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Brain drain and LDCs' growth: winners and losers*

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Abstract

We present an empirical evaluation of the growth effects of the brain drain for the source countries of migrants. Using recent US data on migration rates by education levels (Carrington and Detragiache, 1998), we find empirical support for the "beneficial brain drain hypothesis" in a sample of 50 developing countries. At the country-level, we distinguish between winners and losers among source countries. While the number of winners is smaller, these include nearly 80% of the total population of developing countries.

JEL Classification: F22, J24, O15

Keywords: Brain Drain, Migration, Growth, Human capital formation, Immigration policy.

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1 Introduction

The term "brain drain" designates the international transfer of resources in the form of human capital, i.e., the migration of relatively highly educated individuals from developing to developed countries.¹ This issue has undergone extensive scrutiny since the 1960s (Grubel and Scott, 1966, Johnson, 1967), with this early literature concluding that the welfare of those left behind would fall if the migrant's contribution to the economy were greater than their marginal product. Since this would seem to be the case when the social return to education exceeds its private return, and given the fact that education is often at least partly publicly financed, it was widely recognized until recently that the brain drain was detrimental to the migrants' source countries (Bhagwati and Hamada, 1974). Typical of this view is the following citation: "in contrast to the case of foreign investment, where the gain from the international factor movement is divided by the two countries, the developed country gains now at the cost of those left behind in the less-developed country. The emigrants similarly are seen to gain at the sacrifice of those left behind" (Hamada, 1977, p. 20). In other words, the international mobility of skilled workers was seen as a zero-sum game, and most policy debates in the 1970s concentrated on whether a "tax on brains" could compensate the sending countries for the losses incurred as a result of the brain drain.² The current debate on the brain drain, however, rests on new arguments, and on a new reality.

At the empirical level, there is a fair amount of evidence suggesting that the brain drain is now much more extensive than, say, 25 years ago. While only 300,000 highly skilled workers emigrated from all developing countries to the Western Nations in the period 1961-72 (UNCTAD, 1975), the US 1990 Census revealed that there were more

¹In the non-academic literature, the term may be used in a narrower sense, and relates more specifically to the migration of engineers, physicians, scientists or other very highly skilled professionals with university training.

²See the special issue of the *Journal of Public Economics* on "Income taxation in the presence of international personal mobility", August 1982.

than two and a half million highly educated immigrants from developing countries residing in the United States. This increased brain drain is also apparent from regional and national figures. The relative cumulative "loss of brains" by region in 1990 has been estimated at 15% for Central America, 6% for Africa, 3% for South America, and 5% for Asia (Carrington and Detragiache, 1998), with this latter region providing by far the largest fraction of the total. For Africa, Haque and Jahangir (1999) indicate that the number of highly skilled emigrants increased from 1,800 a year in average in 1960-75 to 4,400 in 1975-84 and 23,000 in 1984-87. Although policy debates in the US and other Western countries tend to be focused on low-skill illegal immigration from the periphery, such migration patterns are not the whole picture. For example, Asian immigrants to the US, Canada and Australia in the 1980s, were typically better educated on average than the native population, and also than immigrants from developed countries such as the United Kingdom (Ong *et al.*, 1992).³ Country studies recently commissioned by the ILO reveal that 40% of Philippines' emigrants are college educated, that 12% of Uruguay's professionals and technicians live abroad, and, more surprisingly, that Mexico in 1990 was also the world's third largest exporter of tertiary educated migrants (Lowell and Findlay, 2001).

These trends are likely to have been confirmed in the 1990s in the face of the increasingly "quality-selective" immigration policies in most OECD countries. Since 1984, Australia's immigration policy had officially privileged skilled workers, with the candidates selected according to their prospective "contribution to the Australian economy". Canadian immigration policy follows along similar lines, resulting in an increasing share of highly educated people among the immigrants selected; for example, in 1997, 50,000 professional specialists and entrepreneurs migrated to Canada with 75,000 additional family members, representing 58% of total immigration. In the US, since the Immigration Act of 1990 - followed by the American Competi-

³Casual evidence suggests that this is indeed the case; for example, Saxenian (1999) estimates that immigrants accounted for 32 percent of the Silicon Valley's scientific and engineering workforce in 1990, the majority of whom originated from China and India (51 and 23 percent respectively).

tiveness and Work Force Improvement Act of 1998" emphasis has been put on the selection of highly skilled workers through a system of quotas favoring candidates with academic degrees and/or specific professional skills. For that latter category, the annual number of visas issued for highly skilled professionals (H-1B visas) increased from 48,000 in 1989 to 116,000 in 1999, the totality of this increase being due to immigration from developing countries, especially India (Lowell, 2000). In the EU countries, immigration policies are less clear and still oriented towards traditional targets such as asylum seekers and applicants requesting family reunion. However, there is some evidence suggesting that European countries are also leaning towards becoming quality-selective. For example, in Germany, Chancellor Schröder announced in May 2000 plans to recruit 10,000 additional specialists in the field of information technology. In France, the Weil Report on Immigration of 1997 also explicitly recommended favoring the immigration of highly educated workers.⁴

The institutional background of the brain drain, therefore, is now characterized by a "demand pull" on the side of the receiving countries, whose immigration policies are increasingly determined according to domestic needs and labor-market conditions, regardless of the consequences for the immigrants' origin countries. Combined with traditional self-selection effects on the supply side, this leads to much higher migration rates among the highly educated, and increased international transfers of human capital from developing to developed countries. In other words, human capital is flowing to where it is already abundant - the rich countries - (Easterly and Levine, 2001).

What are the consequences of this for developing countries? Strangely enough, there has been no systematic empirical assessment of the economic impact of the brain drain for developing countries. The main reason for this seems to be the lack of harmonized international data on migration flows by origin country and education

⁴Most figures are from OECD (2000).

level.⁵ In the absence of such empirical material, the debate has remained almost exclusively theoretical, with the following arguments put forward. First, alongside refinements around the "externality" argument (e.g., Usher, 1977, Blomqvist, 1986), negative effects of the brain drain for the source country have been reformulated in an endogenous growth framework (Miyagiwa, 1991, Haque and Kim, 1995, Reichlin and Rustichini, 1998, Wong and Yip, 1999). Second, the effects of migration prospects on human capital formation have been the focus of several recent studies (Mountford, 1997, Stark *et al.*, 1998, Vidal, 1998, Beine *et al.*, 2001), suggesting that such prospects may in fact *foster* human capital formation and growth in the source country of migrants.⁶ The essence of the argument is that if the return to education is higher abroad than at home, the possibility of migration increases the expected return to human capital, thereby enhancing domestic enrollment in education. More people, therefore, engage in human capital formation as a result of increased migration opportunities. Since only some of them actually migrate, there may be an overall increase in the country's post-migration level of human capital. Alongside the incentives to acquire education, other channels whereby the brain drain may positively affect the sending economy have also been proposed. These include a range of "feedback effects" such as remittances, return migration after additional knowledge and skills have been acquired abroad, and the creation of business and trade networks.⁷

As mentioned above, the literature on migration and human capital formation

⁵Even without considering the skill composition of migration flows, there are many difficulties inherent in the collection of international migration data. Among these, Zlotnik (1998, p. 429) notably mentions the fact that many countries "either lack a system for the continuous registration of international migration or, if they have such a system, do not process and publish the data emanating from it", and that "among those countries that do produce statistics on international migration, the meaning and scope of those statistics vary considerably".

⁶Most papers use an OLG framework in the spirit of Galor and Tsiddon (1997). Using a slightly different perspective, Stark *et al.* (1997) also elaborate on the possibility of a brain gain associated with a brain drain.

⁷See Docquier and Rapoport (2001) for a survey on the growth effects of remittances, and Domingues Dos Santos and Postel-Vinay (2001) on return migration and knowledge diffusion. A "diaspora externality" has long been recognized in the sociological literature (Gaillard and Gaillard, 1997, and Lowell and Findlay, 2001, review this literature) and, more recently, in the field of international trade (Gould, 1994, Rauch and Casella, 1998).

is almost exclusively theoretical. To the best of our knowledge, the only empirical analysis available at the aggregate level is that of Beine *et al.* (2001), who found a positive and significant effect of migration prospects on human capital accumulation in a cross-section of 37 developing countries. However, their study suffers from poor quality data. In particular, due to the lack of available data on migration rates by education levels, gross migration rates were used as a proxy measure for the brain drain. This void was recently filled by Carrington and Detragiache (henceforth CD), who computed emigration rates at three educational levels (primary, secondary and tertiary) for a large set of developing countries and emphasized the overall tendency for migration rates to be much higher for the highly educated. The CD indicators constitute the only comparative data available on the brain drain; however, they suffer from several limitations: (i) They concern stocks of migrants rather than flows; (ii) They are available only for one year, 1990; and, (iii) They are constructed on the basis of various assumptions which appear to be very strong for some countries. In spite of these limitations, their estimations of emigration rates by educational attainments are highly reliable for a relatively large number of LDCs (see Section 3).

