

Brain Drain and Brain Waste

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Abstract

When skilled workers migrate they face the brain waste risk, i.e.: they can end up employed as unskilled. We analyze the effects of brain waste on brain drain, resulting from low international transferability of skills due to a low quality of education at the origin. We show that this type of brain waste: (1) reduces education incentives; (2) weakens the chances for a positive self-selection; and (3) decreases the possibility of a brain gain. In addition, for sender countries of migration, the most effective education policy is not to directly subsidize students, but to target the quality of the education system.

Keywords: Brain drain, brain waste, self-selection, international transferability of human capital.

JEL Classification: F22, J61.

1 Introduction

The traditional view on brain drain is that international migration leads developing countries to lose skilled workers to developed countries, due to higher wages in the latter (Bhagwati and Hamada, 1974)¹. Emigration

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¹The term 'brain drain' designates "the international transfer of human resources and mainly applies to the migration of relatively highly educated individuals from developing to developed countries" (Docquier and Rapoport, 2008).

of the skilled to rich countries can then be detrimental to poor countries economic growth through a set of negative externalities, for example, reduced productivity of those left behind, higher costs of public goods and loss of the investment made in human capital formation.

Recent contributions, however, argue that the brain drain story does not necessarily need to hold (Docquier and Rapoport, 2007). In effect, in a developing economy closed to international migration, the returns to schooling are very low and this discourages investment in education. Though, if an individual is able to migrate to a high wage developed country where the returns to schooling are higher, he/she might have extra incentives to acquire education relatively to autarchy. This new view defends that migration might offset the negative brain drain effect via an increase in the number of people that take education due to higher returns to schooling relatively to autarchy. In particular, migration can conduce to a brain gain when the increase in the number of people that acquire education due to migration prospects more than compensates for the skilled people that migrate.

According to Docquier and Rapoport (2011), the above 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’. In this paper, we investigate the claim by Docquier and Rapoport (2011) on brain waste and brain drain (see also Schiff, 2005).

Brain waste describes a situation with skill downgrading, where an individual is working in a job that requires a skill level lower than the one he/she has acquired (Reitz, 2001). In other words, brain waste arises when a skilled individual incurs in the costs of taking education but he/she does not reap the benefits of human capital acquisition, i.e.: a skilled migrant ends up working as unskilled. With brain waste, then, skilled migrants run the risk of not accessing the rewards to human capital in the destination country. If migrants internalize this brain waste risk, the education incentives that arise with international migration can therefore be reduced, decreasing also the chances for a brain gain.

We focus in one channel of brain waste: low international transferability of skills². Low international transferability of human capital occurs when skills are not easily transferable across borders. As a consequence, a skilled migrant has higher chances to end up employed as unskilled (Chiswick and Miller, 2007). In particular, we look to the case

²Brain waste can also occur due to illegal migration (Coniglio et al., 2009). However, the mechanism through which illegal migration affects brain waste is different from the one under low international transferability of skills. On this issue see footnote 10.

where the low international transferability of skills arises due to a low quality of the education system at the origin³. Several empirical papers document the low quality of education systems in various developing countries (see Bratsberg and Terrell, 2002; Docquier et al., 2010; Haley and Taengnoi, 2011; Mattoo et al., 2008; and Sweetman, 2004).

An analysis of developing countries' migration policies shows in fact a change of focus to the international transferability of human capital (World Bank, 2006). This interest lies in the fact that the international transferability of skills is expected to influence self-selection of migrants, once it affects the returns to migration of the skilled⁴. The main research question in the self-selection literature is if skilled individuals positively self-select into migration relatively to the unskilled (Borjas, 1987). This is an important topic, because it is believed that skilled migrants can promote positive externalities for the host economy. For instance, skilled migrants can encourage economic growth through an increase in the stock of human capital and knowledge spillovers.

In this paper, we then analyze if brain waste, which results from the low international transferability of skills due to the low quality of education at the origin, affects the brain gain and the positive self-selection arguments. Our main idea is that imperfect international transferability of skills creates a brain waste risk. This is so because, a skilled migrant runs the risk that his/her skills are not recognized at the destination. Therefore when a skilled worker migrates, he/she is subject to a kind of lottery. If a skill migrant has the skills recognized, he/she has access to the destination's returns to skill. If a skilled migrant does not have the skills recognized, he/she has invested in education but does not receive the full returns to skills.

