Globalization, Brain Drain and Development

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Abstract

This paper reviews four decades of economics research on the brain drain, with a focus on recent contributions and on development issues. We first assess the magnitude, intensity and determinants of the brain drain, showing that brain drain (or high-skill) migration is becoming the dominant pattern of international migration and a major aspect of globalization. We then use a stylized growth model to analyze the various channels through which a brain drain affects the sending countries and review the evidence on these channels. The recent empirical literature shows that high-skill emigration need not deplete a country's human capital stock and can generate positive network externalities. Three case studies are also considered: the African medical brain drain, the recent exodus of European scientists to the United States, and the role of the Indian diaspora in the development of India's IT sector. We conclude with a discussion of the implications of the analysis for education, immigration, and international taxation policies in a global context.

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1 Introduction

The number of international migrants increased from 75 million in 1960 to 190 million in 2005, at about the same pace as the world population, meaning that the world migration rate increased only slightly, from 2.5 to 2.9 percent.[1] Over the same period, the world trade/GDP ratio increased threefold, rising from 0.1 to 0.2 between 1960 and 1990 and from 0.2 to 0.3 between 1990 and 2000; the ratio of FDI to world output, on the other hand, increased threefold during the 1990s alone. From these figures one might conclude that globalization is mainly about trade and FDI, not migration. However, the picture changes once the focus is narrowed to migration to developed countries and in particular its skilled component. As shown in Figure 1, the share of the foreign-born in the population of high-income countries has tripled since 1960 (and doubled since 1985). Moreover, these immigrants are increasingly skilled: while migration to the OECD area increased at the same rate as trade, high-skill migration (or brain drain) from developing to developed countries rose at a much faster pace[2] and can certainly be regarded as one of the major aspects of globalization. What are the causes of this brain drain at the international level, and what are its consequences for sending countries? This paper surveys four decades of economic research on this topic, with a focus on the more recent period.

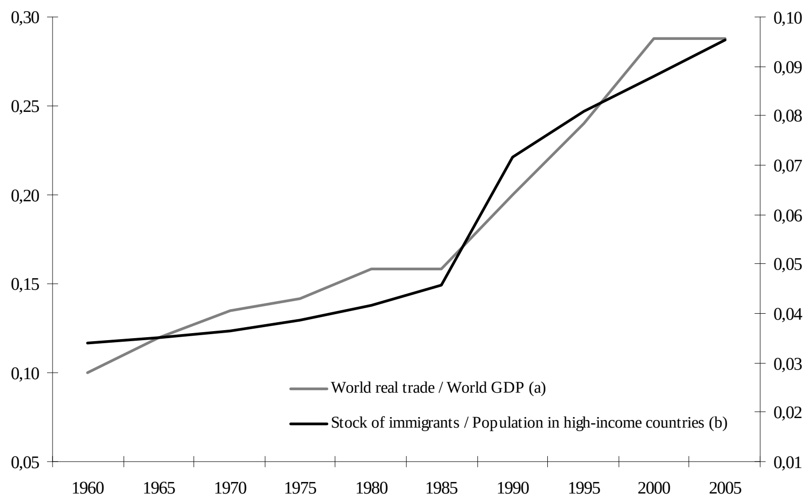
The first wave of economics papers on the brain drain dates back to the late 1960s and mainly consists of welfare analyses in standard trade-theoretic frameworks (e.g., Grubel and Scott, 1966, Johnson, 1967, Berry and Soligo, 1969). These early contributions generally concluded that the impact of the brain drain on source countries was essentially neutral and emphasized the benefits of free migration to the world economy. This was explained by the fact that high-skill emigrants often leave some of their assets in their country of origin, which complements remaining high- and low-skill labor (Berry and Soligo, 1969), as well as sending home remittances. This and other positive feedbacks compensate sending countries for any real loss the brain drain may cause. From a broader perspective, these studies (especially Grubel and Scott, 1966) emphasize high-skill migrants' contribution to knowledge, an international public good, and disregard "outdated" claims on the alleged losses for developing countries. The second wave comes less than a decade later. Under the leadership of Jagdish Bhagwati, a series of alternative models were developed in the 1970s to explore the welfare consequences of the brain drain in various institutional settings. Domestic labor markets rigidities, informational imperfections, as well as fiscal and other types of externalities (Bhagwati and Hamada, 1974, McCulloch and Yellen, 1977) were introduced to emphasize the negative consequences of the brain drain for those left behind. High-skill emigration was viewed as contributing to in-

[1] An increase mostly due to the dislocation of the former Soviet Union. See Ozden et al. (2011).

[2] The number of highly educated immigrants living in the OECD member countries increased by 70 percent during the 1990s (and doubled for those originating from developing countries) compared to a 30 percent increase for low-skill immigrants.

creased inequality at the international level, with rich countries becoming richer at the expenses of poor countries. The first papers to analyze the brain drain in an endogenous growth framework rested on similar arguments and arrived at similar conclusions (e.g., Miyagiwa, 1991, Haque and Kim, 1995).

Figure 1. Globalization, migration to the North and trade



Notes. (a) Authors' computations using trade data from Barriel and Dean (2004) and GDP data from the WDI. (b) UNDP data.

Finally, there has been a third wave of interest since the late 1990s. Based on the fact that the brain drain has both detrimental and beneficial effects for origin countries, its objective was to characterize the conditions under which the net effect on development and welfare is positive or negative. The contribution of the theoretical literature has been to show that under certain circumstances, the brain drain may ultimately prove beneficial (but of course is not necessarily so) to the source country, and to do this while accounting for the various fiscal and technological externalities that were at the heart of the pessimistic models of the 1970s.[3] At the same time, thanks to the availability of new migration data, the various feedback effects emphasized in the early literature have given rise to an increasingly important empirical literature, further contributing to the emergence of a more balanced view of the brain drain. The main contribution of the recent literature, therefore, is that it is evidence-based, something which was not possible until recently due to the lack of decent comparative data on international migration by educational attainment.

[3] Mountford (1995, 1997), Stark, Helmenstein and Prskawetz (1997, 1998), Vidal (1998), Docquier and Rapoport (1999), Beine, Docquier and Rapoport (2001), and Stark and Wang (2002) are the main initial theoretical contributions.

The paper is organized as follows. Section 2 provides a quantitative assessment of the development and spatial distribution of the brain drain and an analysis of its determinants. In Section 3 we develop a benchmark closed-economy model of endogenous human capital formation and economic performance. This model is extended in Section 4 to analyze the various channels through which brain drain migration affects the economic performance and growth prospects of sending countries. The main channels to be covered are remittances, temporary and return migration, human capital formation, and network/diaspora effects on trade, FDI flows, technology adoption, and home country institutions. Section 5 is devoted to country (India), regional (European Union) and sectoral (health professionals) case-studies. Finally, Section 6 discusses policy implications from the perspective of sending and receiving countries.

2 Data and determinants of the brain drain

2.1 How extensive and intensive is the brain drain?

In the rest of this paper we use a number of new migration datasets to analyze the size, development and spatial distribution of the brain drain. These data sets are all very recent and based on OECD immigration data. Therefore, the figures mostly deal with the size and skill structure of immigration to OECD member countries, which we estimate represents about half of the total world migration and about 85 percent of the high-skill migration.[4] While this allows reasonable estimates of the brain drain for most countries to be computed, the fact that South-South migration is excluded may lead to a substantial under-estimation in some cases. However, immigration data by skill level is available for some developing countries and will be used to supplement existing OECD-based datasets.[5]

Following Docquier and Marfouk (2006) we define a "high-skill immigrant" as a foreign-born individual, aged 25 or more, holding an academic or professional degree beyond high-school (i.e., a "college graduate") at the census or survey date. Three caveats immediately come to mind: illegal immigration, home and host-country education, and heterogeneity in human capital levels. The first of these caveats is not a big source of concern because high-skill individuals tend to migrate legally; in addition, the data is for stocks and not flows (there is a high turnover among illegal migrants, many of whom either return home or are regularized after some time).[6] The second caveat, namely, that all foreign-born individuals with college education

[4] In 2000, the number of high-skill immigrants recorded in OECD countries was 20.5 million. In Section 2.5.4, we add 30 non-OECD destinations, increasing the figure to 23.1 million. Given that the number of high-skill migrants to the rest of the world is likely very small, a total figure of 24 million (85% of whom are in the OECD) seems reasonable.

[5] Note that the OECD contains important sending countries such as Mexico, Poland and Turkey.

[6] The United States tries to account for illegal immigration in its census. See Hanson (2006) for a comprehensive analysis of illegal migration from Mexico.

are considered to be part of the brain drain is potentially more serious. As explained below, we are able to correct for this to a large extent provided that age at migration can be used as a proxy for where education was acquired. The third caveat concerns the distinctions between field, degree, and actual occupation. In that case too, we will try to refine the definitions and account for heterogeneity among high-skill workers.

2.1.1 Brain drain to OECD destinations

Table 1 summarizes the data on emigration stocks and rates for different country groups in 1990 and 2000. The figures are taken from Docquier, Lowell and Marfouk (2009) (henceforth DLM), who provide emigration stocks and rates at three educational levels (primary, secondary and tertiary/college) by gender for all the countries of the world based on immigration data from the countries which were members of the OECD in 2000.[7] Countries are grouped according to demographic size, average income (using the World Bank classification), and region. It shows that over the last few decades, the brain drain has increased dramatically in magnitude (in terms of stocks) but not necessarily in intensity (in terms of emigration rates). This can be explained by the parallel rise in educational attainments.[8] As expected, emigration rates decrease with country size: average emigration rates are seven times higher in small countries (with populations of less than 2.5 million) than in large countries (with populations over 25 million). These differences cannot be attributed to differences in the educational structure of the home country population or to greater selection bias (ratio of high-skill to total emigration rates) in small countries. The highest emigration rates are observed in middle income countries where people have both the incentive and the means to emigrate: high-income countries (low incentives) and low-income countries (more binding credit constraints and less transferable human capital) have lower rates. The regions most affected by brain drain are the Caribbean, the Pacific, sub-Saharan Africa, and Central America.

Table 2 depicts the situation of the 30 countries most affected by the brain drain in 2000. The table is restricted to countries with at least 4 million inhabitants. In terms of magnitude (absolute numbers), the main international suppliers of brains are the Philippines (1.111 million), India (1.035 million), Mexico (0.949 million) and China (0.784 million) among developing countries, with the United Kingdom (1.479 million)

[7]DLM (2009) updated and extended (to include gender) the Docquier and Marfouk (2006) data set. Denoting by $M_{i,t}^{s}$ the number of working-aged emigrants from country i of skill s ($s = h$ for high-skill and $s = l$ for low-skill workers) in year t and by $N_{i,t}^{s}$ the corresponding number of residents, they define the high-skill emigration rate as $m_{i,t}^{h} \equiv \frac{M_{i,t}^{h}}{N_{i,t}^{h}+M_{i,t}^{h}}$. Dumont and Lemaître (2004) use similar definitions and provide emigration rates by education level for 102 countries in 2000. They consider the population aged 15+ (rather than the 25+ used by Docquier and Marfouk (2006)) and use a slightly more restrictive definition of "tertiary education".

[8]Recall that these figures are computed for immigration to the OECD only. In Section 2.1.5 we extend the coverage to include some non-OECD countries. Note also that the figures are for gross emigration rates (as we have no data on immigration to developing countries).

and Germany (0.945 million) completing the top of the list. In terms of intensity, small countries are obviously most affected. High-skill emigration rates exceed 80 percent in countries such as Guyana, Jamaica and Haiti, and are above 50 percent in many African countries. After excluding countries with population below 4 million, the top of the list mainly features middle-sized poor countries from various regions.

Table 1. Emigration stocks and rates to OECD destinations

Variable	Total stock[a]		Share high-sk[b]		Rate low-sk[c]		Rate high-sk[c]	
Year	1990	2000	1990	2000	1990	2000	1990	2000
World	41996	58619	29.9	35.0	1.3	1.3	5.1	5.5
By income group								
High-income	18206	19890	31.7	39.9	3.9	3.6	4.0	3.9
Upper-Middle-income	9166	15403	22.2	24.3	2.7	3.6	5.5	6.2
Lower-Middle-income	9884	15586	31.8	36.6	0.8	0.9	8.1	8.1
Low-income	3554	6499	37.5	45.3	0.3	0.3	5.5	7.6
By country size								
Above 25 million	25672	36508	30.6	36.4	0.9	1.0	3.8	4.2
From 10 to 25m	6394	8660	29.2	34.2	2.3	2.3	8.5	8.5
From 2.5 to 10m	7230	10011	28.8	33.2	4.1	4.3	13.9	14.5
Below 2.5 million	1515	2200	31.6	35.4	6.1	6.8	26.5	27.5
By region								
Africa								
Northern Africa	1705	2306	15.3	20.2	2.6	2.6	9.3	7.9
Sub-Saharan Africa	1209	2158	39.7	43.6	0.3	0.4	13.2	12.8
Americas								
Caribbean	1955	3011	35.4	38.2	8.2	10.4	44.0	43.0
Central America	3487	8051	17.3	17.1	7.3	12.1	13.7	17.1
South America	1577	2904	39.9	39.8	0.5	0.7	4.8	5.1
USA & Canada	1427	1537	50.3	61.9	1.9	2.3	1.0	0.9
Asia								
Eastern Asia	2647	4128	48.5	54.6	0.2	0.2	3.7	4.1
South-Central Asia	2070	3691	43.1	52.1	0.2	0.2	3.9	5.3
South-Eastern Asia	2584	4363	46.2	49.3	0.6	0.7	10.8	9.8
Middle East	2204	3202	20.3	23.2	3.4	3.6	9.8	8.4
Europe								
Eastern Europe	3633	4457	24.0	35.4	3.2	2.5	3.6	4.5
Western Europe	15859	16908	25.3	31.5	5.7	5.4	8.9	8.9
Oceania								
Australia & N. Zealand	383	564	43.3	51.9	1.9	2.1	4.3	5.7
Pacific islands	141	228	38.7	37.9	2.7	3.1	61.2	52.3

[a] Total stock of emigrants aged 25+. [b] Share of college graduates. [c] Emigration rate of high- (HS) and low-skill (LS) workers. Source: Docquier, Lowell and Marfouk (2009)

Table 2. Most and least affected countries (with pop. above 4m)

Highest stocks[a]		Highest rates in percent[b]		Lowest rates in percent[b]	
United Kingdom	1479604	Haiti	83.4	Turkmenistan	0.4
Philippines	1111704	Sierra Leone	49.2	United States	0.5
India	1035197	Ghana	44.7	Tajikistan	0.6
Mexico	949476	Kenya	38.5	Uzbekistan	0.8
Germany	944579	Laos	37.2	Kyrgyzstan	0.9
China	783881	Uganda	36.0	Saudi Arabia	0.9
Korea	613909	Eritrea	35.2	Kazakhstan	1.2
Canada	523916	Somalia	34.5	Japan	1.2
Vietnam	507200	El Salvador	31.7	Russia	1.4
Poland	456337	Rwanda	31.7	Azerbaijan	1.8
United States	427081	Nicaragua	30.2	Brazil	2.0
Italy	397247	Hong Kong	29.6	Thailand	2.2
Cuba	331969	Cuba	28.8	Burkina Faso	2.6
France	317744	Sri Lanka	28.2	Australia	2.7
Iran	304389	Papua New Guinea	27.8	Georgia	2.8
Hong Kong	292657	Vietnam	27.0	Argentina	2.8
Japan	278360	Honduras	24.8	Indonesia	2.9
Taiwan	274368	Croatia	24.6	Belarus	3.2
Russia	270794	Guatemala	23.9	France	3.5
Netherlands	258075	Mozambique	22.6	Angola	3.7
Ukraine	249165	Afghanistan	22.6	Paraguay	3.8
Colombia	233364	Dominican Republic	22.4	Venezuela	3.8
Pakistan	220881	Cambodia	21.5	China	3.8
Turkey	176558	Malawi	20.9	Myanmar	3.9
South Africa	173411	Portugal	19.0	Nepal	4.0
Peru	164287	Morocco	18.6	Moldova	4.1
Romania	164214	Cameroon	17.3	Spain	4.2
Greece	162129	Senegal	17.2	Libya	4.3
Serbia Montenegro	161885	United Kingdom	17.1	India	4.3
Indonesia	156960	Togo	16.5	Ukraine	4.3

Notes. [a] Stocks of high-skill emigrants aged 25+ in 2000. [b] Emigration rates of college graduates as percentage of the national high-skilled labor force in 2000. Source: DLM (2009).