The first objective of this research is to contribute to the empirical analysis of the brain drain at the aggregate level, through the use of the CD data on migration rates by educational attainments. Using a sample of 50 developing countries, we find that the migration of the highly educated has a significant positive impact on human capital formation in the origin countries. This is similar to the results obtained by Beine *et al.* (2001), but based on much better data. The second objective of this research is to distinguish between countries in which the overall effect of the brain drain is positive, and countries which are impoverished by the brain drain, as would be expected in the traditional view. Again, this issue has not been addressed previously in a systematic way. For each country of the sample, we sign the effect of a marginal increase in the migration rate of the highly educated, and estimate its growth performance would this migration rate be set to zero. This allows us to

distinguish between winners and losers among source countries, and to derive country-specific policy implications. We find that while there are more losers than winners, the latter include the most important countries in term of demographic size.

The remainder of this paper is organized as follows. Section 2 presents the theoretical background and derives the main testable implications of the analysis. Section 3 details the procedure used by Carrington and Detragiache to obtain their estimates, and, due to their limitations, suggests using sub-samples differentiated by their data quality. The empirical analysis is presented in Section 4; we first address some specification issues, and then give the results for the full sample. Section 5 is dedicated to country-specific calculations, allowing us to distinguish between winning and losing countries, and to compare such gains and losses in terms of annual GDP growth. Section 6 consists of a robustness analysis: the results are shown to be robust with respect to the use of sub-samples differentiated by their data quality; in addition, this section also tests for non-linearities in the relation between migration and growth, as suggested by previous research. Finally, Section 7 offers concluding remarks.

2 The model

2.1 Theoretical background

In this section we summarize the basic mechanisms at work in the above cited literature on migration prospects and growth, and then detail the empirical model.

Consider a small open developing economy taking the world interest rate as given, where all markets are competitive, and technology exhibits constant returns to scale; this fixes the capital/labor ratio and, consequently, the wage rate per efficiency unit of labor. Also assume an exogenous productivity differential, such that the equilibrium wage rate in our economy is lower than in the developed nation(s). In this setting, it is clear that migration prospects increase the expected return to human capital, thereby inducing more people to invest in education. Assume that people

are initially endowed with a given level of inherited human capital, live for two periods, and make two decisions: whether to invest in education during their youth; and whether to migrate in adulthood. It is convenient to model the education decision as a "take it or leave it" choice, involving a unique educational program, \bar{e} . Assume also that this minimal degree of education is a necessary (but not sufficient) condition for emigration to a high-wage destination. The common justification for the latter assumption is that the educational attainment \bar{e} could be set as a prerequisite by immigration authorities, who then randomly select migrants (in proportion m) among the appropriate candidates.⁸ This assumption is consistent with the recent quality-selective orientation of immigration policies in most OECD countries, as detailed in the introduction.

In keeping with Mountford (1997), Docquier and Rapoport (1999), and Beine *et al.* (2001), individuals are assumed to be born with heterogeneous learning abilities: each individual is characterized by his personal learning ability. In other words, the cost of achieving the educational prerequisite, c , is decreasing with the individual's ability. Denoting by a the individual ability to learn, the population distribution in country i is described by the density function $f_i(a)$ defined on R^+ , or by the cumulative distribution $F_i(a)$. The cost of achieving the minimal education threshold, c , also depends on a set of country-specific variables affecting human capital formation in a given country (e.g., public expenditures in education). Let us denote this set of variables by χ_i^h . Hence: $c_i(a) = c(a, \chi_i^h)$, with $c'_a < 0$.

The return to education is measured by the relative wage premium for the educated (relatively to the non-educated). Denoting by m_i the probability that an educated agent from country i migrates to a high-wage destination, and by $(1 - m_i)$ his/her probability to remain in the origin country, the expected return to education,

⁸Another possibility would be to assume that education is a continuous variable, and makes it easier to obtain an immigration visa. In that case, m would have been a function of e , with $m' > 0$. However, to the extent that education is not a perfect signal of individual skills and there are different educational thresholds, each associated with a different migration probability, this would just split the same qualitative results into different subgroups.

rel_i , may be written as a weighted average of the relative return abroad, ω^* , and the relative return in the domestic country, ω_i^d :

$$rel_i = m_i\omega^* + (1 - m_i)\omega_i^d \quad (1)$$

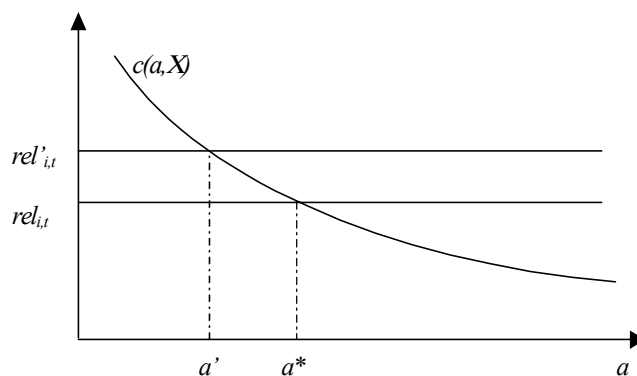
with $\omega^* > \omega_i^d$, implying that $\frac{\partial rel_i}{\partial m_i} > 0$. Recall that given the general assumptions above, ω^* and ω_i^d are constants.

To concentrate on internal solutions, assume that some individuals are educated. Since the cost of acquiring education decreases with individuals' learning abilities and the return to education is constant, the equilibrium proportion of uneducated agents among the younger generation in country i is given by $F_i(a_i^*)$, with a_i^* , the ability of the agent who is indifferent as to whether to invest in education. Therefore, the equilibrium proportion of educated agents in country i is given by:

$$H_i = 1 - F(a_i^*) \quad (2)$$

As shown in Figure 1, an increase in the migration probability increases the expected return to education, so that the critical ability moves to the left. Clearly, the critical ability is a function of m_i , ω^*/ω_i^d , and χ_i^h .

Figure 1: Ability distribution and human capital investment



We model endogenous growth by assuming that education investments exert a positive externality on the initial level of human capital of the following generation.

The growth rate of human capital in a country is positively affected by the ex-post proportion of educated workers within the previous generation (*i.e.*, once migration has been netted out). We denote this proportion hum_i , which is clearly given by:⁹

$$hum_i = \frac{(1 - m_i) [1 - F(a_i^*)]}{1 - m_i [1 - F(a_i^*)]} = \frac{(1 - m_i) H_i}{1 - m_i H_i} \quad (3)$$

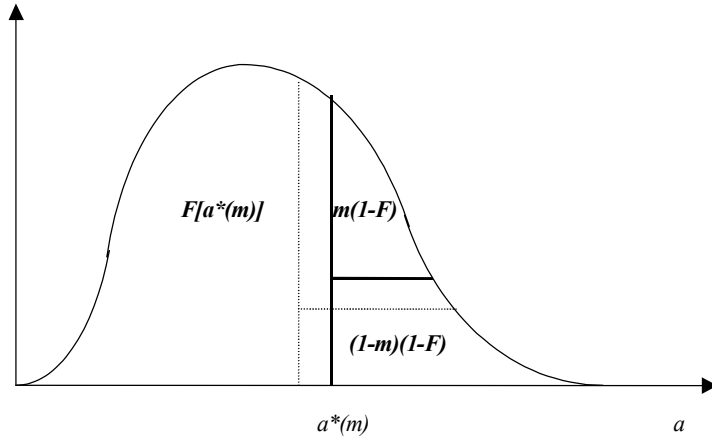
The growth rate, however, is also potentially affected by a set of other country-specific variables, such as physical capital, R&D expenditures, and public infrastructure. Let us denote this set of variables χ_i^g . The human capital growth rate equation may thus be written as:

$$g_i = g [hum_i, \chi_i^g] \quad (4)$$

In such a framework, it is clear that migration has two opposite growth effects, which are captured in the expression of hum_i . On the one hand, migration opportunities increase the expected return to education and, therefore, induce more people to invest in education; we refer to this first effect as "the brain effect". On the other hand, the brain drain obviously reduces the stock of human capital left in the sending country; we refer to this second effect as "the drain effect". These two effects are apparent in Figure 2.: a rise in m_i moves the critical ability to the left, thereby increasing the number of individuals who choose to invest in education. However, only a proportion $(1 - m_i)$ of this higher increased number of educated individuals remain in the home country, so that the sign of the overall effect depends on which effect dominates.

⁹Denoting by $E_{i,t}$ the inherited human capital of generation t in country i (*i.e.*, the number of efficiency units of labor they provide during their youth). The intergenerational externality means that each young individual in generation $t + 1$ inherits a fraction v of the average level of human capital of the adults in generation t who remained in the country. If ω_i^d measures the relative productivity of the educated, one obtains: $E_{i,t+1} = vE_{i,t} [hum_{i,t}\omega_i^d + 1 - hum_{i,t}] \equiv E_{i,t}(1 + g_{i,t})$.