In order to study these issues, we compare a scenario with no brain waste with another with brain waste. We show that brain waste of the type analyzed here: (1) reduces education incentives; (2) weakens the chances for a positive self-selection; and (3) decreases the possibility of a brain gain. In addition, for sender countries of migration, the most effective education policy is not to directly subsidize students, but to target the quality of the education system.

It is important to stress that the mechanism in our paper is new in

³Low international transferability of skills can also be the result of a very restrict skill equivalence policy at the destination. The policy implications of this case are however different from the one analyzed in this paper, since only policy changes at the destination (but not at the origin) can affect brain waste.

⁴The theoretical literature identifies two dimensions of self-selection: selection in terms of observable skills (e.g.: education, language skills and work experience) and selection in terms of unobservable skills (e.g.: ability and motivation). The empirical literature, however, usually only focus in the former (Beine et al., 2008).

the brain drain literature. In particular, it differs from two central mechanisms in the brain drain literature: uncertain migration and higher returns to skill at the origin relative to the destination. When the returns to skill are higher at the origin than at the destination the incentives of skilled workers to take education and to migrate are reduced, promoting therefore a negative self-selection (Borjas, 1987) and a brain drain (Egger and Felbermayr, 2009). At same time, however, skilled workers more likely return home, and this can support a brain gain (Stark et al., 1997). In turn, when the migration decision is uncertain, if a sufficient number of emigrants that have acquired education do not migrate, because for example they do not obtain legal status at the destination, a brain gain is promoted (Docquier and Rapoport, 2007).

The results in our model, however, come through another mechanism from the papers just mentioned. In particular, in here skilled migrants face an uncertainty about the returns to education at the destination that result from low international transferability of skills, i.e.: the brain waste risk. This differs from Borjas (1987); Egger and Felbermayr (2009) and Stark et al. (1997), since the brain waste risk arises even when the returns to skill are higher at the destination than at the origin. In addition, our mechanism is also different from Docquier and Rapoport (2007), given that migrants have no uncertainty about their migration decision, but only about future earnings at the destination.

The remainder of the paper is organized as follows. In the next section, we discuss the empirical evidence on brain waste and the international transferability of skills. In section 3, we introduce the base model. In section 4 and 5, we present the results for the no brain waste and the brain waste scenarios, respectively. In section 6, we analyze the implications of an education policy by the source migration country that subsidizes students and/or improves the quality of the education system. We then discuss the robustness of our results (section 7). We conclude with the main implications of brain waste on brain drain (section 8).

2 Empirical Evidence

In this section, we analyze the empirical relevance of brain waste that results from low international transferability of skills.

Gibson and McKenzie (2011) defend that brain waste does not affect the majority of skilled migrants, since "79 percent of working migrants from developing countries with a bachelors' degree or more are working in occupations in the United States in which the majority of workers have post-secondary education, as are 90 percent of those with a master degree or more, and 96 percent of those with a Ph.D". In our opinion, this evidence does not compromise our argument on the links between

brain waste and brain drain. We think so for a number of reasons.

First, brain waste and the international transferability of skills have been the subject of policy initiatives, in both senders and receivers countries of migration. For instances, sender countries increasingly focus on the quality of their education systems, in order to make skills more transferable internationally for nationals (see Lien, 2008 and Docquier and Rapoport, 2011). This has been especially the case in Latin America and Asia, where skilled emigration is substantial. In turn, receiver countries use more and more resources to evaluate the quality of foreign education systems, so as to have a more effective skills transferability policy for international immigrants. Some examples are the EU (Hiris, 2004), Australia and Canada (Reitz, 2001).

Second, the tradition in the economics literature is to think about expected (and not realized) returns from education and migration. In fact, starting with Becker (1960), economists view education as an investment decision that is based on the expected income for different skill groups. Similarly, since Sjaastad (1962), migration is also modeled as an investment decision: an individual migrates if the expected discounted difference in the stream of income between the new and the old location exceeds moving costs. Therefore, brain waste to have an impact on education and migration choices does not need to be very expressive, it is just necessary that potential migrants expect that it can affect their returns from migration and education.

Third, for a developing country, human capital externalities do not come only from individuals with university education. In fact, the empirical literature on economic growth points out that in developing countries the human capital externalities can be important even for lower levels of education, such as the primary school (Barro, 1997). What this tells us is that the brain waste story is not limited to higher levels of education, such as university. Then, even if migration, due to the brain waste risk, only discourages education for lower schooling levels, this can still have negative growth effects in the origin migration country.