2.1.2 Extensions

Correcting for age of entry. The figures above consider all foreign-born individuals as immigrants independent of where their education was acquired. This may lead to an over-estimation of the brain drain if a substantial proportion of today's highly skilled immigrants emigrated as children and acquired most of their education in their destination countries. Beine, Docquier and Rapoport (2007) (BDR) collected data on the age-of-entry structure of immigration and used this as a proxy for whether education was acquired in the home or the host country. Since this information was not available for all OECD countries, their data set combines observations (75 percent of the data) and estimates from a gravity model (for the remaining 25 percent). As shown in Table 3, controlling for age of entry has a strong effect on the measures of brain drain in countries with a relatively long history of migration.

Table 3. Brain drain from selecteed countries by age of entry (percent)

Origin	Rate 0+[a]	Rate 12+[b]	Rate 18+[b]	Rate 22+[b]	Ratio 22+/0+
Mongolia	7.4	7.3	7.3	7.2	97.4
Mozambique	22.5	22.3	22.1	21.8	96.9
Malawi	20.9	20.4	20.2	20.1	96.2
China	3.8	3.5	3.3	3.0	79.9
Switzerland	9.5	8.3	7.9	7.1	74.0
South Africa	7.4	6.4	5.8	5.4	73.1
Morocco	18.0	15.6	14.2	12.9	71.5
United Kingdom	17.1	14.6	13.3	11.9	69.9
Indonesia	2.9	2.6	2.4	2.0	69.7
Canada	4.7	3.5	3.1	2.7	56.9
Costa Rica	7.1	5.9	4.9	4.0	56.1
Kuwait	7.1	6.4	5.3	3.9	54.8
Cambodia	21.4	17.3	13.5	11.2	52.2
Mexico	15.5	12.4	9.9	7.9	51.3

Notes. [a] Emigration rates of college graduates as in DLM (2009). [b] Idem after excluding those who immigrated before age 12, 18 or 22 (Beine, Docquier and Rapoport, 2007).

Obviously, an approach based on census data is not perfect. As Rosenzweig (2005) explains, "information on entry year is based on answers to an ambiguous question—in the US Census the question is 'When did you first come to stay?' Immigrants might answer this question by providing the date when they received a permanent immigrant status instead of the date when they first came to the US, at which time they might not have intended to or been able to stay." Only surveys based on comprehensive individual migration histories can provide precise information about where schooling was acquired. Such survey data are only available for a few countries, and in general they do not provide a representative cross-sectional picture of immigrants' characteristics. An exception is the US New Immigrant Survey (NIS), a nationally representative multi-cohort longitudinal study of new legal immigrants and their children in the United States. However, the proportion of highly skilled immigrants from each country with US tertiary schooling given by the US census only has a correlation of 0.26 with that given by the NIS in 2000. The NIS dataset indicates that, out of 140 countries, there were 24 which apparently had no skilled emigrants educated in the US and 14 where all of their skilled emigrants were apparently educated in the

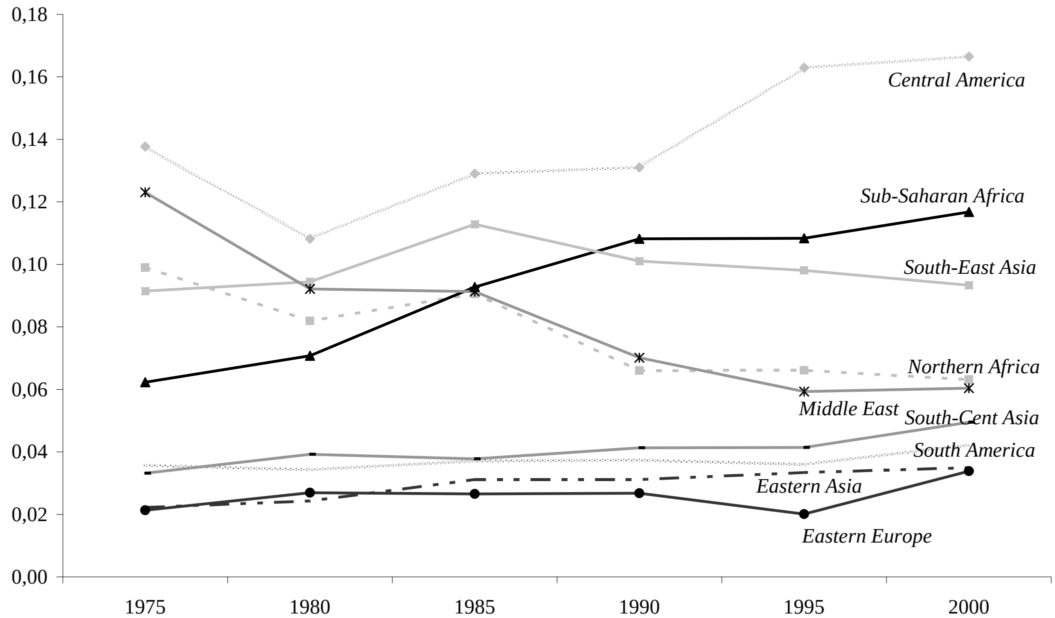
US. This could be due to small sample size; and indeed these 35 extreme observations all concerned very small immigrant communities. The correlation between NIS and census figures rises to 47.7 percent after excluding all the countries with less than 100,000 immigrants to the US. These comparisons indicate that, although the NIS results are derived from answers to a much more precise question, they may be noisy, given the relatively small sample sizes, for countries with a small number of immigrants in the US.

Panel data. As seen above, the brain drain increased both in magnitude and intensity during the 1990s. Is this also true over a longer time-span? Focusing on the six major destination countries (USA, Canada, Australia, Germany, the UK and France), which together account for 75 percent of total immigration to the OECD in 2000, Defoort (2008) computed high-skill emigration stocks and rates for each five-year period between 1975 and 2000. Based on these six destinations, high-skill emigration rates appear to be remarkably stable over this period. This stability is in fact the product of two opposing forces: on the one hand, migration rates increased for all education categories; on the other hand, general increases in educational attainment have driven selection biases down in all parts of the world. However, Figure 2 shows that some regions have experienced an increase in the intensity of the brain drain (Central America, Eastern Europe, sub-Saharan Africa, and South-Central Asia) while significant decreases have occured in others (e.g., the Caribbean, Northern Africa).

The gender dimension. The proportion of women in total international migration increased from 46.8% to 49.6% between 1960 and 2005 (United Nations, 2005). Two recent data sets documenting the gender structure of the brain drain (Docquier, Lowell and Marfouk, 2009, and Dumont, Martin and Spielvogel, 2007) have shown that highly skilled women are over-represented among international migrants (see Figure 3). Using separate regressions for males and females, Docquier et al. (2009) showed that highly skilled women were more migratory than highly skilled males after controlling for country-specific and gender-specific explanatory variables.[9] However, they also showed that the gender gap in international high-skill migration is not evident in a correctly specified model that allows for the interdependencies between males and females migration (due to, for example, joint decisions or family reunion programs). Docquier et al. (2009) also showed that women and men respond differently to push factors, and that skilled women are more responsive to the emigration of skilled men than vice versa.

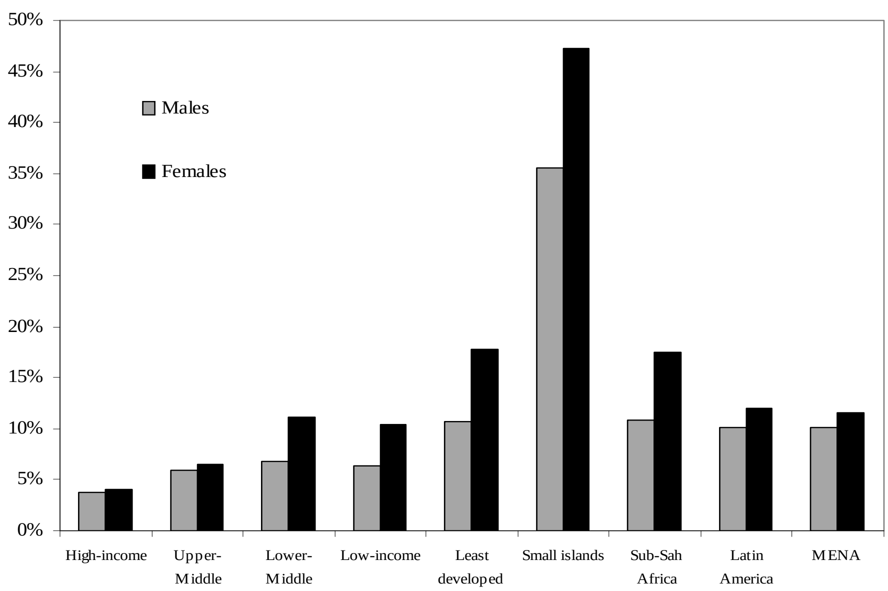
[9] It could also be that the over-representation of women in high-skill emigration is driven by international demands for feminized occupations such as nursing. However, we are not aware of comparative data on occupations by gender which would allow this conjecture to be tested.

Figure 2. Long-run trends in high-skill emigration, 1975–2000



Note. Vertical axis = emigration rate of college graduates. Source: Defoort (2008)

Figure 3. Male and female rates of brain drain in 2000



Note. Emigration rate of college graduates by country group and gender. Source: DLM (2009).

Brain drain to non-OECD countries. A natural extension of the DLM data set is to collect census data on immigration from a set of non-OECD countries for which immigration data by education level is available. In this section, we extend the DLM database by adding census data from ten non-OECD European countries (Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Malta, Romania, Slovenia, Croatia and Macedonia), three Asian countries (Singapore, Israel and the Philippines), six Latin American countries (Argentina, Brazil, Chile, Costa Rica, Colombia, Venezuela), five African countries (South Africa, Rwanda, Uganda, Kenya and Ivory Coast), and estimates for six Persian Gulf countries (Saudi Arabia, Bahrain, Kuwait, Oman, Qatar and the United Arab Emirates). Comparing the high-skill emigration rates in DLM2009 with those in the extended set of 54 host countries, it appears that the brain drain rate for 13 countries is more than doubled when emigration to non-OECD countries is considered: Namibia (×8.7), Lesotho (×6.0), Yemen (×5.5), Bahrain (×5.4), Burkina Faso (×4.3), Swaziland (×3.6), Sudan (×2.6), Tajikistan (×2.5), Uzbekistan (×2.3), Turkmenistan (×2.2), Belarus (×2.2), Niger (×2.1) and Moldova (×2.0). The rate is multiplied by more than 1.5 in 20 other countries.

2.2 Empirical analysis of the determinants of the brain drain

2.2.1 Push and pull determinants of the brain drain

Mayda (2010) analyzed the role of push and pull factors in international migration, showing that the impact of push factors on aggregate emigration rates (without educational breakdown) is relatively small compared to those of distance and pull factors. Using the DLM data set, Docquier, Lohest and Marfouk (2007) proposed a similar analysis by education level. They first decomposed the brain drain as the product of the average emigration rate by the selection bias in emigration:

$$m_{i,t}^{h} \equiv \frac{M_{i,t}^{h}}{N_{i,t}^{h}+M_{i,t}^{h}} \equiv \left[\frac{\sum_s M_{i,t}^{s}}{\sum_s \left(N_{i,t}^{s}+M_{i,t}^{s}\right)}\right] \cdot \left[\frac{M_{i,t}^{h}}{\sum_s M_{i,t}^{s}} / \frac{N_{i,t}^{h}+M_{i,t}^{h}}{\sum_s \left(N_{i,t}^{s}+M_{i,t}^{s}\right)}\right]$$

Table 4 shows Docquier, Lohest and Marfouk's (2007) results for developing countries in Columns (1) and (2), and our own regression results for high-income countries using the same parsimonious specification as theirs in columns (3) and (4). The results are obtained using OLS with White's correction for heteroskedasticity; they are robust to the econometric technique (IV with instrumented level of development, random effect in a panel model with 2 observations per country, SURE). Table 4 gives the results for the parsimonious specifications only, after non-significant variables have been dropped. For example, country size (as measured by the log of population) was initially included in the selection regressions, but turned out to be non-significant and was therefore dropped; hence, it appears in blank in Columns (2) and (4).

The results for developing countries show that high-skill emigration is less sensitive to geographic variables such as distance (whose coefficient becomes less negative once the selection bias is accounted for), increases with the degree of religious fractionalization at origin (via the selection bias) and decreases with the level of development at origin (the effect of the selection bias is larger than that of openness). The size of the country also matters: small states are more open than large countries. Comparing developing and developed countries, we see that the coefficients usually have similar signs but different magnitudes. The brain drain from high income countries is less responsive to distance and other geographic characteristics. The selection bias, on the other hand, is less responsive to immigration policies at destination and to the level of development. Finally, the degree of openness in rich countries does not depend on the level of development (which is more homogenous in high-income countries).

Table 4. Determinants of aggregate high-skill emigration rates

	Developing		High-income	
	Openness	Select. bias	Openness	Select. bias
Native population (log)	-0.175	-	-0.428	-
	(2.82)***		(5.35)***	
Small islands	0.957	-	-	-
	(2.91)***			
Development level	0.535	-0.913	-0.515	-0.488
	(4.18)***	(15.10)***	(1.56)	(3.06)***
Oil exporting country	-0.545	0.193	-2.579	0.403
	(1.48)	(1.54)	(4.35)***	(3.59)***
Dist from selective ctries (log)	-1.021	0.407	-0.257	0.155
	(3.06)***	(4.36)***	(1.39)	(2.71)**
Distance from EU15	-0.394	0.125	-0.189	0.111
	(3.80)***	(2.37)**	(1.81)*	(4.04)***
Landlock	-0.887	0.146	-0.746	0.195
	(2.68)***	(1.37)	(2.14)**	(2.01)*
Religious fractionalization	-	0.585	-	0.333
		(4.05)***		(1.71)*
Main dest = selective country	-	0.890	-	0.110
		(6.10)***		(1.31)
Main destination = EU15	-	0.539	-	-
		(3.16)***		
Constant	10.404	-2.245	8.955	-0.150
	(3.29)***	(2.17)**	(3.29)***	(0.15)
Observations	108	108	36	34
Adjusted R-squared	0.68	0.88	0.68	0.78

Notes. OLS estimates with White correction for heteroskedasticity. Robust t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

2.2.2 The (positive) selection of international migrants

A number of recent empirical studies have used the bilateral dimension of the above described databases to characterize the pattern of selection in international migration. Grogger and Hanson (2011) use the DLM bilateral emigration stocks and rates observed in 2000 and wage and earnings distributions by skills and occupations to explain two important characteristics of international labor movements: positive selection (i.e., migrants having higher than average skills) and positive sorting (i.e., the tendency for highly skilled migrants to locate in countries with high returns to skills). The selection regression reveals that the educational gap between migrants and non-migrants tends to widen with the skill-related difference in earnings between destination and source countries. The sorting regression, on the other hand, reveals that the relative stock of high-skill migrants in a destination increases with the earnings differential between high and low-skill workers. This correlation is stronger when wage differences are adjusted for taxes. On the whole, simulations using the point estimates from the regressions show that wage differentials explain 58 percent of the immigrant-skill gap in bilateral migration flows vis-à-vis the US benchmark.

Using similar techniques and databases, Belot and Hatton (2008) find smaller effects of wage differentials on selection. They measure the skill premium as the ratio of wages in a set of high-skill versus low-skill occupations. They find that the greater the returns to skills in the destination as compared to the source country, the stronger the positive selection of immigrants, as in Grogger and Hanson (2011), however this is obtained only once poverty measures are introduced to account for credit constraints on migration. Belot and Hatton (2008) also find that factors such as linguistic, cultural, and geographic proximity are stronger determinants of selection patterns than factors such as the relative return to skills, poverty in source countries, or immigration policies in receiving countries.

Finally, Beine, Docquier and Ozden (2011) disregard country-specific variables (captured by fixed effects) and focus instead on the role of networks/diasporas (as measured by migration stocks in 1990) on the size and composition of bilateral migration flows. Accounting for the usual determinants of migration and for potential endogeneity biases,[10] they show that larger diasporas increase the size of migration flows and lower the average educational level of new migrants.[11] After extracting the explained partial sum of squares, existing diasporas explain a large proportion of the variability in the size of migration flows (71 percent) and the patterns of migrants' selection (47 percent). These proportions capture the joint effect of network externalities and lower migration costs (self-selection channel) and that of family reunion programs (policy channel).