Figure 2: The proportion of educated agents staying put



The main result of this simple model is expressed by the following proposition:

Proposition 1 *The total growth effect of the brain drain is given by $\frac{dg_i}{dm_i} = \frac{\partial g_i}{\partial hum_i} \times \left[\frac{-[1-F(a_i^*)]F(a_i^*)}{\{1-m_i[1+F(a_i^*)]\}^2} + \frac{(1-m_i)F'_a(-\frac{\partial a_i^*}{\partial m_i})}{\{1-m_i[1+F(a_i^*)]\}^2} \right] \geq 0$, with the first term between the brackets measuring the (detrimental) drain effect and the second term between the brackets measuring the (beneficial) brain effect.*

Proof. This is straightforward when deriving (4) with respect to m_i , and rearranging the terms ■

2.2 The empirical model

We now turn to the empirical model. The two main variables in the above theoretical model have fairly observable empirical counterparts: harmonized data on the human capital stock, hum_i , and, thanks to Carrington and Detragiache (1998), on the migration of highly educated workers, m_i , are available for a large set of developing countries. Also, the vectors of additional explicative variables, χ_i^h and χ_i^g , may be built so as to include variables for which there are harmonized international data. One specific variable of the theoretical model is clearly not observable, namely, the ex-ante proportion of the educated in the population, before migration has been

netted out. However, this variable, H_i , may easily be approached on the basis of equation (3), using the current observations for hum_i and m_i . Hence:

$$H_i = \frac{hum_i}{1 - m_i(1 - hum_i)} \quad (5)$$

Our purpose is to quantify the effects of migration prospects on human capital formation, that is, on the proportion of young individuals who invest in education.

The following system of equation forms our basic econometric model:

$$\Delta H_i + d_H H_{i,lag} = \psi(m_i; \chi_i^h; \epsilon_i^h) \quad (6)$$

$$g_i = \gamma(hum_i; \chi_i^g; \epsilon_i^g) \quad (7)$$

where $\Delta H_i = H_i - H_{i,lag}$ measures the formation of human capital in country i , $H_{i,lag}$ is the lagged value of H_i , d_H is the depreciation rate (educated agents leaving the labor force), and ϵ_i^h and ϵ_i^g are the error terms in the equations of H and g , respectively.

In what follows, we choose an analytical specification for these equations, and estimate their parameters, so as to evaluate the global effect of the brain drain and sign the expected growth effect of a marginal increase in the migration probability for each country.

After completing the estimation procedure, a potentially interesting insight of this model is the evaluation of the closed economy stock of human capital (\tilde{H}_i), that is, the stock of human capital that would be obtained for country i under autarky (or, in other words, if the emigration rate was set to zero for the corresponding current period):

$$\tilde{H}_i = Max \{ \psi(0; \chi_i^h; \epsilon_i^h) + (1 - d_H)H_{i,lag}; 0 \} \quad (8)$$

This stock must be non-negative.

Then, substituting (5) and (6) in (7) yields:

$$g_i = \gamma \left(\frac{(1 - m_i) [\psi(m_i; \chi_i^h; \epsilon_i^h) + (1 - d_H)H_{i,lag}]}{1 - m_i [\psi(m_i; \chi_i^h; \epsilon_i^h) + (1 - d_H)H_{i,lag}]}; \chi_i^g; \epsilon_i^g \right)$$

Hence, the growth effect of a marginal increase in the migration probability is given by:

$$\frac{\partial g_i}{\partial m_i} = \gamma_i^{hum} \times \frac{-H_i(1 - H_i) + \psi_i^m(1 - m_i)}{(1 - m_i H_i)^2} \quad (9)$$

where γ_i^{hum} measures the derivative of γ with respect to hum in country i , and ψ_i^m the derivative of ψ with respect to m in country i . Clearly, this last equation is the empirical counterpart of the result presented in proposition 1.

Such a framework allows us to address three questions which are central in the brain drain literature:

- Is there a possibility of a beneficial brain drain for country i ?
- What is the net current effect of the brain drain in country i ?
- Would an increase in the migration probability of the highly educated stimulate growth in country i ?

The following corollaries of Proposition 1 provide the answers to these questions:

Corollary 1 *A brain drain can be beneficial to country i if and only if $\psi_i^m(0; \chi_i^h; \epsilon_i^h) > \tilde{H}_i(1 - \tilde{H}_i)$*

Proof. This condition implies that the numerator of (9), evaluated at $m_i = 0$, is positive. This is a sufficient (but not necessary) condition ■

Providing this latter condition holds, a small brain drain (i.e., a sufficiently small positive migration probability for the highly educated), stimulates growth in country i , as compared to the closed-economy case.

Corollary 2 *The net growth effect of the brain drain is measured by $\Delta g_i = \gamma(hum_i; \chi_i^g; \epsilon_i^g) - \gamma(\tilde{H}_i; \chi_i^g; \epsilon_i^g)$*

Proof. Obvious when comparing the growth rates with and without migration ■

Corollary 3 *A marginal increase in the migration probability of the highly educated is beneficial to country i if and only if $\psi_i^m(m_i; \chi_i^h; \epsilon_i^h) > \frac{H_i(1-H_i)}{1-m_i}$*

Proof. This condition implies that the numerator of (9) is positive at the current observed migration rate ■

Since the empirical relevance of these conclusions strongly depends on the quality of the data on human capital formation and migration, we now turn to data and specification issues before presenting the results of the estimation procedure.

3 The brain drain estimates

As explained above, empirical evidence on the growth effects of the brain drain has so far been hampered by the lack of reliable data on migration rates per skill levels for a large set of countries and periods. The use of gross migration rates, as in Beine *et al.* (2001), generated interesting preliminary results, but subject to some important limits. In particular, the implicit assumption that emigration rates are equally distributed across educational levels may be questioned. As argued previously, indeed, increasingly quality-selective immigration policies in OECD countries, combined with traditional self-selection effects, are likely to generate much higher migration rates for the highly educated. This point may now be addressed thanks to Carrington and Detragiache (1998). Their estimates of migration rates by educational levels are built for 61 developing countries and three educational levels: primary, secondary and tertiary education. A quick look at the CD migration data immediately reveals two interesting features. First, it is indeed the case that migration rates are higher for the highly educated, confirming that the probability of emigration strongly increases with educational attainments. Moreover, this also suggests that migration prospects are likely to play an important role when taking education decisions. Second, the

brain drain is a general phenomenon, at work for all types of developing countries (large and small) from all regions, and is of tremendous importance for some (notably Carribean) countries.

Carrington and Detragiache used three main statistical sources to construct their database, and had to rely on a number of assumptions to extrapolate some data as well. Since their data is so central in our research, we detail the procedure they used to obtain their figures, and then explain how we are trying to cope with some of the limits of their approach.

Basically, three steps can be distinguished in the construction of the CD data:

Step 1: Calculus of US immigration stock per country of origin and educational level (denoted by $I_{i,s}^{US}$) and non-US OECD immigration stock per country of origin (denoted by I_i^{Non-US})

This first step is based on the 1990 US census which provides detailed information on the US immigrants by country of origin (i) and educational level (s). Three education levels are distinguished: primary (0-8 years of schooling), secondary (9-12 years of schooling) and tertiary (13 years of schooling or more). This information is extrapolated from a 5 percent sample of the Census data and concerns individuals aged 25 or over so as to exclude most foreign students who are temporary residing in the USA. Summing over educational categories gives the total US immigration stock per country of origin: $I_i^{US} = \sum_s I_{i,s}^{US}$. Clearly, illegal immigrants cannot be counted, but this should not excessively distort the estimates for the highly educated.

The immigration stocks in non-US OECD countries are extracted from the "Trends in international migration" published by the OECD. It should be noted that the comparison with the US Census data is not perfect. OECD statistics do not report the educational attainment of migrants or their age. Moreover, for small countries, the estimates of non-US OECD immigration may be seriously understated since most receiving nations only record immigrants for the top five or ten immigrant-sending countries.

Step 2: Calculus of emigration stocks per country of origin and educational level (denoted by $I_{i,s}$)

To evaluate the total stock of emigrants for a country, and its distribution across educational levels, Carrington and Detragiache (1998) assume that non-US OECD immigrants from a given country are distributed across educational categories as do US immigrants from that country. This implies: $I_{i,s} = I_{i,s}^{US} + \frac{I_{i,s}^{US}}{I_i^{US}} I_i^{Non-US}$, which is a very strong assumption for developing countries for which the US is not an important migration destination. This problem is particularly pertinent if the US and the other destination countries differ substantially in their immigration policies on the issue of quality-selection. Finally, emigrants to non-OECD countries, such as the educated manpower that emigrated from many developing countries to the Gulf states, are not included in the data. This might lead in some countries to an under-estimation of the number of emigrants.

Step 3: Calculus of emigration rates per country of origin and educational level (denoted by $m_{i,s}$)

The last step is to evaluate the emigration rates by educational levels for each origin country. This is done by comparing the number of migrants from each educational category to the populations from which they are drawn (denoted by $N_{i,s}$). The emigration rate is then given by $m_{i,s} = \frac{I_{i,s}}{N_{i,s} + I_{i,s}}$.

Population sizes per educational category are computed from the Penn World Tables (total population size), the United Nations Demographic Yearbook (share of the population aged 25 and over), and the Barro and Lee data set on educational attainment. Three limits should be mentioned at this stage. First, for countries where data are not available, continent-wide averages have been imputed. Secondly, some mapping is necessary to reconcile the concepts of the Barro and Lee database with those of the Schooling Census used by Carrington and Detragiache. Finally, the emigrants are likely to be counted as part of the population size ($N_{i,s}$) of some home country. Thus, an alternative measure of the migration rate, *i.e.*, the ratio

I_{is}/N_{is} , offers an upper bound which can be compared to the lower benchmark bound presented above.