The relevance of lower levels of education for source countries is recognized by a series of papers on the effects of migration on schooling choices. For instance, de Brauw and Giles (2006) show a negative relationship between migration prospects and high school enrollment in a panel of household data from China. They argue that this results from potential low returns to high school education among Chinese migrants from rural areas. The reason is that for rural migrants, legal temporary residence status might not confer the same set of benefits typically associated with permanent registration as a city resident.

In turn, Kandel and Kao (2001) find that children in Mexican house-

holds with high levels of US migration are associated with lower aspirations to attend university. They defend that Mexican migrant communities understand that "the US job market does not reward education acquired in Mexico beyond the junior or senior high school levels". McKenzie and Rapoport (2011), also for Mexico, find that living in a migrant household lowers the probability of completing high school by 13 percent for males. This is attributed to the fact that schooling decisions depend on the expectation of migration in the future and previous household migration experience. Given that, most of Mexican migrants work in low skilled jobs, then, the incentives to take education are reduced.

Fourth, in spite of the majority of skilled migrants do not suffer brain waste, this is not true for some groups. This is especially the case for migrants from certain regions, such as Africa, Eastern Europe and Latin America, where the quality of the education system is low (Bratsberg and Terrell, 2002 and Sweetman, 2004; Mattoo et al., 2008; Docquier et al., 2010 and Haley and Taengnoi, 2011). As a result, several studies find a link between brain waste, the quality of the education system at origin and the imperfect international transferability of skills (Reitz, 2001 and Chiswick and Miller, 2007, 2008)⁵. For instance, Reitz (2001) shows that in Canada, immigrants, compared to native-born, receive a smaller earnings premium for formal education⁶.

In the EU, the evidence is also supportive of brain waste as a consequence of a low international transferability of skills, mainly for migrants from Eastern Europe. Hiris (2004) finds that immigrants from Eastern Europe in the EU, in spite of being comparatively more skilled than natives, their employment is relatively less skilled. She argues that this results from the EU migration policy that restricts migration to relatively short periods of employment, and therefore encourages temporary migration. This policy has also promoted the development of a parallel labor market, which favors unskilled activities⁷.

⁵Other factors that affect the international transferability of skills are skin color and height (Hersch, 2008), the working experience or education acquired in the destination (Yamauchi, 2004 and Ferrer and Riddell, 2008) and language skills (Bleakley and Chin, 2004 and Chiswick and Miller, 2009).

⁶In the same way, Chiswick (1978) demonstrates that the partial effect of a year of schooling on earnings for the foreign born in analyses of 1970 US Census data was 5.7 percent, whereas among the natives was 7.2 percent. Comparable patterns have been reported for the US for later Censuses (Chiswick and Miller, 2007), and for other countries: Baker and Benjamin (1994) for Canada; Chiswick, (1980) for Britain; and Chiswick and Miller (1985) for Australia.

⁷Similarly, after the fall of the Communist bloc, the majority of the scientific personnel arriving from Eastern Europe and the former Soviet Union were not incorporated into equivalent sectors in the EU receiving countries. For example, Hryniewicz et al. (1992) show that only 22 per cent of the migrants who had migrated from their

In the OECD, Heuer (2011) also reports a brain waste for migrants from developing countries due to imperfect international transferability of skills. According to Heuer (2011), compared to OECD natives, migrants from developing countries with a university degree, more often are employed in occupational categories requiring less than tertiary education. In particular, 24% of all South-North migrants worked in occupations requiring tertiary education. This proportion is 4.9 percentage points lower than the share of tertiary-educated South-North migrants.

Fifth, and as consequence of the above, the evidence also suggests that brain waste affects the self-selection of skilled migrants. Hence, brain waste is not only a concern for individuals and source countries, but also for destination countries. For instance, Wright and Maxim (1993) point out that in Canada the self-selection of skilled workers has been affected not only by changes in the country-of-origin mix (from developed to developing countries) but also by an imperfect international transferability of skills. They say that in Canada “employers may not value education, work experience or other qualifications obtained prior to entry in Canada as highly as Canadian equivalent”. This is particular the case for migrants from developing countries that, as we have already said, often have education systems with low quality (see also Bloom et al. 1995 and Chiswick and Miller, 2007, 2008).