A common limitation of all the papers discussed above is that they do not record where immigrants' education was acquired. However, the assimilation of highly skilled

[10]Diasporas are instrumented by a dummy variable capturing the existence of bilateral guest-worker programs in the 1960s, and an interaction between indicators of total immigration at destination in 1960, distance, and a measure of conflicts in the source country in the 1950s.

[11]This is in accord with McKenzie and Rapoport's results (2010). They found that migration networks increase the degree of negative selection (or lower the degree of positive selection) among Mexican immigrants to the United States.

workers at destination and the level of their earnings abroad depend strongly on the transferability of human capital. Unsurprisingly, workers trained at destination enjoy higher wages and employment rates than workers trained in their countries of origin, especially if they come from countries with low-quality education systems (Coulombe and Tremblay, 2009). A potentially profitable route for a prospective migrant is, therefore, to migrate first as a student. Using the US New Immigrants Survey (NIS), Rosenzweig (2008) finds that there are larger per-capita numbers of foreign students in the United States from low skill-price countries, and that sending countries with relatively high skill prices succeed in bringing more students back (even after controlling for the quality and quantity of their higher education institutions). This is consistent with the students seeking to acquire schooling abroad in order to obtain jobs in the host countries.

Another important limitation on existing studies is the poor state of knowledge on immigration policies, which are imperfectly captured using variables such as number of asylum seekers or the existence of free-mobility agreements (such as the Schengen agreement). This gap in knowledge is partly filled by Ortega and Peri (2009), who put together a dataset on immigration laws and policies (still very preliminary and incomplete) to augment the Grogger and Hanson (2011) model. On the whole, they confirm the role of income maximization and of immigration laws in determining the size of migration flows. However, their migration dataset is an extension of Mayda's (2010) and makes no distinction between skill groups.

Our overview of the current state of international migration data shows that substantial progress has been achieved in the last decade; however, the state of international migration data remains very poor compared to that on international trade and capital flows. Bilateral international trade data are classified according to a very large and detailed set of characteristics and are reported on a monthly basis. On the other hand, bilateral aggregate (country-level) migration data are obtained mostly from censuses that are conducted every ten years, a reporting frequency that is less than one percent of that for trade data. Partly due to these data constraints, cross-country analyses of international migration still lag behind the empirical literature on international trade and financial flows.

3 A benchmark economy without migration

This section presents a stylized model of human capital accumulation and endogenous growth for an economy without migration; it will be used as a benchmark in the next sections where we allow for high-skill workers' emigration and model the channels through which such emigration affects the growth performance of home countries.

Our model depicts an economy populated by firms and individuals living for three periods: two working periods (youth and adulthood) and a retirement period (old-age). We first characterize the production sector and derive a *wage-setting* equation endogenizing economic performance as a function of human capital. Then we characterize the accumulation of human capital and derive a *skill-setting* equation endogenizing human capital accumulation as a function of economic performance.

3.1 The wage-setting equation

At each period of time, physical capital (K_t) and labor in efficiency units (H_t) are combined to produce a composite good (Y_t) according to a Cobb-Douglas production function. Human capital (or labor in efficiency units) sums high-skill and low-skill labor which we treat as perfect substitutes.[12] Normalizing the number of efficiency units offered by a low-skill worker to one, a high-skill worker is assumed to offer $1+\theta > 1$ units ($\theta > 0$). Hence, the GDP per worker (y_t) is a function of the stock of capital per worker (k_t) and the average number of efficiency units of labor (h_t):

$$Y_t = A_t K_t^{\alpha} H_t^{1-\alpha}; \quad y_t = A_t k_t^{\alpha} h_t^{1-\alpha} \tag{1}$$

where A_t is a time-varying scale parameter affecting total factor productivity and $\alpha \in [0,1]$ is the share of capital in the national income.

International movements of physical capital are such that the returns to physical capital are equalized (net of any risk premiums and transaction costs) across nations. We assume that capital fully depreciates in one period and that from the perspective of potential investors, each country is characterized by a given risk premium.[13] The following arbitrage condition thus implicitly defines the equilibrium amount of capital per worker in the economy:

$$R_t^* \phi_t = \alpha A_t k_t^{\alpha-1} h_t^{1-\alpha} \tag{2}$$

where R_t^* is the risk-free international interest factor at time t (one plus the interest rate) and $\phi_t \geq 1$ is equal to one plus the risk premium.

The wage rate per efficiency unit of labor is given by

$$w_t = A_t k_t^{\alpha} h_t^{-\alpha} \tag{3}$$

Rearranging Equation (2) and substituting it into Equation (1) allows the GDP per capita to be expressed relative to that in the leading economy (denoted by *):

$$\frac{y_t}{y_t^*} = \left(\frac{A_t}{A_t^*}\right)^{\frac{1}{1-\alpha}} \left(\frac{\phi_t}{\phi_t^*}\right)^{\frac{-\alpha}{1-\alpha}} \left(\frac{h_t}{h_t^*}\right) \tag{4}$$

[12] Many empirical studies advocate using an elasticity of substitution between high-skill and low-skill workers greater than two to match skill premium data in developing countries. In their study on immigration and inequality, Ottaviano and Peri (2008) use a range of estimates between 1.5 and 3. Angrist (1995) recommends a value around 2 to explain the evolution of the college premium on the Palestinian labor market during the 1980s.

[13] Note that in our view the risk premium has two components: a standard risk premium borne by all (domestic and foreign) investors and related to the quality of governance in that country, and an international transaction cost borne by foreign investors only. See Section 4.5.1. below where this distinction is formally introduced.

Clearly, the gap in economic performance linearly depends on the ratio of the efficiency units of labor per worker, decreases with the ratio of the risk premiums and is a convex function of the ratio of the productivities.

Using Equations (3) and (2), the wage rate per efficiency unit of labor can also be expressed in relative terms with respect to the leading economy:

$$\frac{w_t}{w_t^*} = \left(\frac{A_t}{A_t^*}\right)^{\frac{1}{1-\alpha}} \left(\frac{\phi_t}{\phi_t^*}\right)^{\frac{-\alpha}{1-\alpha}} \equiv \omega_t \tag{5}$$

The ratio of wage rates ω_t does not depend directly on human capital endowments. However, the level of technology may reasonably be considered as an increasing function of the average quality of workers. This is in line with Lucas (1988) who assumed that productivity positively depends on the economy-wide average level of human capital, and with the neo-Schumpeterian growth literature where the capacity to innovate or adopt modern technologies depends on the average quality of workers. Note that if human capital plays affects the transaction and informational costs between countries, a decline in human capital may also increase the premium ϕ_t and lead to further decreases in local wages and GDP per capita. We assume that $A_t = \lambda^t A(h_t)$, where $\lambda > 1$ is a parameter capturing possible common trends in technological progress,[14] and either $A^{'} > 0$ or $\phi_t = \phi(h_t)$, $\phi^{'} < 0$ (or both) so that the ratio of wage rates is positively related to domestic human capital (i.e., the average skill level of domestic workers) and negatively to the stock of human capital in the most developed countries. This gives the *wage-setting* equation:

$$\omega_t = W(h_t; h_t^*, X_t) \tag{6}$$

where X_t is a set of characteristics affecting risks and technology in developed (leading) and developing countries. We can reasonably suppose $W(0, h_t^*, X_t) > 0$, $W_h^{'} > 0$ and $W_{hh}^{''} \lesseqgtr 0$; this means that our model is compatible with local increasing returns (Romer, 1986) and threshold externalities *à la* Azariadis and Drazen (1990).

3.2 The skill-setting equation

Let us now endogenize human capital formation. Young individuals at time t maximize a utility function which depends on their levels of consumption when young, adult, and retired. When young, individuals can work for a wage w_t and decide whether to invest in education. Education at time t, x_t, is a take-it-or-leave-it decision (x_t is equal to 0 or 1) and entails a monetary cost cw_t where c is an individual fixed effect capturing the ability to learn. For simplicity, we assume that c is uniformly distributed on $[0, 1]$. When adult, individuals receive a wage w_{t+1} (if uneducated) or $(1+\theta)w_{t+1}$ (if educated) which is used for consumption and savings. Finally, savings

[14] A more sophisticated growth process will be introduced in Section 4.

s_{t+1} determine consumption during the retirement period. The utility function is logarithmic and can be written as:

$$U(x_t, s_{t+1}) = \ln(w_t - \widehat{\mu}_t - x_t c w_t) + (1-\lambda)\ln(w_{t+1}(1+x_t\theta) - s_{t+1}) + \lambda \ln\left(s_{t+1}R^*_{t+2}\right) \quad (7)$$

where $\widehat{\mu}_t$ denotes a minimal level of subsistence when young (for simplicity, we assume there is no such minimum threshold in the other periods), and λ is a parameter reflecting both the relative length of the retirement period and time preferences.

Savings are a continuous variable. Maximizing $U(x_t, s_{t+1})$ with respect to s_{t+1} implies that individuals save a fraction λ of their second-period income. Hence, the quasi-indirect utility function can be written as:

$$V(x_t) = \ln(w_t - \widehat{\mu}_t - x_t c w_t) + \ln(w_{t+1}(1+x_t\theta)) + \lambda \ln\left(R^*_{t+2}\right) + F \quad (8)$$

where $F \equiv \lambda \ln(\lambda) + (1-\lambda)\ln(1-\lambda)$ is a constant.

People chose education if $V(1) > V(0)$. The condition for an individual to invest in education is given by

$$c < \frac{w_t - \widehat{\mu}_t}{w_t} \cdot \frac{\theta}{1+\theta} \equiv \widehat{c}_t$$

With a uniform distribution for c, this critical value $\widehat{c}_t$ is equal to the proportion of young individuals opting for education when young. Without migration, this would also give the proportion of educated adults in the next period: $\pi_{t+1} = \widehat{c}_t$. This proportion increases with the local wage rate w_t and with the skill premium θ.

For analytical convenience we express the minimum level of consumption when young as a fraction of the wage rate in the more advanced countries: $\widehat{\mu}_t = \mu w^*_t$.[15] The proportion of high-skilled individuals among young natives then becomes:

$$\widehat{c}_t = \left(1 - \frac{\mu}{\omega_t}\right) \cdot \frac{\theta}{1+\theta} \quad (9)$$

In an economy without migration where each adult has m children, the average level of human capital of the labor force at time t is given by:

$$h_{t+1} = 1 + \frac{\pi_{t+1}\theta}{1+m} = 1 + \frac{\widehat{c}_t\theta}{1+m} \quad (10)$$

which is clearly an increasing function of $\widehat{c}_t$.

Substituting Equation (9) into Equation (10) allows us to characterize the level of human capital as a function of the lagged differential in skill prices:

$$h_{t+1} = 1 + \frac{\theta^2}{(1+m)(1+\theta)}\left(1 - \frac{\mu}{\omega_t}\right) \equiv H(\omega_t) \quad (11)$$

[15] This assumption implies that liquidity constraints are more severe in countries where the wage rates are low compared to those observed at destination, which seems reasonable.

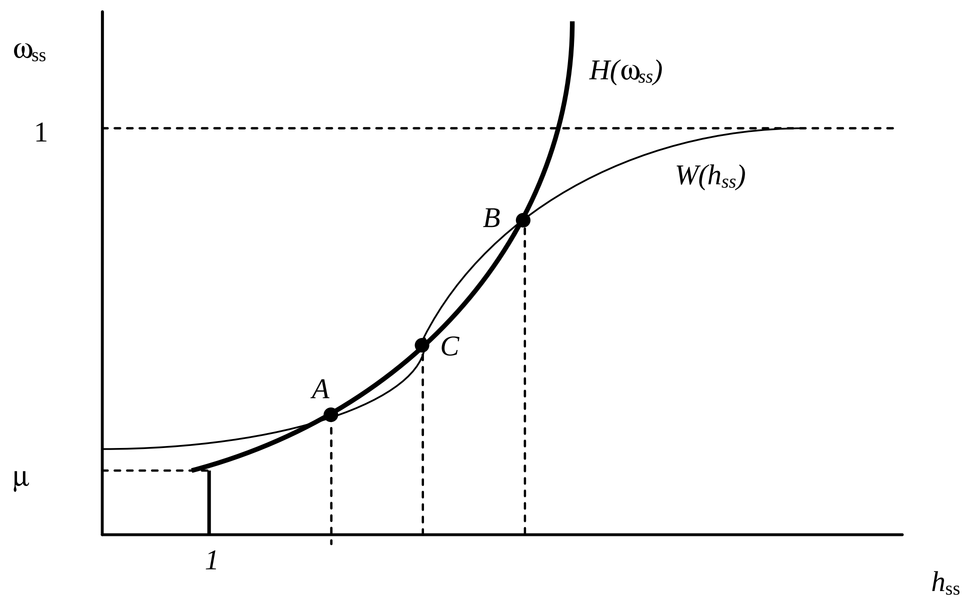
such that $H(\omega_t) = 0$ if $\omega_t < \mu$ and, for $\omega_t \geq \mu$, $H' > 0$ and $H'' < 0$.

Along the balanced growth path, each extensive variable grows at a constant rate and each intensive variable reaches a steady state value (subscripted ss). Hence, $h_{ss} = H(\omega_{ss})$. We refer to Equation (11) as to the *skill-setting* equation.

3.3 Equilibrium

We focus here on balanced growth equilibria, i.e. on the (ω_{ss}, h_{ss}) pairs satisfying the *wage-setting* and *skill-setting* equations. As can be seen by combining (6) and (11), the model is compatible with the existence of multiple equilibria (e.g., a poverty trap with low levels of human capital and large distance to the frontier, and a high-income equilibrium with high levels of human capital and low distance to the frontier). A reasonable configuration is provided in Figure 4, where we assume that the relationship between human capital and relative technological development (represented by the *wage-setting* equation $W(.)$) exhibits increasing returns for intermediate values of human capital (when innovation is being progressively substituted for adoption).

Figure 4. Long-run multiple equilibria without migration



In the diagrammatic example of Figure 4, there are three intersections between these long-run relationships. Provided that A and B are dynamically stable, equilibrium A may be seen as approximating the situation of a developing country and equilibrium B as approximating the situation of a developed country. Such a framework allows changes in domestic policies (e.g., education subsidies that would shift the $H(.)$ curve to the right or growth policies that would shift the $W(.)$ curve upwards) to be analyzed. In what follows we will focus on how high-skill emigration affects long-run outcomes through its effects on these two curves.

In the following section we use our general set-up to analyze the main channels through which a brain drain affects the sending economies and review the existing evidence on these channels.

4 Brain drain: channels and evidence

4.1 A pessimistic view

As explained in the introduction, the 1970s literature and early work dealing with brain drain issues using an endogenous growth framework both emphasized the negative effects for source countries. This pessimistic view was based on two major assumptions: either the before-migration stock of human capital was treated as exogenous to international migration (as in Wong and Yip (1999), who consider only domestic incentives), or, when it reacts to the prospect of migration, the additional human capital ends up abroad (as in Haque and Kim (1995)). Under such circumstances, and notwithstanding possible feedback mechanisms, a brain drain can only be detrimental to the source economy.

To illustrate this argument, assume an exogenous fraction p of the highly skilled population leaves the country. For simplicity, we will assume that low-skill workers do not migrate. The proportion of highly skilled people among the remaining adults is then:

$$\pi_{t+1} = \frac{(1-p)\widehat{c}_t}{1-p\widehat{c}_t} \tag{12}$$

with $\frac{\partial \pi_{t+1}}{\partial p} = \frac{-\widehat{c}_t(1-\widehat{c}_t)}{(1-p\widehat{c}_t)^2} < 0$ and $\frac{\partial \pi_{t+1}}{\partial \widehat{c}_t} = \frac{1-p}{(1-p\widehat{c}_t)^2} > 0$.

If emigration does not modify the incentives to invest in education (i.e., the critical level of ability $\widehat{c}_t$ in (9) is unchanged), then the impact of the brain drain on the proportion of highly skilled people among the remaining adults is clearly negative. This can be represented in Figure 4 by a shift of the $H(.)$ curve to the left: for a given technological level, the economy-wide average level of human capital decreases. In turn, this reduces the capacity to adopt new technologies in relatively poor countries and the capacity to innovate in relatively advanced countries. Stable equilibria A and B shift to the left: the economy ends up having less human capital and being more distant from the frontier.