Table 1: Migration rate of skilled workers per country of origin

Code	Country	Brain drain (in %)	Migration rate (in %)	US Immigrants (in volume)	US Immigrants (in % of OECD)
PART A: Limited sample with highly reliable countries (30 countries)					
Guy	Guyana	77,5	14,5	61936	100,0
Jam	Jamaica	77,4	20,3	159913	61,0
Tat	Trinidad-Tobago	57,8	9,5	65810	100,0
Sal	El Salvador	26,1	11,3	263625	100,0
Gha	Ghana	25,7	0,4	12544	53,3
Pan	Panama	19,6	6,7	68583	100,0
Nic	Nicaragua	18,8	4,7	61168	100,0
Hon	Honduras	15,7	3	54346	100,0
Kor	South Korea	14,9	4,2	377940	36,0
Dom	Dominican Rep.	14,7	6,5	187871	96,7
Gua	Guatemala	13,5	3,4	127346	100,0
Mex	Mexico	10,3	7,7	2743638	100,0
Phi	Philippines	9	3,1	728454	71,6
CR	Costa Rica	7,1	2,4	28784	100,0
Pak	Pakistan	6,7	0,3	52717	35,2
Chl	Chile	6	1,1	36252	54,3
Col	Colombia	5,8	1,1	162739	96,9
Egy	Egypt	5	0,5	53261	50,6
Bol	Bolivia	4,2	0,7	18772	100,0
Ecu	Ecuador	3,8	1,9	89336	100,0
Uru	Uruguay	3,8	1,1	15716	100,0
Per	Peru	3,4	1	86323	87,1
Chn	China	3	0,1	404579	51,5
Arg	Argentina	2,7	0,6	64080	72,3
Ind	India	2,6	0,2	304030	44,1
Ven	Venezuela	2,1	0,4	22634	77,4
Par	Paraguay	2	0,2	4313	100,0
Indo	Indonesia	1,5	na	32172	90,5
Tha	Thailand	1,5	0,2	53118	87,6
Bra	Brazil	1,4	0,2	53904	44,0
Part B: Small countries with missing non-US immigration data (21 countries)					
Gam	Gambia	61,4	0,2	747	100,0
SL	Sierra Leone	24,3	0,3	4155	100,0
Fi	Fiji	21,3	3,6	11420	100,0
Ug	Uganda	15,5	0,1	5060	100,0
Ken	Kenya	10	0,1	8372	100,0
Moz	Mozambique	8,6	na	920	100,0
Mau	Mauritius	7,2	0,2	1100	100,0
Zam	Zambia	5	0,1	1613	100,0
Zim	Zimbabwe	4,7	0,1	3161	100,0
Cam	Cameroon	3,2	na	1694	100,0
Syr	Syria	3	0,7	27504	100,0
Les	Lesotho	2,9	na	160	100,0
Png	Papua-NG	2,2	na	480	100,0
Rwa	Rwanda	2,2	na	200	100,0
Malw	Malawi	2	na	381	100,0
Sud	Sudan	1,8	na	2496	100,0
CAR	Central African Rep.	1,7	na	160	100,0
Tog	Togo	1,3	na	460	100,0
Mali	Mali	0,9	na	220	100,0
Con	Congo	0,5	na	200	100,0
Ben	Benin	0,4	na	180	100,0
Part C: Countries with a share of US emigrants lower than 30% (8 countries)					
Tun	Tunisia	63,3	8,6	2816	1,1
Alg	Algeria	55	6,3	3904	0,6
Sen	Senegal	47,7	2,4	1370	2,0
Tur	Turkey	46,2	8,5	43605	1,9
SrL	Sri Lanka	23,6	0,8	8751	14,1
Mal	Malaysia	22,7	1,2	15261	18,2
SA	South Africa	7,9	0,4	22678	32,4
Ban	Bangladesh	2,5	0,1	12385	25,9

Source: Carrington and Detragiache (1998)

The distribution of the brain drain across developing countries

The brain drain data computed by Carrington and Detragiache (1998) gives us an idea of the stock, rather than the flows, of educated migrants. Moreover, since their estimates are available for 1990 only, time-series investigation is excluded. Table 1 summarizes the CD estimates for the variables we defined above: the share of emigrants among the highly educated ($m_{i,s}$), the global migration rate in percent ($\frac{I_i}{N_i+I_i}$), the total stock US immigrants (I_i^{US}), in volume and in percent of OECD immigrants ($\frac{I_i^{US}}{I_i}$), for 59 developing countries. As apparent from Table 1, we have chosen to split the CD sample into three sub-samples, which differ in terms of data quality.¹⁰ Part A lists the countries for which information is most reliable, that is, for which the US is a major migration destination. The countries for which migratory flows to non-US OECD countries are either not available or underestimated are easily identifiable in the CD data set since they appear erroneously with 100% of their emigrants choosing the US as their destination. For some countries (e.g., Latin American countries), this may be a plausible approximation, and in this case these countries appear in Part A of Table 1; for other countries (e.g., sub-Saharan African countries), this is clearly implausible, and in this case these countries appear in Part B of Table 1. Finally, Part C contains the countries for which the US is clearly not the main emigration destination, that is, less than one-third of their emigrants choose the US as their destination.¹¹

4 Empirical analysis

To evaluate the "brain effect" described in equation (6), the gross formation of human capital between 1985 and 1990 ($\Delta H_i + d_H H_{i,lag}$) is expressed as a function of several explicative variables:

¹⁰See also Section 6.1 for additional justification for this selection procedure.

¹¹In the robustness analysis in Section 6.1., we also restrict the analysis to countries where this share is more than 50%.

- The expected foreign return to high education, whose weight depends on wage differentials and on the probability of migration; as explained in the theoretical section, this is assumed to be given, for country i , by the current proportion of migrants among the highly educated in their country, m_i ;
- The cost of acquiring education, which itself depends on public expenditures in education, denoted by $highex_i$ and $eduex_i$;
- Workers' remittances, rem_i , which may alleviate liquidity constraints impeding investments in human capital; in addition, in the absence of statistics on return migration, they also provide an indirect means of controlling for possible returns in subsequent periods, since preparing one's return is known to be a central motivation to remit;¹² and
- Other control variables; notably, we have used indicators of political tensions and ethnic diversity ($avelf$, $gunn1$ and $gunn2$), along the lines of Easterly and Levine (1997).

Two assumptions were made to facilitate the analysis. First, the depreciation rate of human capital, which expresses the proportion of educated people leaving the labor force during a given period (1985-90 in our case), has been set at 10%.¹³ Secondly, since migration rates by educational attainments are available for the year 1990 only, it is impossible to determine the exact value of $H_{i,Lag}$ and, therefore, to compute the investment in human capital, ΔH_i , in a direct manner. However, recall that the migration rates measure stocks rather than flows; for this reason, it seems reasonable to assume that the ratio H_i/hum_i did not change between 1985 and 1990.

¹²It is well recognized that remittances per head decline as migrants become more integrated in the host economy, although such a decline is only gradual (see, e.g., Funkhouser, 1995). Such a motivation, however, is less likely for the most educated, precisely because these are best integrated abroad.

¹³Computations with other possible values for the depreciation rate of human capital did not change the results much.

With these understandings, the basic equation of human capital formation may be written as:

$$\Delta H_i + d_H H_{i,lag} = \psi(m_i, rem_i, highex_i, gunn_i, eduex_i, avelf_i; \epsilon_i^h) \quad (10)$$

To evaluate the "drain effect" described in equation (7), we regressed the average growth rates over the period 1985-95 on a set of potentially explicative variables, such as:

- The ex-post human capital stock (that is, after migration has been netted out), $hum_{i,t}$, measured at the beginning of each period (*i.e.*, in 1985 and 1990);
- Indicators of the quantity of physical capital, like the number of telephones per worker ($phones_i$), as suggested by Easterly and Levine (1997);
- Workers' remittances, since these may also alleviate credit constraints impeding private investments in physical capital;
- Institutional indicators of ethnic diversity ($gunn2_i$) and political instability ($assass_i$), which were found to have significant growth effects in Easterly and Levine (1997);
- The log of initial GDP ($logy_{i,t}$) for each period so as to test for convergence over the period 1985-95;
- Regional dummies for Sub-Saharan African (ssa_i) and Latin American (lat_i) countries, which were found significantly related to growth performances in Easterly and Levine (1997).

The basic growth equation is therefore given by:

$$g_{i,t} = \gamma(hum_{i,t}, phones_i, rem_i, gunn2_i, assass_i, logy_{i,t}, ssa_i, lat_i; \epsilon_i^g) \quad (11)$$

where g_i denotes the average annual growth rate over the investigated period (1985-1995) in country i .

Note that we have two time-series observations for $g_{i,t}$, $logy_{i,t}$ and $hum_{i,t}$, allowing us to carry out a panel-data regression analysis; the rest of the explanatory variables are nevertheless time-invariant.

Table 2 indicates the symbols used for all the variables, their empirical counterparts, and the data sources.