In this section, we have tried to show that brain waste and the level of international transferability of skills have negative effects on the education incentives of potential migrants, the economic returns from migration and the positive self-selection of skilled migrants. In the following sections, we present a model that aims to capture some of the channels through which these links can emerge.

3 The Model

The model in this section is based on Docquier and Rapoport’s (2007) stylized model on self-selection and brain drain. To them, we add the possibility of skilled workers to face brain waste when they migrate. As discussed in the introduction, the type of brain waste considered by us arises due to the imperfect international transferability of human capital resulting from the low quality of education at the origin. In particular, brain waste occurs since the migrants’ skills are not fully recognized in the destination market and therefore skilled migrants end up working

surveyed institutions were still employed in science. Fassman et al. (1995) have also observed this process in Vienna’s labor market amongst high skilled migrants from Poland and Hungary. Furthermore, some 50 per cent of the high skilled migrants in the sample anticipated their skill waste before arrival.

as unskilled⁸. The brain waste then emerges because an individual has incurred in the costs to acquire education, but he/she does not reap the benefits of it (i.e.: higher wages). In this sense, a skilled migrant runs the risk of brain waste.

The world economy is made up of two countries: the origin and the destination of migration. We focus in the origin country, which is a small developing open economy, and we treat as exogenous the destination country, which is a developed economy. The results in terms of brain drain and the education incentives of migration are mostly relevant to developing countries. In turn, results relative to the self-selection of skilled migrants are also of interest to developed countries.

Production, Human Capital and Wages. Individuals in the origin country live and work for 2 periods, $t = 1, 2$. In the first period, all individuals work as unskilled (U), but they can also decide to take education simultaneously in order to become skilled workers (S). In the second period, all individuals only work, but they can choose where to work: at the origin or at the destination. An individual that has not taken education, whether or not he/she migrates, always works as unskilled. An individual that has taken education and does not migrate always works as skilled. However, due to the brain waste risk, such is not necessarily the case if he/she migrates, i.e.: a skilled migrant can end up employed as unskilled.

Labor supply in period t in the origin country equals the amount of unskilled and skilled labor available in the economy⁹:

$$L_t = U_t + S_t. \quad (1)$$

We consider a very simple linear production function:

$$Y_t = w_t E_t, \quad (2)$$

where w_t is the wage rate and E_t is labor in efficiency units. We need to define w_t and E_t . Start with E_t :

$$E_t = U_t + hS_t, \quad (3)$$

⁸The lack of recognition of foreign credentials can be unjustified when the productivity of skilled migrants is not lower than the one of the natives. We suppose that the destination country has an imperfect ability to evaluate differences between applicants and puts more emphasis on the quality of the education system at the origin. According to the World Bank (2006) this is very often the case.

⁹Our model then only considers two factors of production: unskilled and skilled labor. Michael (2011) also introduces capital in a model of brain drain.

where $h > 1$ is the skilled productivity premium, which is individual specific. Skilled workers are therefore heterogeneous in productivity. The stock of human capital at time t can then be written as:

$$H_t = \frac{E_t}{L_t} = \frac{U_t + hS_t}{U_t + S_t} = 1 + P_t(h - 1), \quad (4)$$

where P_t is the proportion of skilled workers in the origin country:

$$P_t = \frac{S_t}{U_t + S_t}. \quad (5)$$

In turn, the scale factor w_t measures the wage rate per efficiency unit of labor and is endogenous and time-varying. To formalize the spillover effects associated with human capital formation, we assume following Docquier and Rapoport (2007) that w_t is an increasing function of the economy-wide average level of human capital of the workers remaining in the country, H_t :

$$w_t \equiv w(H_t), \quad (6)$$

where $w_0 > 0$. With this formalization we want to capture the idea of positive spillovers on human capital formation.

Individual Education Choices: Autarchy. In order to illustrate the education incentives of individuals, we consider first an autarchy scenario with no migration in the second period. If in the first period an individual only works, his/her wage rate is then w_1 . If in the first period an individual besides working also takes education, he/she has to pay the education costs cw_1 , with $0 < c < 1$. The parameter c is, then, the opportunity costs of education, which is individual specific, i.e.: individuals are heterogeneous on the ability to learn.