These effects could be supplemented by additional mechanisms. First, if the brain drain from the country of origin is large enough to positively affect productivity in the leading economy, this will further increase the technological gap. However, the concentration of human capital in the most advanced economies can stimulate technological progress across the world and trickle down to the less advanced economies (see Grubel and Scott (1966) and, more recently, Kuhn and McAusland (2009, 2011) and Mountford and Rapoport (2011)).

Second, in settings where wages are determined non-competitively, highly-skilled emigration can, paradoxically, increase skilled unemployment. For example, Bhagwati and Hamada (1974) developed a model in which internationally integrated labor markets lead the educated elite of developing countries to bargain for higher wages, with low-skill workers responding by adjusting their wage requirements. On the whole, more integration leads to more unemployment for all types of workers.[16]

Third, a brain drain can induce occupational shortages in certain sectors and professions (e.g., teachers, engineers, physicians, nurses). If the tasks performed by these professionals strongly affect the productivity of other workers, or the accumulation of human capital in the economy, as could be argued for example from an O-ring perspective (Kremer, 1993), then such shortages may have a disproportionately high negative effect on those left behind

These are the main channels through which a brain drain could reduce human capital formation and penalize those left behind. The recent literature is less pessimistic: it puts forward potentially positive feedback effects and emphasizes that migration prospects can, under certain circumstances, favor human capital formation.

4.2 Brain drain and human capital formation

To investigate the impact of the brain drain on human capital formation we must account for the fact that a country's pre-migration human capital stock is endogenous to the prospect and realization of migration. The recent theoretical literature has developed probabilistic migration models with either heterogeneous (Mountford, 1997, Stark et al., 1997, Beine et al., 2001) or homogenous (Stark et al., 1998, Vidal, 1998) agents where migration prospects raise the expected return to human capital, thus inducing more people to invest (or people to invest more) in education at home.[17]

4.2.1 Theory

As in the previous section, assume that high-skill workers have a probability p of emigrating whereas the emigration probability of low-skill workers is normalized to zero. How does this affect education decisions and the skill-setting equation? The quasi-indirect utility function must now be changed to incorporate migration prospects for

[16] Fan and Stark (2007) recently revisited the result that more brain drain can be associated with more educated unemployment using a job search model.

[17] A closely-related, yet differently motivated theoretical argument is that migration enhances the option value of education in a context of volatile domestic returns to human capital (Katz and Rapoport, 2005). Since high income volatility is a feature of developing countries, the argument primarily applies to them. However it can be extended to rich countries by introducing heterogeneous human capital (general or specific, see Poutvaara (2008)), or asymmetric sectoral shocks.

the educated only. Assuming for simplicity that skill premiums are constant across countries, the expected utility of an educated worker becomes:

$$\begin{aligned} V(1) &= \ln(w_t - \widehat{\mu}_t - cw_t) + (1-p)\ln(w_{t+1}(1+\theta)) \\ &\quad + p\ln\left(w^*_{t+1}(1+\theta)\right) + \lambda \ln\left(R^*_{t+2}\right) + F \end{aligned} \tag{13}$$

while the quasi-indirect utility for a low-skill worker $V(0)$ remains as in (8).

The ex-post proportion of educated people is still determined by Equation (12). However, migration prospects now affect the pre-migration proportion of high-skill adults, $\widehat{c}_t$. We have:

$$\frac{\partial \pi_{t+1}}{\partial p} = \frac{(1-p)\frac{\partial \widehat{c}_t}{\partial p} - \widehat{c}_t(1-\widehat{c}_t)}{(1-p\widehat{c}_t)^2} \tag{14}$$

Compared to Equation (9), the critical level of ability is now given by:

$$\widehat{c}_t = \left(1 - \frac{\mu}{\omega_t}\right) \cdot \left(1 - \frac{\omega^p_{t+1}}{1+\theta}\right) \tag{15}$$

If $p = 0$, $\omega^p_{t+1} = 1$ and we get the closed economy level in Equation (9). When p is positive, $\omega^p_{t+1} < 1$ and the proportion of native people who are educated is higher than in the closed economy and increases with p.

A beneficial brain drain (BBD, or net brain gain) is possible when the numerator of Equation (14) is positive. Obviously, when p is close to one, this can never be the case. A necessary condition for a beneficial brain gain is that the above derivative must be positive at $p = 0$. This requires:

$$\ln\left(\frac{w^*_{t+1}}{w_{t+1}}\right) > \theta\left[1 - \left(1 - \frac{\mu}{\omega_t}\right)\frac{\theta}{1+\theta}\right] \tag{16}$$

The main prediction of this model is therefore that:

Summary 1 *There are two conditions for a beneficial brain drain (BBD) to be obtained in the long-run. First, according to Equation (16), the differential in skill prices (ω_{ss}) should be low enough to generate strong incentive effects, but not so low that liquidity constraints on education investment become strongly binding (in which case the incentive effect cannot operate). Second, according to Equation (14), the probability of highly skilled emigration (p) should be sufficiently low.*

If these two conditions hold, then the effect on the $H(.)$ curve is ambiguous: it might shift to the left for extremely poor countries (due to binding liquidity constraints) as well as for rich countries (due to low additional incentives), and shift to the right for middle-income countries.

These theoretical effects can be strengthened or weakened by introducing occupational choices, network effects (Kanbur and Rapoport, 2005), fertility, education subsidies (Stark and Wang, 2002), or "brain waste" into the model. For example, Mountford and Rapoport (2007, 2011) endogenize fertility,[18] human capital formation and technological progress in both the sending and receiving economies in order to analyze the potential for brain drain migration to affect the world distribution of income. Three configurations of "catching up", "divergence", and "core-periphery" (where brain drain migration contributes to increasing the growth rate and reducing the fertility rate in all countries while simultaneously increasing world inequality) emerge from their model. Their simulations show that brain drain migration probably reinforces the changes in the world distribution of income described by Sala-I-Martin (2006), with an initial decrease in global inequality (due to rises in GDP per capita in large, converging developing countries with low emigration rates such as India and China) before contributing to its future rise (as poor, diverging countries with high brain-drain rates grow large demographically).

Political economy extensions include that by Docquier and Rapoport (2003), who show that while the prospect of migration can protect ethnic and religious minorities from excessive discrimination when international mobility is free, restrictions on mobility can paradoxically increase both emigration and domestic discrimination beyond their closed economy level. Mariani (2007), on the other hand, augmented the allocation-of-talent model developed by Murply, Shleifer and Vishny (1991) to show that migration can decrease (resp. increase) the fraction of highly skilled workers who opt for rent-seeking (resp. productive) activities, so offering another channel through which highly skilled emigration can enhance growth.

Finally, the field of study chosen also responds to migration prospects and to shifts in international demands for specific professions. When foreign and domestic needs differ, the cost of such distortions in the supply of skills can be quite large (this was one of the main negative effects of the brain drain put forward by Michael Todaro (1996) in early editions of his classic economic development textbook). To give an extreme example, people contemplating emigration may choose to study geriatrics instead of pediatrics, meaning that if they end up not migrating, their skills are likely to be partly wasted. A similar argument was made recently by Di Maria and Stryszowski (2009) in relation to productivity growth: they assume that adoption and innovation require different types of human capital and, as in our model, that a poor country's productivity growth relies mainly if not exclusively on its capacity to adopt new technology. Since migration prospects tend to drive human capital investments away from fields useful for adoption, poor countries will not benefit from their additional human capital even if would-be migrants end up remaining in the home country. This is one form of migration-induced "brain waste". Brain waste also occurs when people invest in skills they end up not using even if they succeed in migrating (Mattoo, Neagu and Ozden, 2008) (for example, when a medical doctor from the Philippines works as a nurse in London or a geologist from the Dominican Republic works as a taxi driver in New York). Such brain waste may be due to a host of possible circumstances such

[18] See also Chen (2006, 2009).

as lack of information about job market opportunities, discounting of skills due to imperfect transferability of human capital, or purposeful acquisition of a signal aimed at increasing one's chance of emigration. However, empirical evidence suggests brain waste is second order and will therefore be neglected in what follows.[19]

4.2.2 Macro evidence

As explained, the central argument of the theoretical literature rests on the idea that expectations about future migration opportunities affect education decisions. This raises the question of the formation of expectations. Theoretically, there is a full set of possibilities ranging from myopic to rational expectations. Empirically, the "macro" literature has implicitly adopted a myopic view of expectations, where the empirical counterpart of the "migration prospect" variable is simply the emigration rate (or the differential emigration propensity between high and low-skill workers) observed in previous periods. The first paper to adopt such an approach is Beine, Docquier and Rapoport (2001), who used gross migration rates as a proxy for the brain drain in a cross-section of 37 developing countries. They found a positive and significant impact of emigration on gross (pre-migration) human capital formation at origin, stronger for countries with low initial levels of GDP per capita.

More recently, Beine, Docquier and Rapoport (2008) confirmed this result using Docquier and Marfouk's (2006) estimates of emigration rates for the highest (tertiary) education level as their measure of brain drain in a cross-section of 127 developing countries. They obtain an elasticity of 0.054 in the short run and of 0.226 in the long-run, in both their OLS and IV regressions. Taken literally, this means that doubling high-skill emigration prospects multiplies the proportion of highly skilled natives by 1.054 after 10 years and by 1.226 in the long-run. This is not negligible for countries where the average proportion of highly educated people typically lies between 2 to 8 percent. Similar results were obtained using alternative brain drain estimates (controlling for whether migrants acquired their skills in the home or the host country), alternative definitions of human capital (e.g., school enrolment, youth literacy), and alternative functional forms (Beine, Docquier and Rapoport, 2010).

While these results appear robust across specifications, they are obtained in cross-sectional regressions where identification is always disputable. Here we will briefly discuss the two main possible sources of endogeneity bias: reverse causality and omitted variables. First, it could well be that increases in the quantity of human capital are accompanied by increases in its quality, making human capital more internationally transferable and creating spurious positive correlation between human capital

[19] For example, using the 2008 American Community Survey sample, Gibson and McKenzie (2011) calculated that "79 percent of working migrants from developing countries with a bachelors degree or more are working in occupations in which the majority of workers have post-secondary education, as are 90 percent of those with a masters degree or more, and 96 percent of those with a Ph.D. The stereotype of foreign workers with Ph.D.s driving taxis is certainly the exception – only 2 out of 1,936 developing country migrants with Ph.D.s in the ACS sample are taxi drivers".

formation and highly skilled emigration. At the same time, an increase in the number of highly skilled individuals at home can generate an excess supply of skills in the short-run and translate into more emigration. However, the risk of reverse causality is likely to be small given the fact that the dependent variable (human capital investments in the 1990s) barely affected the stock of highly skilled expatriates in 1990. Nevertheless, the reverse causality issue was addressed by Beine et al. (2008) using two sets of instrument variables (population size and networks – measured by emigration stocks in 1990 – with and without racial tensions). Docquier, Faye and Pestieau (2008) use additional instrumental variables such as geographical proximity to developed countries (minimum distance to an OECD country) and indicators of disadvantageous location (dummies for landlocked countries and small islands) in their first stage regressions, with similar qualitative results. Obviously, passing statistical tests is a necessary but not a sufficient condition for instruments validity and there are certainly theoretical reasons why some of the instrumental variables selected might affect human capital formation through channels other than migration prospects. Easterly and Nyarko (2009) use other sets of instruments (former colonial links, population size and distance to the main destinations) for a sample of developing countries; using a growth accounting framework, they find that the brain drain causes (gross) skill creation, and no evidence it causes (net) skill depletion.[20]

Omitted variables and unobserved heterogeneity issues, on the other hand, cannot be addressed properly in a purely cross-sectional setting. They were tackled by Beine, Docquier and Oden-Defoort (2011), who used the Defoort's (2008) dataset to estimate the relationship between migration prospects and human capital formation in a panel setting (six observations per country, one for every five years from 1975 to 2000), controlling for country fixed effects and for the endogeneity of the emigration rate through the use of GMM dynamic estimation techniques. Their results are very similar to those described above, with a significant human capital incentive effect which is stronger for low-income countries. The identification of these incentive effects can certainly be improved: notably, it will be interesting to see whether the existing macro evidence, which points to positive effects of high-skill emigration on gross (or pre-migration) human capital formation in developing countries is confirmed once new rounds of censuses become available.

From the perspective of source countries, however, what matters is not so much the number of people who invest in higher education but the number of educated remaining in the country after emigration is netted out. To address this issue, Beine et al. (2008) used their point estimates to perform counterfactual simulations and compute the net effect of the brain drain for each country and region. The counterfactual experiment consists of equating the high-skill emigration rate to the low-skill emigration rate. As an illustration we will use the following simple numerical exercise: assume a given generation of 100 members, 20 of whom opt of education and half of these then leave the country (i.e., the high-skill emigration rate is 50 percent) while

[20] They also discuss feedback effects in the spirit of section 4.5 below, with a focus on Africa.

out of 80 low-skill workers only 10 leave the country (i.e., the low-skill emigration rate is 12.5 percent). Hence, the emigration rate is 4 times higher for the highly skilled. Assuming this was also the case in the previous generation, then the ex-post, ex-ante and counterfactual human capital stocks are given by $H_p^{2000} = 10/80 = 0.125$, $H_a^{2000} = 0.2$, and $H_{cf}^{2000} = 0.2 - 0.05 * ln(4) = 0.13$. This hypothetical country has a counterfactual stock which is higher than its observed stock; it loses half a percentage point (or four percent) of its human capital as a result of the brain drain. On the whole, the simulations results reveal that the countries experiencing a positive net effect (the 'winners') generally combine low levels of human capital (below 5%) and low high-skill emigration rates (below 20%), whereas the 'losers' are typically characterized by high high-skill migration rates and/or high enrollment rates in higher education. There appear to be more losers than winners, and the losers tend to lose relatively more than the winners gain. The main "globalizers" (e.g., China, India, Indonesia, Brazil) all experience modest gains while many small and medium-size sub-Saharan Africa and Central American countries experience significant losses. However, the absolute gains of the winners exceed the absolute losses of the losers, resulting in an overall gain for the developing world as a whole.

4.2.3 Micro evidence

Evidence of a brain gain effect has also been found at a micro-level. For example, Batista, Lacuesta and Vicente (2011) estimated that in Cape Verde, the brain drain not only has a net positive effect, it is also responsible for the bulk of human capital formation in the country. Similarly, in their survey on Tonga and Papua New Guinea's "best and brightest", Gibson and McKenzie (2011) show that nearly all the very top high-school students (85%) contemplated emigration while still in high school, which led them to take additional classes (e.g., during school vacations, supplementary English classes) and make changes to their course choices (favoring disciplines such as science and commerce). According to Gibson and McKenzie, these substantial brain gain effects combined with high return rates explain the largely positive effects of migration in terms of net human capital formation.

Another micro-example from the Pacific region is provided by Chand and Clemens (2008) who compare the educational investment of ethnic Fijians with that of Fijians of Indian ancestry in the aftermath of the 1987 military coup (which resulted in physical violence and discriminative policies against the Indian minority). The coup sparked massive emigration among highly skilled Indo-Fijians, and led them to invest heavily in higher education in order to "clear the bar" raised by the Australian (and New Zealand) point system. While the political situation has stabilized since the mid-1990s, the Indian minority which remains in Fiji is now significantly more migratory and more educated than comparable ethnic Fijians, which was not the case prior to the military coup. The authors interpret this as quasi-experimental evidence on the brain gain channel. An alternative interpretation could be based on the "option value" argument put forward by Katz and Rapoport (2005) and outlined in the theoretical section above. This argument can be applied to differences in exposure to risk across ethnic or other social groupings within a given country. For example, it can reasonably be argued that ethnic and religious minorities are subject to higher domestic income volatility, be it because they tend to have a less diversified investment portfolio (with more human capital and less physical capital due to the risk of expropriation) or because they may serve as scapegoats in bad economic times, which increases downside risks and, hence, overall income volatility.

4.3 Remittances

For some time now scholars have conjectured that remittances from highly-skilled emigrants can serve to replenish the stock of human capital potentially depleted by the brain drain (e.g., Grubel and Scott, 1966). For this to be the case, we must first understand the remitting behavior of the highly-skilled, and second we must ask whether their remittances are used for education investment. Answering these questions is also important in the current context of increasingly quality-selective immigration policies, which have raised concerns in developing countries as to whether the increasingly high-skill nature of international migration could both hamper the rise in remittances and weaken the share of remittances invested in education.