Table 2: Variables definition and empirical counterparts

Variable	Definition	Empirical counterparts	Statistical sources
m	Migration rate of high skilled workers	Migration rate to OECD, tertiary schooling level - 1995	Carrington and Detragiache (1998)
diff	GDP differential with OECD countries	GDP differential with respect to average G7 countries - 1990	Chelem Database- OECD
dens	Population density	Population density - 1990	World Bank
hum	Ex-post proportion of highly educated	Highest school attainment in % of total population - 1990	Barro and Lee (1993) data set
humlag	Lagged ex-post proportion of highly educated	Highest school attainment in % of total population - 1985	Barro and Lee (1993) data set
eduex	Public expenditures in education	Public expenditures in education in % of GDP - 1980	United Nations (1997)
highex	Share of expenditures - higher education	Expenditures in higher education in % of total expenditures - 1990-94	United Nations (1997)
gdp	GDP per head level	Level of GDP per head in PPP units - 1990-1980	Chelem Database- OECD
g	Growth rate	Growth rate of GDP per head in PPP units - average 1985-1995	Chelem Database- OECD
rem	Workers' remittances	Workers' remittances in % of GDP- 1990	IMF-IFS database
elife	Life Expectancy at birth	Life expectancy - 1992	World bank
avelf	Composite indicator of ethnic diversity	Based on 5 measures of ethnic diversity	Easterly and Levine (1997)
gunn1	Indicator of ethnic diversity	Population in % not speaking the official language - 1991	Gunnemark (1991)
gunn2	Indicator of ethnic diversity	Population in % not speaking the most widely used language - 1991	Gunnemark (1991)
demc	Indicator of democracy	Measure of democracy - 1980	Gastil (1990)
racial	Indicator of racial tension	Racial tension - 1984	The International Country Risk Guide
assass	Indicator of political stability	Number of political murders per 1000 inhabitants - 1980-89	Banks (1994)
purges	Indicator of political stability	Systematic elimination of political opponents - 1980-89	Banks (1994)
warciv	Indicator of political stability	Civil war, dummy variable - 80s	Sivard (1993)
road	Indicator of infrastructure	Paved roads in % of total	Easterly and Levine (1997)
phone	Indicator of technology	Log of telephones per 1000 workers	Easterly and Levine (1997)
spread	Indicator of financial efficiency	Interest rate spread (lending minus deposit rate) - 1990	World Bank (2000)
pop	Population	Population - 1990	United Nations (1997)
Sub-saharian	Dummy for Sub-saharian African countries	-	-
Latin America	Dummy for Latin American countries	-	-

4.1 Econometric issues

Before we carry out the estimations, we first address some specification issues.

A first important question concerns the exogeneity of the migration probability

used in the econometric analysis. Indeed, in the attempts to determine the impact of migration on education, one has to control for the reverse effect since, on average, a large share of educated agents is likely to cause higher migration rates (this is particularly the case when there is an excess supply of highly skilled in the source country). For this reason, the exogeneity of the migration probability is highly questionable. In an attempt to cope with this issue, recent empirical growth analyses have been concerned with the use of truly exogenous instruments.¹⁴ Along the lines suggested in these studies, the following variables have been selected for our instrumentation procedure: the population density in the source country ($dens_i$) as a proxy for soil occupation, and life expectancy at birth ($life_i$) as a proxy for general living conditions. Another potential instrument variable is the country's population size (pop_i). This choice stems from a basic feature of the immigration policy of the United States in the past, which was based on a quota system. Although such quotas do not exist any more, one may suspect that in practice, immigration restrictions are less binding for small countries, as found by Beine *et al.* (2001). Consequently, population size may serve as a useful instrument in the first-stage emigration equation. Furthermore, racial tensions ($racial_i$) were also taken into account, as well as the (log of the) stock of migrants of the origin country in OECD countries ($lstock_i$). The latter variable is expected to display a positive relationship with migration flows: a higher initial stock of immigrants (better migration networks) is generally assumed to reduce migration (especially information-related) costs and, therefore, would be expected to increase the number of future migrants (Carrington *et al.*, 1996).

All these instruments have been tested in our procedure.¹⁵ Life expectancy at

¹⁴See for instance Hall and Jones (1999).

¹⁵In addition, as shown in Barro and Sala-I-Martin (1995), the GDP per capita of the source country, expressed as a proportion of the average GDP per capita of the G7 countries ($diff_i$), is a good proxy for wage differentials which are supposed to influence the migration rate. However, one may question the exogeneity properties of such an instrument with respect to the human capital stock; as a crude test, the correlation between $diff_i$ and H_i is above 0.5, indicating that the use of this variable as an instrument may give rise to some problems. Therefore, we did not use this variable in our instrumentation procedure.

birth did not prove to be a reliable instrument for our estimations. By contrast, $lstock_i$, pop_i and $racial_i$, were found to be significantly related to m_i .¹⁶

To assess the relevance of our instrumentation procedure, we report the results of the OLS regression of the migration equation for the full sample on the four instruments retained (t-statistics are reported between brackets):

$$\begin{aligned}
 m_i &= -0.082 + 0.061 lstock - 0.003 dens_i - 0.098 pop_i - 0.036 racial_i \quad (12) \\
 &\quad (-0.79) \quad (5.90) \quad (-0.16) \quad (-6.40) \quad (-2.89) \\
 R^2 &= 0.561 \\
 Nobs &= 50
 \end{aligned}$$

Regardless of the measure retained for migration rates (lower or upper bound),¹⁷ the four instruments were found significant at a 10% significance level in the full sample, except $dens_i$. Together, they account for more than 56% of the migration variability, which is quite satisfactory in a cross-section perspective. Note that population size enters with a negative sign; this supports the conjecture mentioned above, according to which immigration quotas are binding for larger countries. In turn, this further justifies the assumption that education decisions are taken in a context of uncertainty regarding future migration opportunities, as posited in our theoretical model. Finally, note also that the signs of $racial_i$ and $lstock_i$ are in keeping with intuition: greater racial tensions and a higher initial stock of migrants both stimulate emigration.

4.2 Full-sample estimation results

We now turn to the estimation of our basic system (equations (10)-(11)). The first equation is estimated through instrumental variables, while the second equation is

¹⁶Population density ($dens_i$) turned out to be significant only for a subset of countries (see Section 6), but not in the full sample. Therefore, we kept it in the instrumentation procedure throughout the analysis.

¹⁷The results using the upper bound are not reported here but are available upon request.

estimated by panel OLS regression.¹⁸ The number of instruments (including a constant) and explanatory variables imply that equation (10) is just-identified. In both equations, the constant term turned out to be non-significantly different from zero and therefore was dropped.

Our full (unadjusted) sample covers 59 developing countries, which represent about one-half of the total number of developing countries, but nearly 90% of the total population living in developing countries. Moreover, a quick glance at the list of countries reveals that these are more or less equally distributed across regions, thus ensuring the representativeness of the sample. Because the values for the variables $racial_i$ and $gunn2_i$ are not available for some countries, the full sample for the estimation of equations (10)-(11) is restricted to 50 countries.

The estimation results are given in Table 3a (for the human capital equation) and Table 3b (for the growth equation).

Table 3a : Estimation results

Dependent variable=Gross investment in human capital. Full Sample

Variable	(1)	(2)	(3)	(4)
<i>m</i>	0.054 [5.597]	0.051 [5.742]	0.053 [5.794]	0.051 [9.729]
<i>avelf</i>	-0.007 [-2.263]	-0.008 [-2.230]	-0.003 [-0.541]	-0.008 [-3.486]
<i>rem</i>	-	0.051 [0.675]	0.103 [1.178]	0.030 [0.960]
<i>highex</i>	-	-	0.002 [0.754]	-
R^2	0.731	0.732	0.735	0.661
<i>Nobs</i>	50	50	50	59

Notes:

a) Between brackets, T-statistics

b) Columns 1 to 3 :Instrumental variable estimation , Four instruments and a constant

c) Instruments : population size, population density, racial tensions, stock of migrants in OECD countries

d) Column 4 : OLS

Table 3a provides the estimation results for the human capital equation. Column

¹⁸Since the two equations share some common regressors, another candidate estimation technique is the seemingly unrelated regressions (SURE). Using SURE, we obtained fairly similar point estimates and significance levels.

(1) reports the estimation results obtained with ethnic diversity as the only control variable. Column (2) reports the estimation results obtained when adding workers' remittances as a control variable. As apparent from Table 3a, workers' remittances turned out to be insignificant in the human capital equation, at least for the full sample. However, workers's remittances were found to be significant for the sub-samples.¹⁹

Most importantly, Table 3a shows that the coefficient of the migration rate (the empirical counterpart of ψ_i^m) is highly significant and positive. This strongly supports the main empirical conclusion formulated by Beine *et al.* (2001), according to which the net effect of migration on human capital formation is positive, but, this time, with much better data. Depending on the specification, the value of the coefficient lies between 5.1% and 5.4%. It should be emphasized that this estimated value is rather stable across specifications (Columns 1 to 3) and across estimation methods (instrumental variables or OLS).

In line with the findings of Easterly and Levine (1997), the effect of ethnic diversity on human capital formation is found to be negative and significant. Finally, the share of public expenditures in higher education was found to be positive but not significant (see Column 3); however, one should be taking this latter result with caution since the definitions of H_i and $highex_i$ are not fully consistent.²⁰

Table 3b reports the estimation results for the growth equation. This equation is estimated over the 1985-1995 in a panel regression framework. Using panel data provides at least two main advantages as compared to pure cross-section analysis. First, pooling time-series data and cross-section data increases the number of observations. Secondly, and more importantly, panel analysis allows us to account for unobserved heterogeneity. Such an heterogeneity may play an important role in growth analy-

¹⁹For the two sub-samples selected in Section 6 on the ground of data quality for migration rates, workers' remittances turn out to be significant at the 10% level, suggesting that liquidity constraints are indeed binding in some developing countries.