In the second period all individuals just work. Unskilled workers earn w_2 and skilled workers hw_2 . As such, the condition to acquire education in autarchy is:

$$(1 - c)w_1 + hw_2 > w_1 + w_2. \quad (7)$$

In the steady state when $w_1 = w_2 \equiv w$ this condition simplifies to:

$$c < c_{Aut} \equiv h - 1, \quad (8)$$

where the sub-script *Aut* stands for autarchy. In other words, all individuals with $c < c_{Aut}$ will acquire education. It can be easily noted that in order to obtain interior solutions we need that $h \in]1, 2[$. If otherwise, all individuals would have incentives to acquire education.

Individual Migration Choices: Open Economy. In an economy open to international migration, at the end of period 1 an individual can decide to migrate abroad. At the destination, the wage per-efficiency units for natives is $w^* > w$. Since our focus is in the origin country, w^* is exogenous. In addition, the wage premium for skilled workers at the destination is the same as at the origin, i.e.: $h = h^*$. In a subsequent section, we relax this assumption.

We consider, however, that when skilled workers migrate, they can suffer a brain waste. In our model, a skilled worker suffers brain waste if at the destination, he/she works as unskilled. In this sense, the skilled worker instead of receiving hw^* , his/her earnings are only w^* , i.e.: $w^* < hw^*$ (i.e.: brain waste). In a subsequent section, we also consider a situation where migrants (skilled and unskilled) besides the brain waste also suffer wage discrimination relatively to natives.

In addition, migration is costly. Migration costs include not only the monetary cost to move from one country to another, but also other costs such as those related with adapting to a new culture and being away from dear ones. Accordingly, we assume that migrants (skilled and unskilled) incur in a migration costs of kw^* , with $0 < k < 1$, i.e.: migration costs are measure in terms of the wage rate in the destination country. In a subsequent section, we analyze also the case where skilled and unskilled workers have different migration costs.

No Brain Waste *versus* Brain Waste. In the second stage an individual migrates if the gains from migration are larger than the costs. Given that wages are higher at the destination, the source country can lose skilled workers to migration, i.e.: brain drain. The brain drain literature, however, presents three mechanisms that can make it possible for a developing country to achieve a brain gain: return migration (Mayr and Peri, 2008; Stark et al., 1997 and Azarnert, 2012); remittances (Cox Edwards and Ureta, 2003); and uncertain migration decision (Beine et al., 2001 and Mountford, 1997). The possibility of a brain gain is increased: if the flow of skilled workers returnees is sufficiently high (return migration); if remittances reduce liquidity constraints in the education of the younger (remittances); or if many individuals that have invested in human capital do not migrate because, for example, they do not get a legal visa (uncertain migration).

As usual in the brain drain literature, we consider only one channel for brain gain. We choose temporary migration, because, and according to Mayr and Peri (2008), one fourth of all migrants return, and an even greater proportion in the case of the highly educated. We then assume that migrants spend a share γ of their second period working life in the destination country and $1 - \gamma$ as returnees. One way to justify this

assumption is to think like in Docquier and Rapoport (2007) that candidate migrants are only allowed by the host country authorities to spend a fraction γ of their working life in the destination. In fact, as defended by Docquier and Rapoport (2007) many immigration programs targeting the educated and skilled are designed for temporary immigrants.

In Docquier and Rapoport (2007) migrants would benefit from a longer duration of their migration experience, if they were allowed to do so; hence, the (fixed) length of the migration episode is actually constrained by immigration policies adopted at destination. Letting d represent the duration of the migration experience, the assumption in Docquier and Rapoport (2007) can actually be interpreted as $d \leq \gamma$, with utility-maximizing migrants choosing the constrained optimum $d = \gamma$.

Additionally, we compare two scenarios in the destination country: (1) no brain waste; and (2) brain waste. We model the brain waste case as a probability p_S of a skilled worker to work as skilled. In this way, a higher p_S stands for a higher international transferability of skills. As mentioned in the introduction, we consider that brain waste arises due to imperfect international transferability of skills resulting from a low quality of the education system at the origin¹⁰.

In the no brain waste scenario, therefore, a skilled worker always works as skilled at the destination. This is the case usually considered in the brain drain literature (Docquier and Rapoport, 2007). Then, for skilled workers, under perfect international transferability of skills (i.e.: work as skilled), $p_S = 1$. In turn, in the brain waste scenario, skilled workers have a probability $p_S \in (0, 1)$ of working as skilled in the destination country (and $(1 - p_S) \in (0, 1)$ of working as unskilled). As can be seen from figure 1, skilled workers choose between a safe option of not migrating with earnings hw , and a gamble/lottery of migrating with: (i) a probability p_S to end up working as skilled with wage hw^* ; (ii) and a probability $1 - p_S$ to end up working as unskilled with wage $w^* > w$. In this sense, we talk about a brain waste risk.