4.3.1 Theory

The first question has to do with the effect of education on remittances: do the highly-educated remit more? There are many reasons for expecting a positive answer: better educated migrants have a higher income potential, are less likely to be illegal and more likely to have bank accounts and access to less costly transfer means. In addition, their education may have been funded by implicit loans from family members to be repaid with interest in the form of remittances. On the other hand there are also many reasons for expecting a negative answer as more educated migrants often come from richer families and have a higher propensity to migrate with their entire household (hence, less need to send remittances) and a lower propensity to return, reducing the incentives to remit as a way of maintaining prestige and ties to the home community. A priori then, it is not clear whether the highly skilled will remit more or less on average. Regarding the use of remittances, recent literature has emphasized the potential for remittances to relax credit constraints on physical and human capital investments.[21] However, this has been shown for remittances in general, with no specific attention paid to the remittances from highly-skilled individuals.

To translate these discussions into our analytical framework, let us assume that

[21] See Yang (2008) for a convincing identification of the effect of remittances on households' investments, and Rapoport and Docquier (2006) for a comprehensive survey of the literature on migrants' remittances. See also McKenzie and Rapoport (2007) on the dynamics of migration and inequality.

young individuals receive a given amount of remittances, R_t, that for convenience we express as a share r of the foreign wage: $R_t = rw_t^*$. Starting from Equation (7), their income in the first period of life becomes: $w_t + rw_t^* - \widehat{\mu}_t - x_t c w_t$.

The critical level of ability below which education is optimal is clearly increasing in the amount of remittances received:

$$\widehat{c}_t = \left(1 - \frac{\mu - r}{\omega_t}\right) \cdot \left(1 - \frac{\omega_{t+1}^p}{1+\theta}\right) \tag{17}$$

Going back to Figure 4, remittances shift the $H(.)$ curve to the right. However, it is not clear whether remittances sent by high-skill migrants reach the credit-constrained segment of the population. In sum,

Summary 2 *Remittances sent by high-skill migrants may help to overcome liquidity constraints, stimulate education investments and reduce poverty at origin. The size of the effect depends on the amounts transferred and on their distributional impact.*

4.3.2 Evidence

At a macro level, the only empirical studies to look at this issue across a range of countries are two recent papers (Faini, 2007, and Niimi, Ozden, and Schiff, 2010), both of which use cross-country macroeconomic approaches to claim that the highly skilled remit less. Faini (2007) shows that remittances decrease with the proportion of highly skilled individuals among emigrants and concludes "this result suggests that the negative impact of the brain drain cannot be counterbalanced by higher remittances". Faini's result is confirmed by Niimi et al. (2010) after instrumenting the number of emigrants (but treating the proportion of highly skilled as exogenous). Such analyses can at best tell us whether countries which send more (or a larger share of) highly skilled emigrants receive more or less in remittances than countries that send relatively less skilled emigrants. However, there are many other ways that countries differ, and so any correlation between remittances and the skill level observed across countries may be driven by other factors. For example, if poverty is a constraint to both migration and education, we may find richer developing countries being able to send more migrants (yielding more remittances), and that these migrants also have more schooling. Moreover, these studies suffer from the fact that they use migration data for emigrants to the OECD area only while the remittance data are for remittances sent from all over the world, not just the OECD. This creates important potential sources of bias.

At a micro level, Bollard et al. (2011) combine fourteen household survey data on immigrants in eleven destination countries. They show a mixed relationship between education and the likelihood of remitting, but a strong positive relationship between education and the amount remitted conditional on remitting.[22] Combining

[22] There is also a lot of anecdotal evidence that highly skilled emigrants do remit large amounts.

these intensive and extensive margins suggests that education has an overall positive effect on remittances, with an expected amount remitted of $1,000 annually for a migrant with a university degree against $750 for someone without a university degree. The micro-data also allow the reasons why the more educated remit more to be investigated. Bollard et al. (2011) find the higher income earned by migrants, rather than the characteristics of their family situations, explains much of the higher remittances. Note that these results hold for most of the surveys used, and for the pooled sample. In contrast, Dustmann and Mestres (2010) use successive waves of the German Socio-Economic Panel database (one of the fourteen surveys used by Bollard et al., 2011) and show a negative effect of education on remittances after controlling for intentions to return and for household composition at destination.

We can now partially answer the two questions posed at the beginning of this section. As we have seen, the micro and macro studies available give contradictory answers to the first question (as to whether the highly skilled remit more). We conjecture that this could be due to the above mentioned issues in the macro studies but could also be due to sample composition issues in Bollard et al. (2011). Indeed, they find higher expected remittances among the highly skilled in most surveys but lower remittances in a minority of them while the pooled micro data are not necessarily representative of the size and skill structure of global migration. Let us consider for a moment that Bollard et al.'s (2011) results are more trustworthy and give a good approximation of the macro picture. Simple arithmetic suggests that the highly educated, who represent one third of total emigration to the OECD and send home on average 25 percent more than migrants with primary and secondary education, send about 40 percent of total remittances. This is clearly substantial. However, in the absence of surveys matching sending and receiving households and looking at the relationship of interest – not to mention the difficulties in identifying the effect of remittances on children's education –, we have no way of knowing the extent to which these remittances reach credit constrained households.

4.4 Temporary migration and return

4.4.1 Theory

Stark et al. (1997) were first to demonstrate the possibility of a brain gain associated with a brain drain in a context of migration, imperfect information and return. In such a context, low-ability workers invest in education for the purpose of emigrating and being pooled with high-ability workers on the foreign job market. Once individual productivity is revealed, low-ability workers return home with the human capital they would not have acquired if it was not for the possibility of emigration, hence the possibility of a brain gain with a brain drain. Returning migrants may also have

To give just one example, Kangasniemi et al. (2007) report that nearly half of Indian medical doctors working in the UK remit income to their home country and, conditional on remitting, remit on average 16% of their income.

accumulated additional knowledge and financial capital while abroad, so generating additional benefits, especially with respect to technology adoption and productivity growth at home. This idea was formalized by Domingues Dos Santos and Postel-Vinay (2003) in a setting where growth is exogenous at destination and endogenous at origin thanks to the knowledge embodied in migrants returning from the more advanced economy. Dustmann, Fadlon and Weiss (2011) and Mayr and Peri (2009) employ similar theoretical frameworks.

The effect of return migration on productivity can easily be accounted for in our setting by assuming that returnees are endowed with a productivity gain $\eta > 0$ per unit of time spent abroad, which we can denote by a fraction q of their adulthood. The average level of human capital is then given by

$$h_{t+1} = 1 + \frac{\theta}{1+m} \frac{(1-q)\widehat{c}_t(1+\eta q)}{1-q\widehat{c}_t}$$

For a given ex-ante proportion of educated people ($\widehat{c}_t$), temporary migration increases human capital when $\eta > \frac{1-\widehat{c}_t}{1-q}$ (i.e., when η and $\widehat{c}_t$ are large, q is low). Under this condition, the temporary migration of high-skill workers shifts the $H(.)$ curve to the right on Figure 4.[23] The same result obtains indirectly if return migrants facilitate knowledge diffusion and technology spillovers between countries, except that in this case it would be the $W(.)$ curve which would shift upwards in Figure 4. In both cases, return migration is a potential source of growth for the home country.

In terms of the effects on human capital formation, the are qualitatively similar to those obtained with uncertain migration prospects. Indeed, for an educated individual, the expected utility function becomes

$$\begin{aligned} V(1) &= \ln(w_t - \widehat{\mu}_t - cw_t) + \ln\left(qw^*_{t+1} + (1-q)w_{t+1}\right) \\ &\quad + \ln(1+\theta) + \lambda \ln\left(R^*_{t+2}\right) + F \end{aligned} \tag{18}$$

whereas the quasi-indirect utility function for a low-skill worker remains the same as that in an economy without migration.

The critical level of ability below which education is chosen becomes:

$$\widehat{c}_t = \left(1 - \frac{\mu}{\omega_t}\right) \cdot \left(1 - \frac{1}{(1+\theta)(1+\frac{q}{\omega_{t+1}} - q}\right) \tag{19}$$

which is equivalent to Equation (9) when $q = 0$, and increasing in q as soon as $\omega_{t+1} < 1$. This additional effect plays an important role in Dustmann et al. (2011) and Peri and Mayr's (2009) analyses, as well as in Domingues Dos Santos and Postel Vinay's (2004) extension of their 2003 paper. A beneficial brain drain can be obtained if the fraction of time spent abroad (q) is not too large and if the differential in skill prices is neither too large nor too small. In sum,

[23] Note that if η is an increasing function of q, this condition depends on q in an ambiguous way.

Summary 3 *Temporary high-skill emigration is beneficial to the source country if enough additional skills are accumulated abroad, if returnees contribute directly or indirectly to the diffusion of new technologies, and/or if the perspective of temporary migration stimulates education investments ex-ante. A positive net effect is likely to be obtained if the fraction of time spent abroad q is not too large and if the productivity differential with destination countries is neither too large nor too small.*

Note that in the above developments, the migration duration, q, is exogenous, as if return migration were involuntary. More complex models would allow the migration duration to be endogenized, for example under a "savings target" constraint, as proposed in the literature on return migration and access to entrepreneurship back home (e.g., Dustmann and Kirchkamp, 2002, Mesnard, 2004). The same rationale can be applied to highly skilled migrants whose migration is aimed at accumulating managerial skills and gaining access to foreign networks (e.g., Wahba and Zenou, 2009; see also the Indian case study in Section 5.3 below).

4.4.2 Evidence

Are such channels empirically relevant? Return migration is probably the most understudied aspect of international migration. Empirical studies of return migration have focused on assessing the propensity to return at different skill levels. While Borjas and Bratsberg (1996) showed that in general return migration is characterized by negative self-selection, more recent studies have shown mixed patterns. On the whole, return rates among skilled professionals tend to increase with home country skill prices and growth prospects. This is known to be the case for foreign students in the US (Kwok and Leland, 1982, Rosenzweig, 2008) and for UK immigrants (Dustmann and Weiss, 2007). Mayr and Peri (2009), on the other hand, argue that for migrants from Eastern Europe, the human capital acquired while in Western Europe yields a higher premium in the home country (the "return premium"), giving rise to positive selection in return migration. The models in Mayr and Peri (2009) and Dustmann et al. (2011) also clarify the conditions under which a brain gain can be obtained when return migration and schooling decisions are endogenous. Mayr and Peri's model was calibrated and simulated using real data and estimates from the literature; they conclude that an increase in the probability of skilled emigration from 0 to 20 percent, replicating the rise in Eastern European skilled migration during the 1990s, raises average schooling there by one full year after adjusting for the quality of the repatriated human capital.

Destination-based surveys conducted among skilled expatriates generally find high return intentions among interviewees (see for example, Kangasniemi et al. (2007), on Indian medical doctors in the UK, and Bollard et al. (2011), who find that return intentions are similar across skill groups in a wide range of micro surveys).[24] In their survey designed specifically for tracking top students from Tonga, Papua New Guinea

[24] However, there is often a huge gap between intentions and actual returns.

and New Zealand, Gibson and McKenzie (2011) find relatively high rates of return despite the substantial monetary losses entailed and suggest that return decisions are affected by country characteristics and individual considerations beyond income maximization. Many studies have also emphasized the role of return migrants in launching new projects and even whole industries at home. For example, a survey conducted in Taiwan showed that a large fraction of companies in the Hsinchu Science Park (Taipei) had been started by returnees from the USA (Luo and Wang, 2002). The Indian case study in the next section also documents the role of returnees in the rise of the IT sector in India.

4.5 The role of migration and diaspora networks

An important literature emphasizes the potential for migrants to reduce international transaction costs and facilitate the flow of goods, factors, and knowledge between host and home countries. Such migration and diaspora network effects have long been recognized by sociologists and in the early work for the brain drain literature. However, empirical evidence on these channels is quite recent.

4.5.1 Theory

Let us first refine our description of the mechanism through which human capital affects long-run economic growth and the productivity gap between countries. Productivity growth is usually seen as depending on the country's capacity to innovate (γ_t) and adopt modern technologies (g_t). Following Benhabib and Spiegel (2005) and Vandenbussche et al. (2006), the dynamics of productivity can be written as:

$$A_{t+1} = A_t(1+\gamma_t) + g_t(A_t^* - A_t)$$

where A_t^* denotes the level of productivity in the leading developed economy at time t, γ_t measures the productivity gain resulting from innovations, and g_t measures the speed of adoption of leading technologies.

In the leading economy, we simply have $A_{t+1}^* = A_t^*(1+\gamma_t^*)$. It follows that the evolution of the distance to the frontier ($a_t \equiv A_t/A_t^*$) is governed by

$$a_{t+1} = \frac{g_t}{1+\gamma_t^*} + \frac{1+\gamma_t - g_t}{1+\gamma_t^*} \cdot a_t$$

On the balanced growth path, we must have:

$$a_{ss} = \frac{g_{ss}}{\gamma_{ss}^* - \gamma_{ss} + g_{ss}}$$

which is clearly increasing in g_{ss} and γ_{ss}, and decreasing in γ_{ss}^*.

Innovation capacity γ_t is a non-decreasing function of human capital (h_t) with possible increasing marginal returns. Similarly, adoption capacity is an increasing and concave function of human capital. It is likely that the various stages of the education system play different roles in these processes: adoption of foreign technologies requires individuals with strong technical and professional skills developed through secondary or specialized higher education, whereas innovation is research-based and requires the presence of high-level scientists and engineers. Other variables are also likely to have an impact on productivity growth. Innovation depends on country characteristics such as public investments in R&D and in higher education, quality of governance, etc. Adoption depends on subsidies to private R&D and on the intensity of contacts and exchanges with leading countries.

The sociological literature (e.g., Gaillard and Gaillard, 1997, Meyer, 2001) has long recognized that the migration of scientists can facilitate the international diffusion of knowledge and technology be it directly, through brain circulation, or indirectly through the creation and development of networks. For developing countries, this network externality is likely to affect mainly technological adoption. It is a priori unclear whether such externalities depend on the proportion or the number of high-skill natives living in the leading economies. Let us write

$$g_t = g(h_t, pN_{h,t}^{\delta}) \tag{20}$$

with partial derivatives $g_1^{'}, g_2^{'} > 0$. $N_{h,t}$ is the number of high-skill natives (i.e. $\widehat{c}_t N_t$), $pN_{h,t}$ is the number of high-skill emigrants, and $\delta \in [0,1]$ is a parameter. If $\delta = 1$, what matters is the size of the high-skill diaspora abroad; if $\delta < 1$, what matter is the proportion of high-skill natives living abroad.

Assuming $\gamma_{ss} = 0$ and γ_{ss}^{*} is given (i.e., the brain drain from a particular country is too small to affect innovation at destination), the long-run impact of the brain drain on productivity becomes:

$$\frac{\partial a_{ss}}{\partial p} = \frac{\gamma_{ss}^{*}}{(\gamma_{ss}^{*} + g_{ss})^2} \left[g_1^{'} \cdot \frac{\partial h_{ss}}{\partial p} + g_2^{'} \cdot N_{h,t}^{\delta} \right]$$

The first term between brackets can be positive or negative depending whether the incentive mechanism is smaller or larger than the emigration effect (see Equation (14)). The second term is positive and measures technological diaspora externalities.

There are additional network/diaspora effects which are likely to complement the productivity growth effect of technological diffusion. Many recent studies have investigated whether migration favors or discourages trade and FDI. In a standard trade-theoretic framework, the relationship between migration and trade as well as between migration and FDI is a relationship of substitutability. Indeed, trade contributes to factor-price equalization and therefore lowers the incentives for factor mobility; at the same time, factor movements (beyond the Rybszinski cone) reduce price differentials and differences in factor returns and, hence, the scope for trade and further factor flows. However, migrants also reduce international transactions costs; this facilitates the movement of goods and capital between host and home countries. These network externalities have been shown to affect the pattern of trade and FDI and seem to be mainly driven by highly skilled emigration, at least in the case of FDI. They can be captured in our framework through their distinct effects on the two components of the country–risk premium ϕ we introduced in Section 3: international transaction costs, which are borne by foreign potential investors and trade partners only, and an institutional risk related to the level of corruption and the quality of governance, borne by all agents (and also potentially affected by the existence of political diaspora networks, as we shall see).

Using the same notations as above, we can write:

$$\begin{aligned} \phi_t &= \phi(h_t, pN^{\delta}_{h,t}) \\ \frac{\partial \phi_{ss}}{\partial p} &= \phi_1^{'} \cdot \frac{\partial h_{ss}}{\partial p} + \phi_2^{'} \cdot N^{\delta}_{h,t} \end{aligned} \tag{21}$$

with partial derivatives $\phi_1^{'}, \phi_2^{'} < 0$.