²⁰Note that the choice of IV estimation method prevents the estimation of equation (10) with more than five explanatory variables.

sis: indeed, introducing individual effects in the growth regressions tends to explain an important part of the variability of growth performances across countries. We consider two time-series observations (average growth between 1985 and 1990 on the one hand, and between 1990 and 1995 on the other hand). These observations are available for 50 countries. We build on earlier work by Easterly and Levine (1997) for choosing the basic specification. In particular, we account for possible catching-up effects à la Barro and Sala-I-Martin through the introduction of the (log of) initial income. We also introduce Sub-Saharan and Latin America dummies that were found highly significant in the growth equations of Easterly and Levine (1997). Since we use time-invariant explanatory variables, the model is estimated with random individual effects.

As expected, the results show that an increase in the level of human capital tends to favor GDP growth. It is worth noting that this positive effect turns out to be very robust across various specifications. Depending on the specification, the impact of the proportion of the highly educated in the population (in logs) on the average growth rate of the GDP per capita ranges from 0.020 to 0.024. This is consistent with the results obtained by Easterly and Levine (1997), who measured human capital through a country's general school attainment. Regardless of the specification, this positive growth effect of human capital is significant at the 5% level. This is also the case for the proxy variable for physical capital ($phones_i$) at the 10% level. The results also support the presence of a convergence process over the period 1985-95 through the negative and significant effect of initial income. This convergence effect is also very robust across regressions. By contrast, the introduction of other control variables (such as political instability, ethnic diversity, or regional dummies) does not seem to increase the explanatory power of the growth regressions. Finally, it should be emphasized that, as expected, individual effects explain a significant part of the growth variability across countries: similar regressions that we carried out over the same countries in a pure cross-section framework turned out to give a R^2 value of

about 30%, whereas in our panel analysis, this value is close to 80%.²¹

Table 3b : Estimation results
Dependent variable=growth of GDP per head (g). Full Sample

Variable	(1)	(2)	(3)	(4)
<i>Log(hum)</i>	0.0204 [2.01]	0.0232 [2.25]	0.0232 [2.24]	0.0239 [2.31]
<i>Log(initial income)</i>	-0.0254 [-2.02]	-0.0255 [-2.03]	-0.0270 [-2.15]	-0.0278 [-2.24]
<i>Log(Phones)</i>	0.1463 [1.80]	0.1433 [1.77]	0.1431 [1.89]	0.1251 [1.71]
<i>rem</i>		0.3234 [0.393]		0.4570 [0.683]
<i>gunn2</i>		-		0.0803 [0.837]
<i>assass</i>				-0.00002 [-0.303]
<i>Sub-saharian</i>			0.0845 [1.38]	0.0569 [0.863]
<i>Latin America</i>			-0.0118 [-0.172]	0.0085 [0.123]
<i>R²</i>	0.779	0.780	0.782	0.782
<i>Nobs</i>	100	100	100	100

Note : Panel Regression; Random individual effects ; time series observation : 1985-1990 and 1990-1995; 50 countries

5 Country-specific implications

The estimation results obtained in the previous section may be used to compute the country-specific effects of the brain drain. Along the lines suggested in the theoretical model (Corollaries 1 to 3), we compare a country's current growth performance to its predicted performance under autarky (when setting the migration rate at zero), and sign the growth effect of a marginal increase in the migration probability of the highly educated, both at the current level of migration and in the no-migration virtual case.

This allows us to address three distinct questions: i) Can a brain drain constitute a growth-enhancing opportunity?; ii) Should the brain drain be greater or smaller than its current level? and, iii) Who wins, who loses, and how much?

Our analysis is restricted to the 30 countries shown in Part A of Table 1, that is,

²¹The cross-section regression results are available from the authors upon request.

for which the CD data are most reliable.

5.1 Can a brain drain constitute a growth-enhancing opportunity?

Can a (sufficiently) small brain drain stimulate growth in the source country? To address this issue, we use Corollary 1 and compare the effect of a marginal increase in the migration probability (ψ_i^m evaluated at $m_i = 0$) to the country-specific value of $\tilde{H}_i(1 - \tilde{H}_i)$. Note that our linear specification of the human capital equation (10) implies that the marginal effect of the migration probability is constant and equals 0.051 (see column 2 in Table 3, part A). However, the predicted stock of human capital in the no-migration economy depends on country-specific variables and should, therefore, be computed for each country.

This is apparent from Figures 3.1 and 3.2, where the white areas measure the values of $\tilde{H}_i(1 - \tilde{H}_i)$, renamed $B0(i)$ in the legend, for each country. Countries for which the $B0(i)$ bound is lower than the critical value 0.051 are those for which the brain drain may stimulate growth (as compared to the no-migration solution). The figures clearly show that for 14 countries (about 47% of the sub-sample but 85% of its total population), there is a clear interest in allowing (at least some of) their highly educated citizens to emigrate. This is the case, in particular, for countries such as Indonesia, Ghana, China, Pakistan, Guyana, Jamaica or Trinidad-Tobago, which are all characterized by a very low proportion of highly educated within the population (formally, the value of hum is less than 2% in all of these countries). On the contrary, countries for which the value of hum is above 5% (and which may therefore be described as having a relatively performant educational system), such as Ecuador, Korea, the Philippines, or Costa Rica, would benefit from a total ban on emigration.

5.2 Should the brain drain be larger or smaller?

To address this second question, we examine whether some countries may benefit from a marginal increase in the migration probability of their highly educated above its current level. Using Corollary 3, we determine whether $\psi_i^m(m_i; \chi_i^h; \epsilon_i^h) > \frac{H_i(1-H_i)}{1-m_i}$. Given our linear specification of the human capital equation, the critical value ψ_i^m is the same as in the previous subsection (0.051). For each country, the value for the bound $\frac{H_i(1-H_i)}{1-m_i}$, renamed $B1(i)$ in the legend, is reported on Figures 3.1 and 3.2. It is apparent from these figures that a country would gain from increasing the magnitude of the brain drain when the bound $B1(i)$ is below the critical value 0.051. Using this criterion, the sample is divided between two distinct groups. Figure 3.1 gathers countries which would gain by increasing the migration probability of their highly educated, while Figure 3.2 gathers countries which would gain by reducing it.

Only 9 countries, less than one-third of the sample, are in the first group. However, this group includes the countries with the greatest demographic size (China, India, Indonesia, Brazil and Pakistan). By contrast, the second group comprises 21 countries of small and medium demographic size. These include the countries already mentioned in sub-section 5.1 as being potentially better-off under autarky (17 countries), and which combine a relatively performant educational system with relatively low migration rates. These also include 4 additional Caribbean or Central American countries (El Salvador, Guyana, Jamaica and Trinidad and Tobago), which combine a relatively poor educational system with extremely high migration rates (26%, 77%, 77.5% and 56% respectively).

Figure 3.1 : Growth effect of a marginal increase in brain drain
(countries with a positive effect evaluated at the current migration rate)

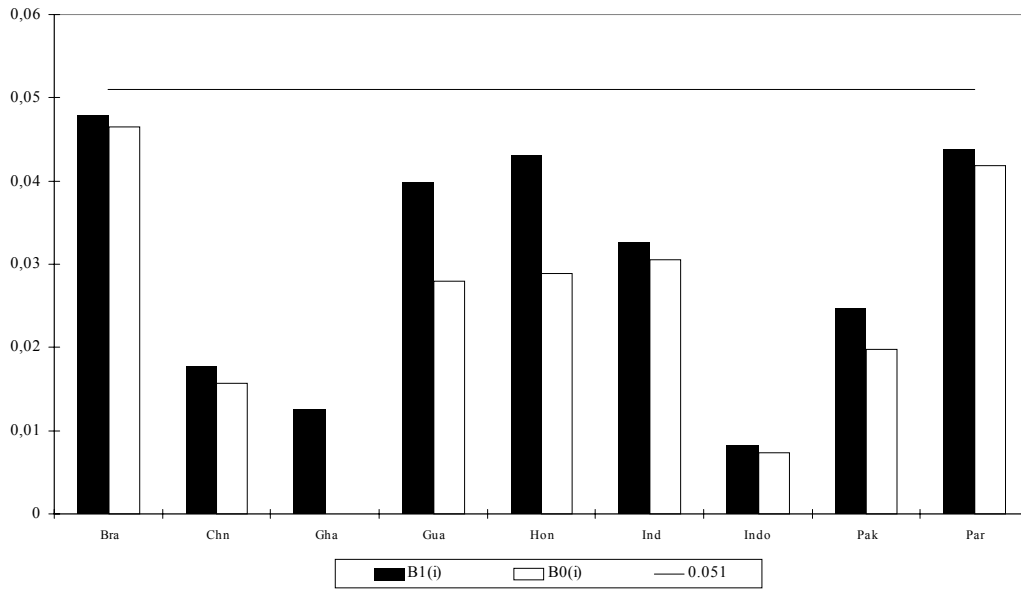
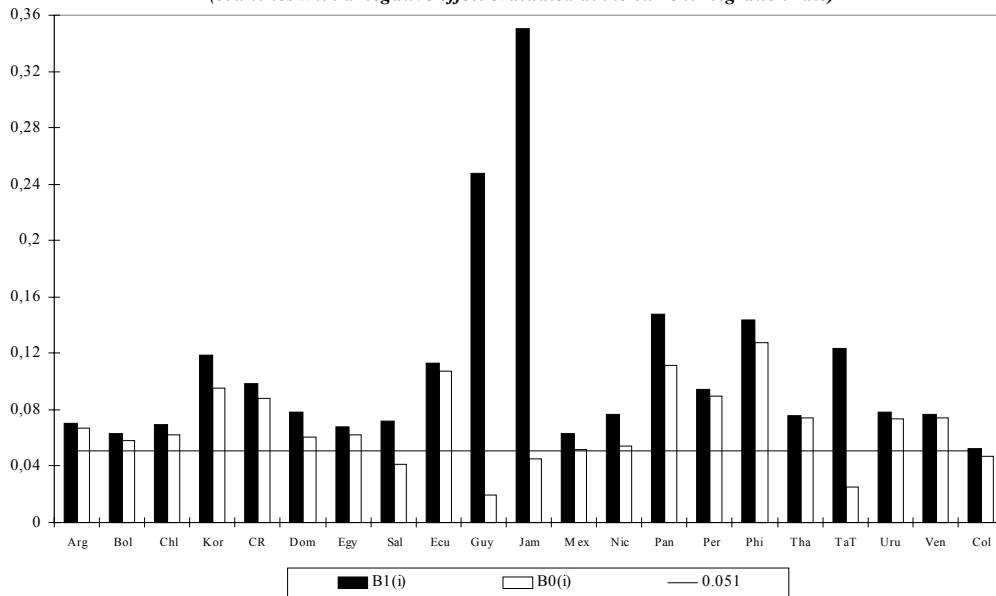


