS.

Table 1
Theoretical variables and empirical counterparts

Variable	Empirical counterpart	Measure	Sources
hum_i	UN education level indicator	1994 level	United Nations (1997)
grw_i	Growth rate of GDP per capita	Average growth rate 1988–94, PPP units	Chelem database (OECD)
mig_i	Migration rate	Number of migrants from country i to OECD countries/population of country i-(average rate, 1988–94)	OECD (1997), United Nations (1997)
$epub_i$	Public expenditures in education	Education expenditures, % of GDP (average, 1992–94)	United Nations (1997)
rem_i	Workers' remittances	Workers remittances in % of GDP (1990 level)	World Bank (1997)
$diff_i$	GDP per head differential with OECD countries	GDP per head of country i/mean GDP per head in G7 countries in PPP units (1990 level)	Chelem database (OECD)
pop_i	Population size	Population size, 1990 level	United Nations (1997)

Countries included in the sample: Algeria, Bangladesh, Brazil, China, Colombia, Cuba, Cyprus, Dominican Republic, Ecuador, Salvador, Fiji, Ghana, Guatemala, Guyana, Haiti, Honduras, Hong Kong, India, Iraq, Iran, Jamaica, Kenya, Lebanon, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Philippines, South Africa, South Korea, Sri Lanka, Surinam, Thailand, Trinidad and Tobago, Tunisia, Turkey.

where hum_i, diff_i, mig_i, epub_i, grw_i, rem_i denote, respectively investments in human capital, wage differentials with respect to G7 countries, migration rates,[12] public expenditures in education, growth rates of GDP per capita, and workers' remittances for country i.

As a whole, the signs of the estimates are in accordance with the theoretical predictions sketched out in the theoretical analysis. Eq. (9) shows a positive and significant correlation between migrations and wage differentials, and a strong and significant negative correlation between migrations and the population size. This last result is rather interesting, as it may suggest that immigration constraints are indeed binding. In turn, this supports one fundamental assumption of our theoretical framework, i.e., the fact that educational decisions are taken in a context of uncertainty regarding effective migration opportunities.

Given the cross-section nature of the data, the value of the R^2 relative to Eq. (10) is quite high. More importantly, the coefficient of $\mathrm{mig}_i^* \mathrm{plev}_i$ is positive and highly significant. At least, this means that, as predicted by the model, the incentive effect of migration prospects cannot be easily dismissed on empirical grounds, especially when controlling for non-linearities. Finally, although quite poorly estimated, Eq. (11) displays a positive link between human capital accumulation and growth. By contrast, the first variable (mig_i) that is thought to capture the drain effect is not significant at conventional significance levels. Even though the estimations are not fully controlled for heterogeneity across countries and should therefore be read with caution,[13] the results suggest that the empirical evidence from a large set of countries does not allow to reject the theoretical analysis.

5. Conclusion

Our model focuses on the impact of migrations on human capital formation and growth in the source country of migrants. The first impact, potentially beneficial, accounts for the fact that migration opportunities foster investments in education since it is awarded a higher expected return when the economy is opened to migrations; we have called this first effect the "brain effect". The second impact, undoubtedly detrimental but which should not be the sole consideration, is due to the departure of some, if not all educated agents, we have called this second effect the "drain effect". Obviously, the sign of the total impact depends on which effect

[12] The ex post migration rate is thought to capture, at the aggregate level, the ex ante individual probability to migrate (p in the theoretical model). Estimating more precisely these ex ante probabilities would require individual data and the use of a probit model for instance. As already underlined above, such a data set is unfortunately not available.

[13] Once more, this would be the case if one could rely on panel data techniques.

dominates. At the theoretical level, we have derived the conditions for a BBD to be observed. We have shown that a BBD is likely to occur in two cases: when the economy is originally closed to an underdevelopment trap and that migration probabilities are not too high, and when the economy already exhibits a relatively high growth performance and that migration probabilities take intermediate values. At the empirical level, we have provided some evidence showing that the possibility of a BBD is perhaps more than a theoretical curiosity, mainly because migration prospects seem to play a significant role in education decisions.

Policy implications may therefore be derived cautiously. From the perspective of the source countries, it is obvious that the imposition of barriers to the international mobility of skilled-labor, arguing for instance, that human capital has been partially publicly financed, could end up with opposite effects and result in a decrease in the long-run level of human capital. At the policy level, the critical issue in self-selection models is that of the appropriate pricing of human capital (tax and subsidy policies) that would allow the human capital that is necessary for growth to be retained at home. Our analysis, however, suggests that subsidies to education are likely to be inefficient if the probability of leaving is high for the educated (this is quite obvious), but also if wage differentials are important. In both cases, the expected return to education is high, so that no subsidy is required to foster human capital formation. From the perspective of destination countries, selective immigration policies could also be reconsidered in the light of their impact on growth in the source countries of migrants.

Acknowledgements

We are grateful to Elise Brezis, Oded Galor, Philippe Michel, Ady Schnytzer, Jean-Pierre Vidal, Fabrizio Zilibotti, and two anonymous referees, for comments and suggestions on earlier drafts. We also thank participants at the 1998 EEA Meeting, and seminar audiences at Bar-Ilan University, Hebrew University, University of Lille, University of Paris–Sorbonne, and Ben-Gurion University, for their remarks.

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