These analytical developments are compatible with the *wage-setting* equation (6) and provide a rationale for including diasporas in the set X_t of characteristics affecting the origin country's risk and technology levels. In sum,

Summary 4 *By reducing international transaction costs and facilitating the diffusion of knowledge and ideas, highly-skilled diasporas settled in the developed countries encourage technology diffusion, stimulate trade and FDI and contribute to improving domestic institutions. It is a priori unclear whether such diaspora externalities depend on the proportion or absolute number of highly-skilled emigrants.*

4.5.2 Evidence

The key issue in this literature is the identification of the causal effect of networks. As explained by Manski (1993), the presence of omitted covariates might explain the positive correlation between diaspora size and the dependent variables. Following Munshi (2003), most studies have used instrumental variables estimation techniques to identify network effects.

Business networks: trade and FDI. There are many studies confirming the trade creation effect of migration (e.g., Gould, 1994, Head and Ries, 1998; Rauch and Trindade, 2002, Rauch and Casella, 2003, Combes, Lafourcade and Mayer, 2005). While these studies provide evidence that networks are important in overcoming informal trade barriers (notably, they find that immigrant networks have stronger effects on trade in differentiated products), they do not consider specifically highly skilled migrants. An exception is Felbermayr and Jung (2009), who use bilateral panel data on trade volumes and migration by education levels and find a significant pro-trade effect of migration: a one-percent increase in the bilateral stock of migrants raises bilateral trade by 0.11 percent. However they do not find significant differences across education groups.

In the same vein, we may ask whether FDI and migration are substitutes or complements.[25] The first studies to explore the links between migration and FDI have focused on sectoral or regional case studies. For example, Aroca and Maloney (2005) found a negative correlation between FDI flows and low-skill migration between the border states of Mexico and the United States (i.e., substitutability) while in the spirit of Rauch's work on trade, Tong (2005) finds that ethnic Chinese networks promote FDI between South-East Asian countries and beyond, especially where the institutional quality is relatively high. The first paper to introduce the "skill" dimension of migration in a bilateral setting is Kugler and Rapoport (2007). Using bilateral FDI and migration data, they investigate the relationship between migration and FDI for U.S./rest of the world flows during the 1990s. The dependent variable is the growth rate of the capital stock of a country (for 55 host countries) that is financed by FDI from the US between 1990 and 2000. This is regressed on the stock of migrants in the US originating from country i in 1990, on the log-difference of the change of that stock between 1990 and 2000, and a number of standard control variables. Regional fixed effects and their interaction with migration are also introduced to deal with potential unobserved heterogeneity. Their results show that manufacturing FDI towards a given country is negatively correlated with current low-skill migration, as trade models would predict, while FDI in both the service and manufacturing sectors is positively correlated with the initial U.S. high-skill immigration stock of that country. Javorcik et al. (2011) confirm these results after instrumenting for migration using passport costs and migration networks with a 30-year lag.

Finally, at a micro level, Foley and Kerr (2008) quantify firm-level linkages between high-skill migration to the US and US FDI in the sending countries. They combine US firm-level data on FDI and on patenting by ethnicity of the investors and find robust evidence that firms with higher proportions of their patenting activity performed by inventors from a certain ethnicity subsequently increase their FDI to the origin country of the inventors. They use ethnicity-year fixed effects to control for unobserved heterogeneity, and also instrument the ethnic workforce share in each firm using city-level data on invention growth by ethnicity. They find that a one percent increase in the extent to which a firm's pool of inventors is comprised of a certain ethnicity is associated with a 0.1 percent increase in the share of affiliate activity conducted in the country of origin of that ethnicity. This provides firm-level evidence of a complementary relationship between high-skill immigration and multinational firms' activity.

Scientific networks and technology diffusion. The identification of scientific networks effects is extremely recent. Agrawal et al. (2011) developed a model in which innovation depends on access to knowledge and this in turn depends on access

[25] Interestingly, Buch, Kleinert and Toubal (2006) show that immigration can also attract FDI from the migrants' home country to their host country. Using regional differences in the origin-mix of immigrants to Germany, they show that the presence of immigrants from a given country significantly affects the regional pattern of FDI to Germany.

to both "co-location" and "diaspora" networks.[26] While on average the co-location effect is found to be much larger than the diaspora effect, the diaspora effect is strongest for the most cited patents, which are presumably the ones with the highest social and economic value. Kerr (2008) also uses patent citation data to examine the international transfer of knowledge between the US and the home countries of US-based diasporas. He finds strong evidence of knowledge diffusion along the ethnic diaspora channel, especially for the Chinese diaspora, and evidence that such transfers have a direct positive effect on manufacturing productivity in the home countries, especially in the high-tech sector. Kerr (2008) minimizes the risk of reverse causality by introducing a large set of country-industry and industry-year fixed effects. He also uses an alternative/indirect specification in which ethnic US patents are replaced by exogenous changes in US immigration quotas by country of origin (following the Immigration Act of 1990). The findings of this exercise are qualitatively in line with the results obtained from the direct ethnic patenting approach.

Political networks and effects on institutions. It is also only recently that diaspora externalities in terms of institutional quality and governance and the role of foreign-educated elites on democracy, have been explored. On the one hand, migration and associated remittances offer a safety net and as such can relax economic and political pressures to reform. On the other hand, once abroad, migrants can engage in economic and political activities that affect the institutional development of their home country. In addition, the existence of migration networks abroad increases the home country population's exposure to foreign political norms and values.

The empirical assessment of these effects is still at an early stage and, like the productivity growth channel above, the literature of this topic is limited to just a few working papers. Li and McHale (2009) used the World Bank governance indicators (Kauffman, Kraay and Mastruzzi, 2005) and the Docquier and Marfouk (2006) migration data set in their cross-sectional analysis. Focusing on high-skill migration, they conclude that the brain drain has a positive effect on "political" institutions but a negative effect on "economic" institutions at home. However, the way they dealt with endogeneity (bad institutions leading to more emigration) by using geographic variables to instrument for migration, is problematic as geography affects institutions in a number of ways, not just through migration (e.g., Rodrik, Subramanian and Trebbi, 2004; Acemoglu, Johnson and Robinson, 2005a).

Spilimbergo (2009) and Docquier et al. (2011) consider instead dynamic-panel regressions to investigate the effects of foreign students and of migration/diaspora networks, respectively, on home-country institutions (as measured by standard democracy indices). Following the literature on institutions and human capital (e.g., Acemoglu et al., 2005b), both papers estimate an equation of the type:

$$D_{i,t} = \beta_0 D_{i,t-1} + \beta_1 h_{i,t-1} + \beta_2 m_{i,t-1} + \beta_3 X_{i,t-1} + \eta_i + \alpha_t + \varepsilon_{i,t},$$

[26] To undertake this research, the authors have developed an original data set allowing Indian inventors to be identified by their last names.

where D is a measure of democracy, m is the emigation rate/share of foreign students (interacted with a weighted average of democracy scores at destination in Spilimbergo's paper), h is a measure of human capital, X is a set of time-varying controls, and η_i and α_t are country and time fixed effects. All the lagged variables are predetermined and the estimation uses a rich set of internal instruments (e.g., all variables in levels are instrumented with suitable lags of their own first differences) and combines the regression in differences with the regression in levels in a single system (SYS GMM) (see Bond, Hoeffler and Temple, 2001).

Spilimbergo (2009) finds that foreign-trained individuals promote democracy in their home countries only if the foreign education was acquired in a democratic country. While he does not identify the exact mechanisms through which such an influence takes effect, he suggests a number of possible channels (e.g., the fact that foreign educated leaders and technocrats may want to preserve the quality of their alumni networks by serving reasonably democratic regimes and share a sense of common identity with the international democratic community). More generally, the presence of foreign-educated individuals make it more difficult for dictatorial regimes to maintain repression: repressive activities become more costly since foreign-trained individuals have easier access to external media and foreign governments.

All this can easily be generalized to any individual experience of high-skill emigration and return and adds to the more general channels mentioned above for the effects of migration in general. Indeed, Docquier et al. (2011) find that the level of emigration and the level of human capital both have a strong positive effect on institutional quality in a large sample of developing countries. The marginal effect of brain drain migration is therefore uncertain as high-skill emigration simultaneously increases total emigration and decreases the stock of human capital left in the country. Their numerical simulations of this question show a generally positive but non-significant effect of skilled emigration on democracy at home. However, once incentives effects of emigration on human capital investments are taken into account, a significant institutional gain obtains for a limited number of countries in the short run and for a majority of countries in the longer run.

On the whole, the recent theoretical and empirical brain drain literature shows that high-skill emigration needs not deplete a country's stock of human capital and can generate positive network/diaspora externalities. First and foremost, it shows that the brain drain side of globalization creates winners and losers, as the case studies in Section 5 illustrate, and suggests that the circumstances under which a country gains or loses from the process can, to a large extent, be affected by public policy, as discussed in Section 6.

5 Case studies

The previous section showed that the brain drain is a diverse phenomenon, which can constrain the development potential of some countries and enhance the economic performances of others. This section briefly presents three case studies that illustrate the various facets of the brain drain and analyzes them within our theoretical framework.[27] While the rest of this paper uses a broad definition of high-skill migration, turning to case studies is an opportunity to put the focus on specific professions and occupations. African medical doctors, European scientists and researchers, and Indian IT specialists differ in many respects but they also have many things in common, notably their very high emigration rates, and the fact that they are or have been viewed as emblematic of the worst types of brain drain. African doctors in London, Lisbon or Paris still experience a good deal of opprobrium from public opinion. To a large extent, the same holds true for the exodus of Europeans researchers and scientists. Expatriated Indian engineers and IT professionals were long been accused of being traitors to the national cause before the contribution of the resulting diaspora to the Indian growth miracle became acknowledged and, indeed, celebrated.

5.1 Africa's medical brain drain

It is common to point to the medical brain drain (MBD) as one of the major factors leading to the under-provision of healthcare staff in Africa and, ultimately, to low health status and shorter life expectancy (e.g., Bundred and Levitt, 2000). Two data sets can be used to document the emigration of African physicians: Clemens and Pettersson (2006), who collected data on foreign-born physicians and nurses from nine destination countries in 2000 (UK, US, France, Australia, Canada, Portugal, Belgium, Spain and South Africa); and Bhargava and Docquier (2006), who used the same methodology but collected data from 18 countries (17 OECD countries plus South Africa), defined migrants according to their country of training, and had a larger geographic (not just Africa) and temporal (yearly observations for 1991-2004) coverage. Regional comparisons reveal that the medical brain drain is highest in sub-Saharan Africa (with average rates above 20% compared to 13% in South-Asia and less than 10% in the other regions). The figures are relatively stable over the period.

Determinants of the medical brain drain. Surveys of African doctors and empirical analyses of the determinants of the MBD in Africa deliver similar results on the push and pull factors involved. For example, among the physicians surveyed by Awases et al. (2003) in six African countries, 50 percent declared that they were contemplating emigration to gain access to better wages, working conditions and lifestyles, while the risks associated with caring for HIV/AIDS patients were often mentioned as an important push factor. Bhargava and Docquier (2008) analyzed the determinants of the African MBD empirically (using their data set described above) and found that countries with lower pay for doctors, higher enrollment in secondary education, and higher HIV prevalence have higher MBD rates.

Is there a medical brain gain? In the spirit of section 4.2 above, we may ask whether the prospect of emigration generates enough incentives to induce a net

[27] The factual aspects are taken from Docquier and Rapoport (2009a).

medical brain gain. Three studies have investigated this issue empirically: Clemens (2007), who used a cross section of 53 African countries, Chojnicki and Oden-Defoort (2011), and Bhargava, Docquier and Moullan (2011), who both used a panel setting. Regressing the log of domestic doctors per capita on the log of medical doctor emigrants per capita, Clemens (2007) found a positive correlation of .7. However, the effect of emigration becomes insignificant once controls such as GDP per capita, school enrolment and ethnic conflicts are introduced and the number of emigrant physicians is instrumented using country size and linguistic links. This suggests that emigration does not create a shortage of medical doctors in Africa, a finding Clemens attributes to the positive effect of emigration on enrolment in medical schools.[28] Bhargava et al. (2011) use random-effect models to investigate possible brain gains in the medical sector, following Beine et al.'s (2008) empirical specification. Although their model also suggests that migration prospects have a positive effect on medical training, the magnitude appears too small to generate a net brain gain in the medical sector. This implies that stopping the medical brain drain would increase staffing levels in developing countries. The effect is convex in the rate of the medical brain drain.

Impact on health. Given the lack of strong evidence of brain gain (or loss) in the African medical sector, another route is to enquire whether the MBD is responsible for the bad health outcomes of Africa. A positive answer would be consistent with the view that the MBD is not just about the quantity of doctors remaining in the continent, but also about their quality. Using the methodology described above, Clemens (2007) found no evidence for a causal impact of the number of physicians and nurses abroad on child mortality, infant mortality under the age of one, vaccination rates, or the prevalence of acute respiratory infections in children under the age of five. Chauvet, Gubert and Mesplé-Somps (2008) investigated the determinants of child mortality in a sample of 98 developing countries between 1987 and 2004 and also found the number of physicians per 1,000 people to have no significant impact. However, the MBD was found to significantly deteriorate child health indicators, suggesting that emigrants positively self-select out of the physicians' population, with only the most talented obtaining a qualification abroad and leaving. Bhargava and Docquier (2008) found that the MBD appears to have additional detrimental effects: a doubling of the MBD rate is associated with a 20 percent increase in adult deaths from AIDS. Finally, Bhargava et al. (2011) used numerical simulations to investigate the effect of medical emigration on infant mortality and vaccination rates in developing countries. Although the medical brain drain reduces the supply of doctors in the home country, they show that stopping it would only produce a marginal improvement in health outcomes unless the supply of complementary inputs (e.g., medical infrastructures,

[28] This could also be due to omitted variables such as the size and quality of the medical training system. Our computations reveal strong correlations between country size and both the number of medical schools (.82) and the annual number of domestically-trained medical graduates (.6). In addition, the number of schools and graduates is significantly higher in English-speaking countries. Hence, country size and linguistic links might have a direct impact on the domestic supply of doctors.

availability of drugs, number of nurses) were also increased.

5.2 Europe and the global competition for talent

Where does Europe stand? In the race for innovation and economic leadership, Europe clearly lags behind the US: it produces more science graduates per capita (PhDs), but has fewer researchers (5.36 per 1,000 workers against 8.66), a gap which, as we shall see, is largely dues to the exodus of European researchers. Using bilateral data in Docquier, Lowell and Marfouk (2009), we find that by 2000 the EU15 suffered a net loss of 0.120 million tertiary educated workers to the rest of the world. This constitutes a tiny 0.3 percent of the European highly skilled labor force. However it should be compared to the huge combined gains (12.5 percent of the highly skilled labor force) of the US, Australia, Canada and New Zealand. The deficit vis-à-vis these countries is enormous: 2.6 million individuals in 2000, a gap which is almost certainly due to the impact of wage premiums, differential income taxes, and the other push and pull factors reviewed in Section 2.2.

Quantitatively, the net deficit of the EU15 is low because the losses to the other developed countries are compensated for by the substantial migration of highly skilled workers from developing countries. Qualitatively, the picture is darker for two reasons: first, immigrants are usually less productive than natives with similar formal levels of education, with the difference being greatest for workers from low-income countries (Coulombe and Tremblay, 2009); and second, the European brain drain affects top-skill workers. Table 5 shows brain drain rates from Europe to the US for PhD holders and for researchers employed in science and technology. To make the figures comparable with the DLM brain drain indicators, they are expressed as a proportion of the total number of researchers/PhD holders employed in the country of origin and in the US. The brain drain of PhD holders and researchers employed in science and technology (S&T) is strongly correlated with the general brain drain (.33 and .74 respectively) but is on average 2.2 and 5.3 times larger. In other words, European high-skill emigration to the US is strongly biased towards the most highly qualified workers. An aggravating factor is that the return rates to all large European countries except the UK decreased during the 1990s (Tritah, 2008).