Figure 3.2 : Growth effect of a marginal increase in brain drain
(countries with a negative effect evaluated at the current migration rate)



In conclusion, the set of countries for which an increase in the magnitude of brain drain would be beneficial for growth typically includes countries with low current migration rates (i.e., below 20%) and low current levels of human capital (i.e., below 5%). These conditions are verified in a very limited number of cases but concern the biggest countries in terms of demographic size.

5.3 Who loses, who wins, and how much?

This third question may be dealt with by using Corollary 2. Instead of computing the effect of a marginal increase in the brain drain, we now compute each country's predicted growth performance if the migration rate was set to zero, and compare it to its current (or observed) economic performance. Figure 4.1 reports the net positive gains of the winners, and Figure 4.2 the net negative losses of the losers, respectively. Given the logarithmic specification used for equation (11), it is impossible to compute this effect for countries where \tilde{H}_i equals zero. Note also that, for countries which have very poor educational attainments, the procedure we use could lead to an overestimation of their growth gains. To avoid such cases, we exclude from our computations the countries for which either $\tilde{H}_i = 0$ or $hum_i < 1\%$.

Not surprisingly, countries that incur important losses are those which have very high migration rates. Nevertheless, it should be emphasized that the magnitude of the losses and gains, expressed in terms of annual growth rate of the GDP per capita, remains relatively limited for most countries. Notable exceptions are Jamaica and Guyana, which have extremely high migration rates. Except for these two countries, the net variation of the growth rate in terms of output per capita is always lower than 0.20% per year. This is certainly not negligible in a long-run perspective, but indicates that the growth effects of the brain drain have perhaps been overstated in previous research.

Figure 4.1 : net growth gain (% of annual GDP per head)

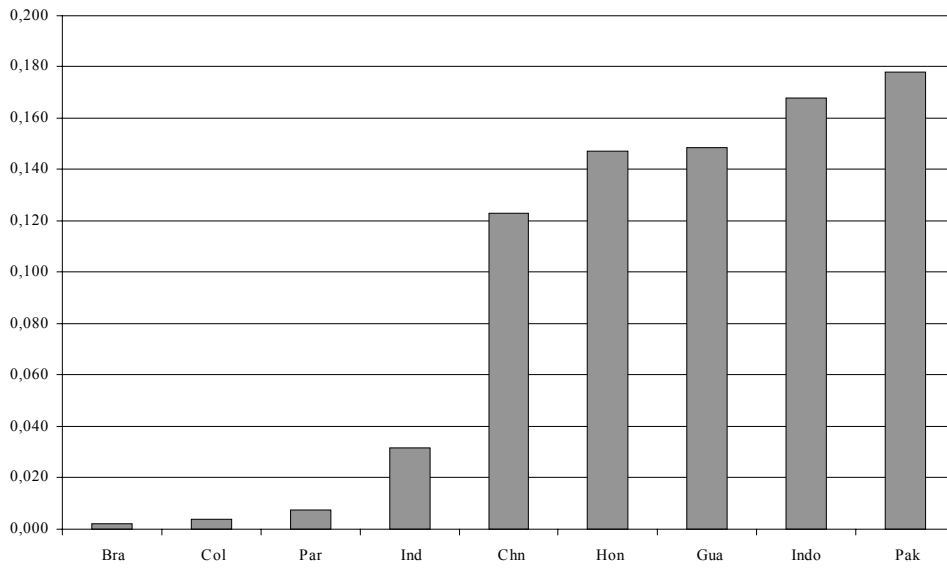
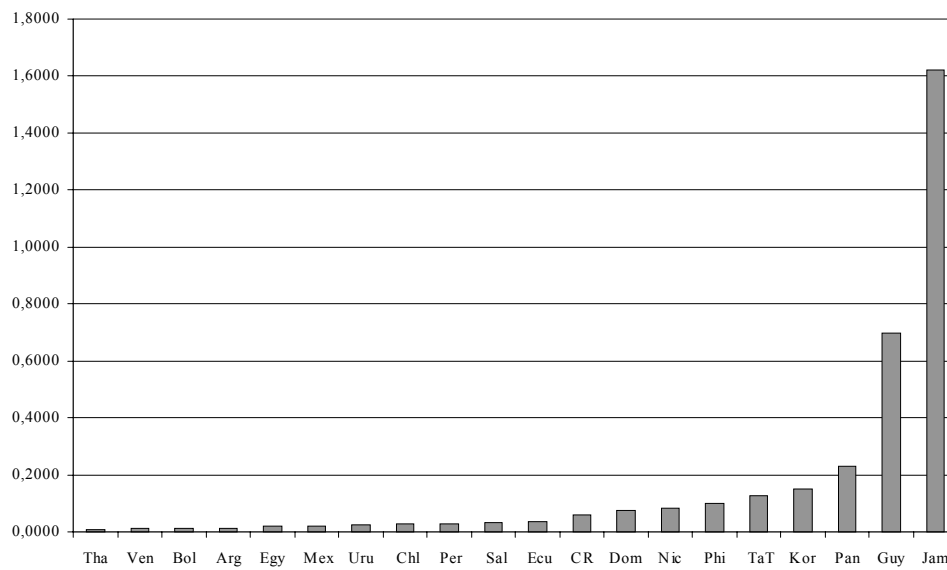


Figure 4.2 : growth net losses (% of annual GDP per head)



6 Robustness analysis

The computation of the net growth effects of the brain drain and the identification of losers and winners rests on the estimation of the derivative ψ_i^m , the coefficient of m_i in the human capital equation. Since this estimate is so central to our analysis, we dedicate this section to a robustness analysis of our conclusions. Toward this end, we extend our econometric approach in two directions:

- We first consider three sub-samples of countries, selected on the grounds of the (increasingly selective) quality of the data on their migration rates.
- We then extend our basic specification for the human capital equation by allowing for non-linear growth effects of migration, as suggested in Beine *et al.* (2001).

6.1 Selected samples

As explained above, our estimates are based on the indicators computed by Carrington and Detragiache (1998). Recall that these were obtained by assuming that, for each country, the educational structure of its emigrants could be extrapolated from that observed for the US. The validity of this assumption is highly questionable for countries where the proportion of emigrants to the US is low, that is, for which the US is not the main emigration destination. To address this issue, we restrict our sample by dropping countries with poor quality data. For this purpose, we use a two-step procedure.

First, we drop from the sample the countries for which the data provided by CD is obviously misleading. As noticed by Carrington and Detragiache (1998, note 14 p. 20), "for a number of small countries, migratory flows to non-US OECD countries may be underestimated, because the reporting system of some receiving countries provides country-of-origin information for migrants from major sending countries [only]". As a result, a number of small countries appear in their data (see Part A of Table 1)

with 100% of their immigrants to OECD countries choosing the US as destination. This is obviously erroneous and simply indicates the lack of data on immigrants by country of origin in some non-US OECD countries. For Central and South American countries, however, a rate of 100% of immigrants to OECD countries choosing the US may approximate the reality,²² while this is clearly not the case for small African countries (whose main destination is the EU) and, to a lesser extent, for countries from Asia and the Pacific, whose emigration destinations are relatively diversified. Applying this rule yields a sub-sample of 38 countries, after the exclusion of Fiji, Papua New Guinea, Syria, and 18 out of 23 African countries (see Table 1).

Second, we exclude from the sample the countries for which the proportion of emigrants to the US is lower than a given threshold. We consider two possible thresholds: one-third, and one-half.²³ The application of this rule leads to the exclusion of 12 (8+4) additional countries, yielding sub-samples of 30 and finally 26 countries.