EU's brain drain and R&D policy. In the same way that we asked whether the medical brain drain was responsible for Africa's bad health outcomes, we may ask whether the exodus of European scientists is to blame for Europe's poor record in research and development. A hint that the causality could well go the other way is given by Tritah (2008), who showed that European emigrants increasingly come from the occupations that matter the most for the knowledge economy (engineers, researchers and academic personnel) and that "countries that have increased their R&D spending more in proportion to their GDP are also those whose expatriation of scientists and engineers to the United States has increased the least". Based on an estimated supply and demand framework, Tritah found the brain drain to be a symptom of the lack of demand for high-skill labor in Europe. This corroborates the results from opinion surveys of European researchers, who consistently complain that low investments in R&D translate into low wages for scientists, unstable or unattractive jobs, and an excessive load of administrative tasks. On the whole, the picture in Europe is that of a lack of incentives to enroll in graduate studies in science and technology; and yet Europe consistently trains more PhDs in these fields that the United States. While this persistent gap between the supply and demand of researchers in Europe can be explained by a host of potential factors, it is consistent with the theory that the brain drain both provides additional incentives to invest in education and absorbs the excess domestic supply of European scientists and researchers.

Table 5. The brain drain of European scientists from selected countries to the US (%)

Country of birth	College graduates[a]	PhD holders[b]	Researchers in S&T[c]
Austria	3.7	4.2	12.6
Belgium	1.0	2.3	12.9
Denmark	2.3	4.8	9.3
Finland	1.3	1.4	1.9
France	1.0	2.8	7.6
Germany	2.4	2.7	18.0
Greece	4.2	8.5	28.4
Ireland	10.6	16.0	33.0
Italy	3.2	2.6	17.0
Netherlands	2.3	3.1	15.6
Spain	1.1	1.9	n.a.
Sweden	1.8	1.6	6.7
United Kingdom	4.8	6.2	29.0
Czech Republic	2.7	3.9	12.5
Hungary	4.7	12.5	24.9
Latvia	4.7	8.7	45.3
Lithuania	3.2	5.6	24.3
Poland	5.7	5.7	n.a.
Romania	4.1	4.8	34.4
Japan	0.9	1.8	4.9
China	2.1	22.8	14.9

Sources: [a] Emigration rates of college graduates; source: DLM (2009). [b] Emigration rates of PhD holders; based on SESTAT (NSF) and UNESCO data. [c] Emigration rates of researchers in S&T; based on SESTAT and OECD main S&T indicators

5.3 The Indian diaspora and the rise of India's IT sector[29]

The Indian-born population in the US doubled (from one half to one million) in the 1990s, with half of the increase being due to the arrival of highly skilled workers. Table 2 shows that there were more than a million highly skilled Indian emigrants worldwide in 2000, placing India second only to the Philippines among developing countries (and almost on a par with the Philippines after excluding people arrived before age 22 – see Table 3). As is well known, Indians also represent the bulk of H1-B visas holders in the US, a visa category aimed at skilled professionals in sectors with occupational shortages (in practice, IT specialists).

The presence of highly educated Indians among the business, scientific and academic elites of the UK, the US, and other Western countries is impressive and has long been both a matter of national pride and of persistent concern. Echoing this ambivalence, Desai et al. (2009) evaluated the fiscal cost of the brain drain for India at 0.5 percent of the Indian GDP (or 2.5 percent of total Indian fiscal revenues), a conservative estimate in their view. However, their computations are based on the assumption that all Indian engineers abroad would have worked as engineers in India, and would have engaged in engineering studies in the first place, which is disputable. If one assumes that in alternative occupations their wages would have been lower, then their figures for the fiscal loss can equally reasonably be seen as an upper bound. On the other hand, the fact that many Indian engineering graduates end up in managerial jobs (for example, 52 percent of the graduates of IIT-Bombay of 2005-6 ended up in consulting and finance), which pay much better than engineering. Perhaps more importantly, if the loss is not that of engineers per se but a selection bias in which entrepreneurial talent is lost, then the tax losses are on corporate and VAT/sales taxes rather than income taxes. In any event, recent years have seen a gradual reversal in media and public attitudes in India,[30] and it is now common to celebrate the contribution of the Indian diaspora to the country's industrial and economic success.

We will focus here on the role of the Indian diaspora, especially that established in the Silicon Valley, in the rise of the IT sector in India. Studies pointing to the role of the Indian diaspora in the rise of the software industry in India include Saxenian's (1999, 2002) well-known work. She noted the large numbers of Indian (and Chinese) entrepreneurs in the Silicon Valley: Indians were shown to run 9 percent of Silicon Valley start-ups in the period 1995-98, a majority of which (nearly 70 percent) were in the software sector.[31] Saxenian (2002) also documented their strong business links

[29] We are indebted to Devesh Kapur, Binod Khadria, and Ramana Nanda for references, comments and discussions on this case-study.

[30] Khadria's (1999) book on India's "migration of knowledge workers" also contributed to this change by emphasizing that human capital can return without people physically returning and by discussing the policy environment conducive to such circulation.

[31] A more recent survey (Wadhwa et al., 2007) shows Indian immigrants now outnumber Chinese immigrants as founders of engineering and technology companies in the Silicon Valley, with Indians being key founders of 15.5 percent of all Silicon Valley startups.

with India: 52 percent of the Indian entrepreneurs travelled to India for business purposes at least once a year, 27 percent reported regularly exchanging information on jobs/business opportunities and on technology with people back home, 46 percent had been a contact for domestic Indian businesses, 23 percent had invested their own money into Indian start-ups, and 45 percent reported that is was likely that they would return to live in India. These results are based on a non-representative sample (due to self-selection into the professional associations surveyed and to the group of respondents) but are nevertheless suggestive of very strong connections to India.

The role of the Indian diaspora has been singled out as a primary factor of India's emergence onto the global IT scene, notably by Kapur (2010), whose account can be linked to our general arguments. First, India's brain drain provided foreign investors with information on the Indian labor force, sparking demands for Indian IT specialists in countries without experience of Indian migrants (e.g., Germany, Japan) as well as international demand for IT services exported from India.[32] Two closely related factors probably contributed to the visibility of the Indian IT professionals: the Y2K bug problem, which led many organizations to engage primarily Indian staff to solve this issue; and the presence (thanks to the first wave of brain drain) of Indian managers working in the IT departments of large US/European companies, who then got in touch with people they knew in India (and vouched for their quality). This is in line with our description of the transaction cost channel, especially with the argument in Section 4.5.1 that migrant workers convey information through their presence in the host countries labor markets and are key to establishing business links.

Second, India's brain drain helped diffuse knowledge through a variety of mechanisms: skill upgrading for those working in the US, with diffusion to India through return migration and brain circulation.[33] This may have been driven, in part, by the recession following the dot-com bust (when many skilled professionals were without jobs and returned home), and the simultaneous take-off of the Indian economy following the reforms of the early 1990s. These reforms were driven by macro-economic factors such as a balance of payments crisis. The reduction in import restrictions after the opening up of the economy also contributed to the growth of the software and service industries and allowed the entry of multinational corporations who began paying dollar-equivalent salaries in rupees (which was incredibly attractive on a PPP basis). This is a perfect illustration of the knowledge and technology diffusion channel, as well as of the brain circulation or return migration with additional repatriated skills and human capital (Sections 4.4 and 4.5.2).

Third, the diaspora has been a decisive factor in setting up effective sectoral institutions and formal networks. The national association of software and service companies (NASSCOM) had several returnees as prominent advisors of board members and

[32] See also Banerjee and Duflo (2000).

[33] This is confirmed by a recent comprehensive survey of India's software industry, showing that 30 to 40 percent of the higher-level employees have relevant work experience in a developed country (Commander et al., 2008).

helped raise the profile of the industry in India and abroad. Another organization (TiE – the Indus entrepreneur) also helped to provide a forum for aspiring entrepreneurs of Indian origin, first in the US and then in India. These institutions and networks also helped to lobby for a better framework for entrepreneurship in India, and successfully lobbied the Indian government to change the regulatory framework for venture capital. This exemplifies the type of institutional reform leading to better regulations and more effective economic and political institutions that we emphasized and documented in Section 4.5.3 on political networks. While this example is restricted to a particular sector, it is not difficult to imagine that once such lobbying organizations are in place, with their set-up costs already met, they can also be activated towards achieving broader political and institutional reforms.

And fourth, instead of developing a protectionist attitude by trying to keep engineers and IT specialists at home, the Indian industry realized the benefits of foreign experience and supported an increase in the number of H1-B visas for Indian professionals in the US. The reason for this lies in changes in the market structure of the global IT industry, itself a lagged effect of previous emigration. Ten of the largest twenty-five companies hiring foreign nationals with H-1B visas are IT firms based in India or US-based IT firms run by Indian nationals. This can clearly be interpreted along the lines suggested in our Sections 4.2 (on endogenous human capital formation) and 4.4. (on return migration).

All this demonstrates the crucial role played by the Indian diaspora at the onset of the IT revolution which took place in the 1990s and in the later phases. India's IT revolution is already well advanced, and this raises the question of whether the diaspora will maintain its leading role or simply serve as an adjuvant in the coming phases. The findings from a recent survey sent to all the CEOs of Indian software firms are probably indicative of such qualitative changes. Indeed, Nanda and Khanna (2010) found that while entrepreneurs who live in hubs do not necessarily gain significantly from diaspora networks, having personal experience abroad allows entrepreneurs based in smaller cities, with weaker networking and financing environments, to gain access to business and financial opportunities through diaspora networks. They conclude that brain circulation is crucial: such networks are successful not just because of the expatriates who live abroad, but because some of them have returned back home and learned how to effectively tap into the diaspora.

6 Policy implications

Should emigration countries rethink their education policy in the face of the brain drain? Are immigration policies in receiving countries at odds with their aid and development policies? Is a "tax on brains" required (or feasible) for a better sharing of the global surplus arising from international high-skill migration? To address these policy issues within our framework we will assume that the implicit social welfare function guiding government intervention is to maximize efficiency as measured by

GDP per capita in source countries.[34]

6.1 Education policy in sending countries

Given that the social return to education is higher than its private return, education subsidies can in theory be, and are in practice used to address human capital externalities. Should they be adjusted in the context of a brain drain? This issue has been addressed in a few recent studies, first by Stark and Wang (2002) who explored how migration and education subsidies may be substituted for as policy tools. Docquier et al. (2008) refine the argument and provide empirical evidence showing that it is true that public expenditure on education is lower in high-skill emigration countries, including after instrumenting for emigration. Poutvaara (2008) proposes a theoretical model where the brain drain distorts the provision of public education away from internationally transferable education (e.g., exact sciences, engineering, economics, medical professions) and towards country-specific skills (e.g., law), with the source country possibly ending up training too few engineers and too many lawyers; he then demonstrates that such a negative outcome could be avoided by introducing graduate taxes or income-contingent loans to be (re)paid if the student subsequently emigrated.

To address this question, we introduce education policy into our model. Suppose the government subsidizes education by covering a fraction σ of the education cost and levies a proportional income tax on resident highly skilled workers. Compared to Equation (13), the expected utility for an educated worker becomes:

$$\begin{aligned} V(1) &= \ln\left(w_t - \widehat{\mu}_t - (1-\sigma)cw_t\right) + p\ln\left(w^*_{t+1}(1+\theta)\right) + \\ & (1-p)\ln\left(w_{t+1}(1-\tau)(1+\theta)\right) + \lambda\ln\left(R^*_{t+2}\right) + F \end{aligned} \tag{22}$$

while the quasi-indirect utility function for a low-skill worker $V(0)$ remains identical to that in an economy without migration (see Equation (8) with $x_t = 0$).

The critical level of ability below which education is optimal becomes:

$$\widehat{c}_t = \left(1 - \frac{\mu}{\omega_t}\right) \cdot \frac{1}{1-\sigma} \cdot \left(1 - \frac{\omega^p_{t+1}}{(1+\theta)(1-\tau)^{p-1}}\right) \tag{23}$$

If $\sigma = \tau = 0$, we obtain the closed economy level in Equation (15). The critical ability level $\widehat{c}_t$ increases with σ and decreases with τ (at least if $p < 1$).

The no-deficit condition can be written:

$$(1-p)\widehat{c}_{t-1}\tau \geq (1+m)\sigma\frac{\widehat{c}_t}{2} \tag{24}$$

where $\frac{\widehat{c}_t}{2}$ is the average ability level of the young educated and $1+m$ is the number of young per adult. For a given rate of brain drain p, the education policy allows

[34] See however Docquier and Rapoport (2009b) for a discussion of the possible efficiency-equity tradeoffs which would arise from more complex social welfare functions.

for increasing human capital when the critical ability level in (23) exceeds the no-intervention level in (15). This requires:

$$\sigma \geq \frac{\frac{1}{(1-\tau)^{1-p}} - 1}{\frac{1+\theta}{\omega_{t+1}^{p}} - 1} \equiv \sigma_{\min}(\tau),$$

and, on the balanced growth path ($\widehat{c}_{t-1} = \widehat{c}_t$), the no-deficit condition (24) requires

$$\sigma \leq \frac{2(1-p)\tau}{1+m} \equiv \sigma_{\max}(\tau).$$

The function $\sigma_{\min}(\tau)$ represents the set of improving education policies; it is increasing and convex in τ. The function $\sigma_{\max}(\tau)$ represents the set of feasible education policies; it is increasing and linear in τ. Figure 5 represents these two functions for two possible values of p: the black curves depict the closed economy case ($p = 0$) and the grey curves a case where some brain drain takes place. Clearly, the brain drain shifts the $\sigma_{\min}(\tau)$ and $\sigma_{\max}(\tau)$ curves downwards: for each possible tax rate, it reduces $\sigma_{\min}(\tau)$, the minimum subsidy rate required to stimulate human capital formation. The reason is that educated individuals now anticipate that they will only pay domestic taxes with probability $1 - p$. It also reduces $\sigma_{\max}(\tau)$, the maximum subsidy rate balancing the budget constraint. In other words, the brain drain expands the set of improving tax rates and reduces the set of feasible subsidy rates.

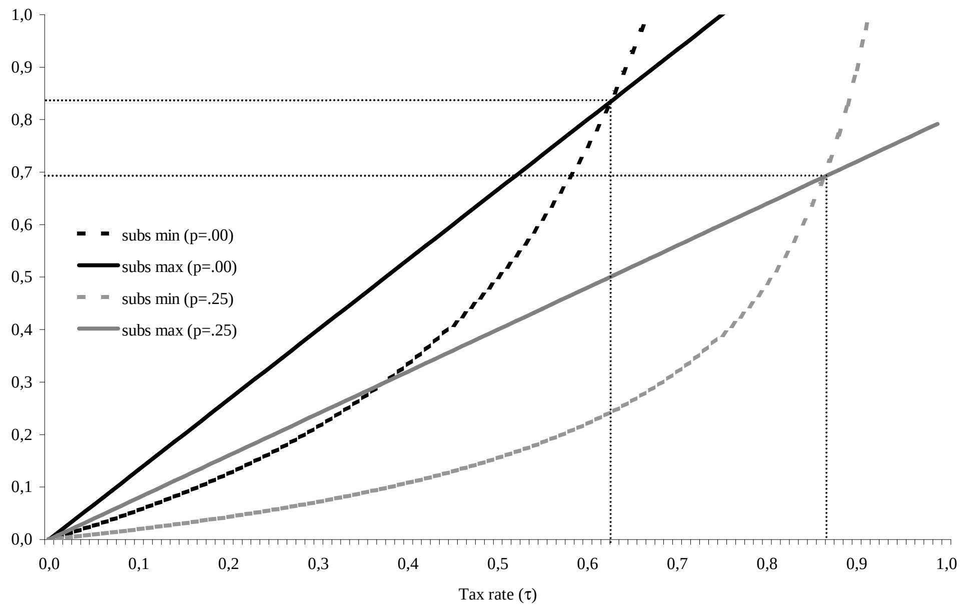
These analytical developments suggest that governments should react to the departure of the highly educated by adjusting the public supply of higher education.[35] As Figure 5 suggests, the feasible education subsidy rates decrease and the tax rates required to balance the budget increase with high-skill emigration. Cutting subsidies (possibly in particular fields) is therefore likely to be the appropriate policy response in a context of high brain drain. Other possible routes include promoting foreign education, adjusting education quality, or having a strategy of exporting skilled professionals. We briefly discuss these possibilities below.