Table 4 presents the estimation results of equation (10) for these three sub-samples, using a specification that includes ethnic diversity and workers' remittances, which turned out to be significant in some subsamples. In addition, columns (4) and (5) report alternative results obtained for the same specification as in column (1), but with either a different value for the depreciation rate of human capital, d_H (15% instead of 10%) (Column 4), or using OLS estimations instead of IV estimations (Column 5).

²²For example, Zlotnik (1998) notes that "the United States is the major destination of migrants from throughout Latin America and the Caribbean ... [while] the presence of Latin Americans in other regions remains limited" (p. 464).

²³This is in fact the "rule of thumb" proposed by Carrington and Detragiache (1998) to ensure the quality of their data.

Table 4 : Estimation results - Robustness analysis

Dependent variable=Gross investment in human capital. Adjusted samples

Variable	(1)	(2)	(3)	(4)	(5)
<i>m</i>	0.049 [5.613]	0.048 [4.161]	0.044 [3.564]	0.054 [6.201]	0.060 [7.542]
<i>avelf</i>	-0.010 [-1.786]	-0.013 [-2.222]	-0.012 [-1.529]	-0.007 [-1.432]	-0.012 [-2.030]
<i>rem</i>	0.083 [1.141]	0.134 [1.461]	0.171 [1.727]	0.115 [1.787]	0.032 [0.818]
R^2	0.725	0.606	0.564	0.756	0.702
<i>Nobs</i>	38	30	26	38	38

Notes :

a) Between brackets, T-statistics

b) Columns 1 to 4 Instrumental variable estimation , Four instuments and a constant

c) Instruments : population size, population density, racial tensions, stock of migrants in OECD

d) Column 4 : Depreciation rate of human capital set to 15% instead of 10%

e) Column 5 : OLS estimation

On a whole, our conclusions regarding the impact of migration on human capital formation remain fairly similar when restricting the sample to ensure a higher quality of the migration data. Depending on the sub-sample and the specification used, the estimated coefficient of ψ_i^m is between 4.4% and 6.0%, which is in line with the results obtained with the full sample (Table 3a). It is worth pointing out that when using the sub-samples, the positive effect of workers' remittances turns out to be significant at a 10% level, whereas public expenditures on high education remain non-significant.

6.2 Allowing for non-linear effects

Previous studies (e.g., Mountford, 1997, Beine *et al.*, 2001) predicted non-linear effects of migration prospects on human capital formation. More precisely, these theoretical models reveal that a net positive effect of the brain drain should be observed mostly in the poorest countries. The essence of the argument is that in such countries, the incentives to invest in human capital are extremely low, unless substantial outside options are offered to prospective students. Using gross migration rates as a proxy for the brain drain, the empirical evidence documented in Beine *et al.* (2001) supported that prediction for a cross-section of 37 developing countries.

In this section, we test for such non-linear effects. To address this issue, we propose

the following specification for the human capital accumulation equation (10):²⁴

$$\Delta H_i + d_H H_{i,lag} = b_0 + b_1 m_i + b_2 (dev_i * m_i) + b_3 avel f_i + v_i \quad (13)$$

where dev_i is a dummy variable which equals 1 if country i is under a given threshold in terms of GDP per capita (see below), and equals 0 otherwise.

This specification involves a non-linearity in the variables; if additional effects are present for relatively less developed countries, the coefficient b_2 should be positive and significant. An important point concerns the choice of the threshold to be retained, and the underlying economic variable on which the threshold is based. Here, we report the results obtained using the level of GDP per capita in 1990 (gdp_i) as the underlying variable for which the threshold is defined, but very similar results were obtained using the level of education in 1990 (hum_i) or the UNDP composite indicator of human development (Human Development Report, 1997).²⁵

Given that there is one additional explanatory variable in the human capital equation, it is necessary to include more than three instruments (and a constant) for the equation to be identified. Therefore, in order to keep an overidentified equation, we used one additional instrument, $avel f_i$.

We first set the threshold value for the GDP per capita (in PPP value) at 1000 US\$, obtaining an almost perfect division into two of the full sample (24 countries out of 50 below that threshold). Decreasing the value of the threshold to 600 US\$ lead to a sub-group of 18 countries for lower GDP per capita, and a further decrease to 400 US\$ gives a sub-group of only 11 countries. Table 5 reports the estimation results obtained for these different thresholds.

In contrast to Beine *et al.* (2001), Table 5 shows no evidence of non-linear effects of migration on human capital formation, whatever the threshold considered. In other words, the poorest countries do not seem to benefit from additional positive effects.

²⁴This specification is similar to that proposed by Beine *et al.* (2001).

²⁵These results are not reported here but are available upon request.

For these countries indeed, the coefficient of m_i remains significantly positive, and its value is quite similar to that reported in Table 3a. Rather, this stresses the robustness of the results to different specifications, thus confirming the previous results obtained with a linear specification.

Table 5 : Estimation results - Robustness analysis

Dependent variable=Gross investment in human capital. Nonlinear effects

Variable/ Threshold	<i>gdp=1000</i>	<i>gdp=800</i>	<i>gdp=600</i>	<i>gdp=400</i>
<i>m</i>	0.054 [6.106]	0.054 [5.832]	0.058 [6.366]	0.062 [6.605]
<i>dev m</i>	0.066 [1.296]	0.071 [1.169]	0.075 [1.070]	0.124 [1.076]
<i>avelf</i>	-0.011 [-1.978]	-0.011 [-1.869]	-0.010 [-1.973]	-0.011 [-1.885]
R^2	0.534	0.492	0.608	0.593
<i>Nobs</i>	50	50	50	50

Notes :

a) between brackets, T-statistics

b) Columns 1 to 4 Instrumental variable estimation , Four instruments and a constant

c) Instruments : population size, population density, racial tensions, stock of migrants in OECD countries

7 Conclusion

In this paper, we provide further empirical evidence to support the "beneficial brain drain" hypothesis at the aggregate level. Using recent migration data by education levels computed by Carrington and Detragiache (1998), we showed that migration prospects exert a positive effect on human capital formation for a cross-section of 50 developing countries. This conclusion is robust to the choice of a variety of specifications used in our analysis: different control variables in the human capital equation, instrument variables to account for the endogeneity of the migration rate, quality of the measurement of these rates by educational attainment, and choice of a linear versus a non linear specification to test for additional effects in the poorest countries. As a whole, our results confirm the findings of Beine *et al.* (2001), but with a larger sample and much better data.

Another notable innovation of this paper is the computation of the growth effects of the brain drain for individual source countries. On the basis of our estimates,

we identified the countries gaining or losing from the brain drain, comparing their respective gains and losses in terms of annual GDP growth. We found that most countries combining low levels of human capital and low migration rates of skilled workers are positively affected by the brain drain. By contrast, the brain drain appears to have negative growth effects in countries where the migration rate of the highly educated is above 20%, and/or where the proportion of highly educated in the total population is above 5%. While there are more losers than winners, it is striking that the latter include the biggest countries in terms of demographic size, representing nearly 80% of the total population currently residing in the developing countries.

These results suggest that the traditional perception of the brain drain, often viewed as a kind of predation whereby rich countries extract the most valuable human resources from the poor countries, has no empirical justification at an aggregate level. The simple fact that, among the sending countries, there are winners and losers, points to the necessity of a better understanding of the circumstances and factors favoring the beneficial brain drain. Further empirical research is therefore required before policy implications may be derived for sending as well as receiving countries. From this perspective, we see two major possible extensions for this research. The first direction would be to improve the analysis so as to better distinguish between the main potentially positive aspects of the brain drain. As underlined in the introduction, alongside the incentive to acquire education, on which we focused here, such positive channels include remittances, return migration of skilled professionals, and the creation of business networks. While we controlled for the impact of remittances, we were unable to control directly for the other two possible sources. Nevertheless, we have some reasons to believe that these other possible growth effects of the brain drain are small, at least for the period covered in our study. First, although there is no comparative data on return migration, there are many case-studies suggesting that reverse migration is negligible for the highly skilled unless it is preceded by

sustained economic growth.²⁶ As for the creation of trade and business networks, it is not clear how such networks affect human capital formation and, in any case, such positive aspects of globalization would seem to be more relevant for the 1990s than for the 1980s, which is the period covered in our study. A second possible extension of this research, therefore, would be to expand its time-horizon, so as to test for possible dynamic effects of the brain drain associated with network activation and/or reverse migration flows.

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²⁶For example, Kwok and Leland (1982) indicate that only 6,000 out of the 50,000 college graduates who left Taiwan during the period from 1960 to 1979 returned during that period. The experience of South Korea is also interesting. Despite the incentives offered to qualified returnees, less than 10% of the Korean Ph.D. graduates from foreign universities returned home during the 1970s. Since the mid-1980s, this situation has changed and most Ph.D. graduates (around two-thirds) now tend to return, but it is clear that in the case of Korea, economic growth preceded rather than resulted in this reverse flow (Song, 1992). For China and India also, return flows appear marginal. We know that the Chinese authorities were extremely concerned by the absence of returns among their expatriate students in the late 1980s (see e.g., Brooded, 1993), whereas in India, even in the field of IT, whose recent development is often magnified as an example of industrial success, it seems that the number of returning engineers is too small to make an impact (Saxenian, 2001, p. 26).

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