Home governments can free ride on destination countries' foreign education programs, and encourage students to get their education abroad. This certainly represents a source of fiscal gain, especially for small countries suffering from very high emigration rates. On the other hand, outsourcing tertiary education makes access to education more unequal and, as emphasized by Rosenzweig (2005), foreign education gives its possessors a better chance of finding a job in the training country. This means that student mobility is likely to further increase the brain drain. Alternatively, home governments can increase education expenditures and improve the quality of domestic higher education institutions to retain more students, for example through quality-assurance programs (i.e., certification of the quality of higher education by national

[35] A possible endogenous policy response in source countries is to adjust the supply of public infrastructure (Grossman and Stadelmann, 2011).

or international agencies). Such a strategy is aimed at reducing uncertainty about education quality (while at the same time making it more transportable internationally) and has been adopted in a number of Asian and Latin American countries.[36] Finally, the government can disengage from higher education and encourage the emergence of private universities and professional schools. The Philippines are often cited as an example of such disengagement coupled with a deliberate strategy of exporting skilled workers.[37]While it is beyond the scope of our stylized model to show which route is preferable, this discussion suggests that the answer depends on the extent to which the quality of domestic education affects the transferability of human capital. It also suggests that policy responses need not be uniform as countries with different characteristics will have different optimal strategies.

Figure 5. Brain drain and the feasibility of an improving education policy



Notes. The tax rate τ is on the horizontal axis and the subsidy rate σ on the vertical axis. The "subs min" curve depicts $\sigma_{\min}$ as a function of τ and defines the set of improving education policies. The "subs max" curve depicts $\sigma_{\max}$ as a function of τ and defines the set of feasible education policies. The black curves represent the no-migration case and the grey curves an economy with $p = .25$. Simulations are based on $\omega = .4$, $\theta = 2$ and $m = .5$.

[36]See Lien (2008) for examples and a theoretical discussion of the effects of such programs.

[37]Observing the very high rates of enrolment in higher education in the Philippines in spite of the low domestic returns to human capital, Lucas (2004) commented: “It is difficult to believe that these high, privately financed enrolment rates are not induced by the possibility of emigration. There are signs that the choice of major field of study ... responds to shifts in international demands. Higher education is almost certainly induced to a significant extent by the potential for emigration”.

6.2 Immigration (and emigration) policy

The implications of this analysis for migration policy are also far reaching. Provided that Condition (16) holds, Equations (14) and (15) determine the brain drain rate maximizing human capital accumulation at origin, p^*. This rate satisfies:

$$\begin{aligned} 0 &= (1-p^*)\frac{\partial \widehat{c}_t}{\partial p} - \widehat{c}_t(1-\widehat{c}_t) \\ \frac{\partial \widehat{c}_t}{\partial p} &= \left(1-\frac{\mu}{\omega_t}\right)\cdot\frac{\omega_{t+1}^{p^*}\ln\omega_{t+1}^{-1}}{1+\theta} \end{aligned}$$

This gives the following implicit condition:

$$(1-p^*)\frac{\omega_{t+1}^{p^*}\ln\omega_{t+1}^{-1}}{1+\theta} - \left(1-\frac{\omega_{t+1}^{p^*}}{1+\theta}\right)\left[1-\left(1-\frac{\mu}{\omega_t}\right)\left(1-\frac{\omega_{t+1}^{p^*}}{1+\theta}\right)\right]$$

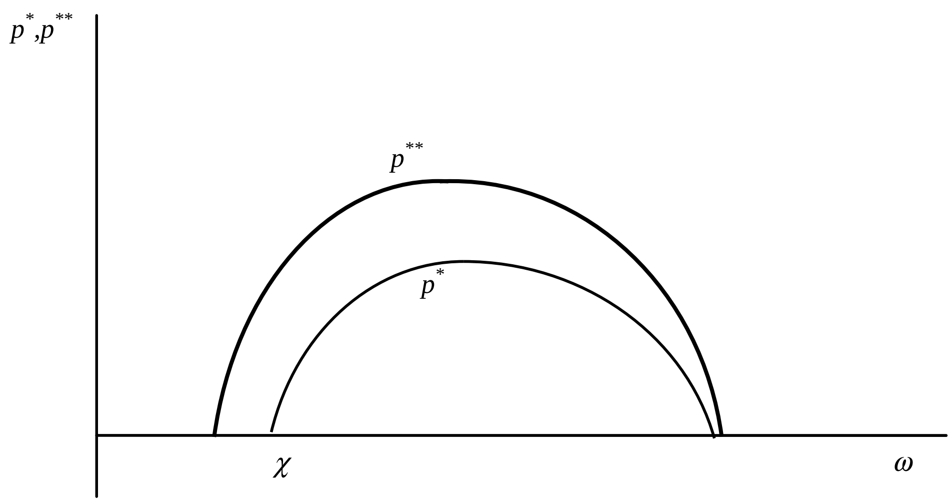
Using the implicit function theorem, it can easily be shown that $\frac{\partial p^*}{\partial \omega} < 0$ for $\mu = 0$. This result is intuitive: in the absence of liquidity constraints, the incentive mechanism is stronger in poorer countries and the optimal brain drain rate decreases with the level of development. When μ is positive, the incentive mechanism is less strong in poor countries. If $\frac{\mu}{\omega_t}$ is such that condition (16) does not hold (i.e., if $\frac{\mu}{\omega_t}$ exceeds some critical value χ), $p^* = 0$. When Condition (16) holds but $\frac{\mu}{\omega_t}$ is slightly lower than χ, we have $\frac{\partial p^*}{\partial \omega} > 0$. In sum, p^* is an inverted-U shaped function of the wage ratio ω. It increases with development at low levels of development but decreases at higher stages of development (see Figure 6).

In analyzing p^*, we will focus on human capital accumulation but disregard other feedback effects such as remittances and diaspora/network externalities. Introducing these additional feedback effects would increase the optimal rate of emigration to $p^{**} > p^*$. The difference between p^{**} and p^* is also likely to depend on the country's distance to the technological frontier (because adoption externalities are more important at lower stages of development) and on other characteristics such as institutional quality, especially if diaspora size and geographic proximity matter for network externalities.

From the perspective of developing countries, the main implication of this result is that the optimal emigration rate of their highly educated population is likely to be positive (at least at intermediate levels of development), which implies that imposing restrictions on the international mobility of educated residents could actually decrease the long-run level of their human capital. From the perspective of receiving countries, the main implication is that selective immigration policies aimed at attracting the highly educated and skilled may or may not contradict the objectives of their aid and development policies. However, there is little a host country can do to alter the origin-mix of its immigrants as diaspora networks and invariant bilateral variables largely explain the size and skill composition of their immigration (see Section 2.2).

For the sake of illustration, let us briefly analyze the origin-mix of highly skilled immigrants to Western Europe (EU15). Europe is currently less selective than the United States and other traditional immigration countries and therefore has greater potential for more selectivity. Given what we know from cross-country analyzes on the push and pull factors of migration, a change in European immigration policies (such as the introduction of point-systems or similar selection devices) will primarily affect the traditional suppliers of skills to the European economy. Europe disproportionately attracts migrants from demographically small, economically poor, and institutionally disadvantaged countries, especially African ones. These countries are typically those negatively affected by the brain drain and they are often lacking the characteristics required to enjoy positive interactions with diaspora networks. Hence, they would suffer from immigration policy becoming both more restrictive (i.e., discouraging low-skill immigration) and more quality-selective (i.e., favoring high-skill immigration) in Europe. Conversely, the United States have a much less quality-selective immigration policy than Canada or Australia, and many immigration reformers in the U.S. advocate going to a point system (e.g., Borjas, 1999). To the extent that most US immigrants come from large, fairly globalized economies, an increase in high-skill emigration from these countries would not necessarily harm them; they would certainly suffer, however, if the U.S. immigration policy becomes more restrictive.

Figure 6. Optimal rate of high-skill emigration and development



Notes. The p^* curve gives the high-skill emigration rate maximizing human capital accumulation in the source country as a function of the development level, ω. Idem for p^{**} once remittances and diaspora externalities are taken into account.

6.3 Taxation policy: the case for a Bhagwati tax

The idea of a "tax on brains" was first proposed in the 1970s by Jagdish Bhagwati. He argued that: i) it should be an income tax paid by highly skilled emigrants on top of their regular income tax, with its proceeds transferred to the home country government; ii) the rationale for the tax is double: compensation (for the negative externality imposed on those left behind and on home governments for their public funding of education), and equity (through redistributing the rents accruing to skilled emigrants as a result of restrictions on international labor mobility).

How does a Bhagwati tax fit into our model? Consider the economy described in Section 6.1 and assume the foreign wage of high-skill emigrants is taxed at a rate T. The expected utility function of educated individuals becomes:

$$\begin{aligned} V(1) &= \ln\left(w_t - \widehat{\mu}_t - (1-\sigma)cw_t\right) + p\ln\left(w^*_{t+1}(1-T)(1+\theta)\right) + \\ &\quad (1-p)\ln\left(w_{t+1}(1-\tau)(1+\theta)\right) + \lambda\ln\left(R^*_{t+2}\right) + F \end{aligned} \tag{25}$$

while the quasi-indirect utility function for a low-skill worker $V(0)$ remains identical to that in an economy without migration (see Equation (8)).

In this situation individuals invest in education if its cost is below

$$\widehat{c}_t = \left(1 - \frac{\mu}{\omega_t}\right) \cdot \frac{1}{1-\sigma} \cdot \left(1 - \frac{\omega^p_{t+1}}{(1+\theta)(1-\tau)^{1-p}(1+T)^p}\right), \tag{26}$$

The budget constraint of the government becomes

$$(1-p)\widehat{c}_{t-1}\tau\omega_t + p\widehat{c}_{t-1}T \geq (1+m)\sigma\frac{\widehat{c}_t}{2}\omega_t, \tag{27}$$

assuming that the proceeds from the tax are fully allocated to education policy.

Introducing a Bhagwati tax requires cooperation between the home and host country governments. We assume such cooperation takes emigration rates as exogenous but allows for fiscal adjustments. It is reasonable to assume that for a given emigration probability p, the government at destination chooses taxes T to maximize the number of high-skill emigrants $p\widehat{c}_t$. The government at home, on the other hand, chooses taxes τ to maximize the number of educated adults remaining, $\frac{(1-p)\widehat{c}_t}{1-p\widehat{c}_t}$. In both cases, their objective is to maximize $\widehat{c}_t$ subject to Constraint (27) and to an incentive compatibility constraint: the net income of emigrants should exceed the net income of the home country residents: $(1-T) > (1-\tau)\omega$.

Substituting (27) into (26) and assuming a balanced growth equilibrium ($\widehat{c}_t = \widehat{c}_{t-1}$), the joint maximization problem of the goverments at origin and destination can be written as

$$\underset{\tau,T}{Max}\left\{\frac{1+m}{1+m-2(1-p)\tau-2p\frac{T}{\omega_{ss}}} \cdot \left(1 - \frac{\omega^p_{ss}}{(1+\theta)(1-\tau)^{1-p}(1+T)^p}\right)\right\}$$

An interior solution (τ^*, T^*) to this optimization problem requires

$$\omega_{ss}(1 - T^*) = (1 - \tau^*), \tag{28}$$

which clearly satisfies the incentive-compatibility constraint. In particular, a positive Bhagwati tax (from the point of view of the destination country) is obtained when $t > 1 - \omega_{ss}$, that is, when the tax rate in the country of origin is large enough and when the distance to the frontier is not too large.

In its current version, the Bhagwati tax proposal goes part of the way towards addressing the various objections raised at different stages of its formulation. The main issues currently discussed are whether the tax should be administered at a bilateral level or by some international authority (see McHale, 2009), and whether it should be based on a compensation principle. As noted by Bhagwati (2009), there may be no need for compensation as education is often privately financed and/or acquired abroad. In addition, many highly skilled emigrants would be unemployed or ineffectively employed at home, while others emigrate to escape corruption, violence, and economic discriminations – conditions which should certainly not be encouraged by fiscal compensations.[38] It has also been argued the Bhagwati tax is equivalent to an exit tax and represents a form of extortion. In its latest version, therefore, the tax is basically one on retained citizenship (i.e., emigrants can avoid paying the tax by voluntarily forfeiting their citizenship). However, the countries whose emigrants would be happy to renounce their citizenship are precisely those whose characteristics are conducive to a detrimental brain drain. This suggests that opting for a compensating mechanism on a voluntary basis may prove impossible in practice. Finally, the very principle of compensation can be questioned as many developing countries appear to actually benefit from high-skill emigration. Even though there is now a growing consensus that the rationale for such a tax should be surplus sharing, a formula supported by all the sides involved has yet to be found.

7 Conclusion

This paper has reviewed four decades of economics research on the brain drain, with a focus on recent contributions and on development issues. We started with an assessment of the magnitude, intensity and determinants of the brain drain, showing that high-skill migration is becoming the dominant pattern of international migration and a major aspect of globalization. The fact that international migration from poor to rich countries is becoming more of the brain drain type is a serious source of concern in developing countries and the development community. Through the brain drain, it would seem, globalization is making human capital scarcer where it is already

[38] See also Wilson (2011), who shows that a tax on brains could benefit the home country even when home country governments are malevolent, and Wilson (2008) for a voluntary mechanism based on an insurance-upon-return tax cut proposal.

scarce and more abundant where it is already abundant, thereby contributing to increasing inequality across countries, including among the richer ones. To examine the mechanisms and evidence behind this view, we designed a stylized growth model, flexible enough to encompass the various channels through which a brain drain affects sending countries, and reviewed the evidence on these channels.

The recent literature shows that high-skill emigration need not deplete a country's human capital stock and can generate positive network externalities. The brain drain side of globalization creates winners and losers among developing countries, and certain source-country characteristics in terms of governance, technological distance, demographic size, and interactions between these, are associated with the ability of a country to capitalize on the incentives for human capital formation in a context of migration and seize the global benefits from having a skilled, educated diaspora. As illustrated with case studies of the African medical brain drain, the exodus of European scientists to the United States, and the role of the Indian diaspora in the development of India's IT sector, the conditions under which a country is gaining or losing are not a matter of fate; to a large extent, they depend on the public policies adopted in the receiving and sending countries.

Where do we go from here? As we have seen, an urgent task is to improve the state of international migration data along several dimensions: time series and frequency, occupations, more disaggregated education levels, age of entry and gender decompositions, country coverage and bilateral disaggregation, and tracking; in particular, migration "flows" are currently measured as changes in the stocks over a given period and it is impossible to know how exactly these changes balance attrition (and whether attrition is caused by death, return migration or emigration to a third country) and new entry flows. The state of comparative data on immigration laws and policies, especially their bilateral dimension, may be the second most limiting factor on cross-country analyses of the determinants of migration flows and for the analysis of the consequences of these flows on the receiving and sending economies.

Partly because of data constraints, many of the macro studies surveyed do not identify the causal effects of high-skill emigration on development in a fully convincing way. As a result, the sign and magnitude of these effects remains a source of controversy among economists. Similarly, micro studies of migration and development have not yet taken full advantage of the randomization revolution; while this is beginning for migration studies in general (see McKenzie and Yang, 2010), the only paper we are aware of which exploits a (policy) experiment targeting high-skill migrants is Clemens' (2010) study of the income gains from migration for Indian H1-B visa lottery winners.[39] Another urgent task is thus for researchers to design and exploit the panel and bilateral dimensions of future migration data sets[40] for

[39]Until 2006, visa applications to the US were processed on a "first come first serve" basis. In 2007 and 2008, the number of applications from India in the first hour greatly exceeded their quota and so it was decided to process applications through a lottery.

[40]Ozden et al. (2011) has both the panel and bilateral dimensions but lacks the skill dimension.

cross-country analysis and, at a micro level, to investigate existing natural and policy experiments (e.g., the US Diversity Lottery Visa) to identify the causal effects of high-skill migration on development outcomes.

Finally, it is noteworthy that although the links between high-skilled emigration and economic development are clearly bidirectional, they have only been investigated in a single direction so far. However, empirical analyses of the determinants of high-skilled emigration show that poor economic performance and its correlates (such as rampant poverty, bad institutions, discriminations, political repression, etc.) are all important determinants of emigration in general and of high-skill emigration in particular. In these studies (surveyed in Section 2), country characteristics are treated as exogenous. On the other hand, from section 3 onward, we investigated the causal impact of brain drain migration on economic development. Combining these two approaches at the aggregate and bilateral levels is a promising avenue of research. The bidirectional causal link between emigration and poverty can induce both vicious and virtuous circles (e.g., an adverse economic shock can induce high-skill workers to leave the home country while the migration response to the shock determines its eventual effect on the economy). Endogenous high-skill emigration can therefore be a source of multiplier effects and contribute to propagate shocks across regions; this opens the possibility of multiple equilibria and coordination failures in emigration decisions. A third important direction for future research, therefore, is to try to better understand these interdependencies and derive their implications for the design of development policies.

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