For a given individual, the life time income alternatives, under both the no brain waste and the brain waste scenarios, are then:

¹⁰In footnote 2, we have argued that brain waste can also be caused by illegal migration, but that the mechanism is a different one from the imperfect international transferability of skills. If brain waste occurs because of illegal status, migration should be portrayed as a sequential, two-step, decision: a skilled worker first decides whether to apply for a legal permit; if he/she is denied such a permit, then he/she has to choose whether to migrate illegally and suffer from a brain waste, i.e. work as an unskilled at destination.

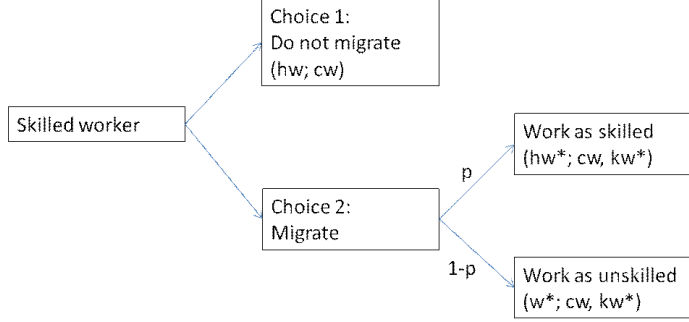


Figure 1: Migration decision of skilled workers

$$\begin{aligned}
 I(S, NM) &= (1 - c) w_1 + hw_2 \\
 I(S, MI) &= (1 - c) w_1 + w^* (\gamma (1 + p_S (h - 1)) - k) + (1 - \gamma) hw_2 \\
 I(U, NM) &= w_1 + w_2 \\
 I(U, MI) &= w_1 + w^* (\gamma - k) + (1 - \gamma) w_2,
 \end{aligned} \tag{9}$$

where NM stands for non-migration and MI for migration.

Also, assuming a uniform distribution of abilities, the proportion of educated workers at the origin at a given point in time is:

$$P_{p_S} = \frac{(1-\gamma)c_{p_S}}{1-\gamma c_{p_S}}. \tag{10}$$

Discussion of the Model¹¹. In this sub-section, we argue that the brain waste risk differs from other mechanisms in the migration literature. In particular: high returns to skill at the origin relatively to the destination (Borjas, 1987; Egger and Felbermayr, 2009; and Stark et al., 1997); and uncertain migration (Docquier and Rapoport, 2007). We discuss first the former and then turn to the latter.

In our model the return to skill is hw at the origin and $p_S hw^* + (1 - p_S) w^*$ at the destination (see figure 1). The destination return to skill is as such equal to hw^* for p_S skilled migrants that do not suffer brain waste and w^* for $(1 - p_S)$ skilled migrants that suffer brain waste. For the latter, two scenarios are possible: (1) $w^* > hw$; or (2) $w^* < hw$. If $w^* < hw$, the case considered in Borjas (1987), Egger and Felbermayr (2009) and Stark et al. (1997), a skilled migrant that suffers brain waste loses with migration. If this is the case, a utility-maximizing migrant

¹¹See also section 7, where we analyze the robustness of our results to different assumptions from the central case.

would decide to return home, i.e.: $d = 0$. If we want to keep the assumption that $d = \gamma$, then we need to rule out the case that $w^* < hw$. This is not a drawback of our model, on the contrary, because it clearly shows that what drives the results in our model is different from other models in the literature, Borjas (1987), Egger and Felbermayr (2009) and Stark et al. (1997). In other words, contrary to Borjas (1987), Egger and Felbermayr (2009) and Stark et al. (1997), the main mechanism in our model, the brain waste risk, is independent of having a high return to skill at the origin than at the destination¹².

In turn, if $w^* > hw$, a skilled migrant that suffers brain waste can still gain by migrating, if the wage returns at the destination pays for the migration and the education costs. However, he/she would be potentially better off without taking education, i.e.: without paying the costs of education cw . As we have seen above, this is the brain waste risk: the incentives for an individual to take education can be reduced if at the destination an unskilled worker can do as well as him/her, without the need to incur in the additional costs of education¹³. The choice to migrate, then, depend on the relation between the return to skill at the origin (which is certain) and the expected return to skill at the destination (which is uncertain).

The migration decision in our paper has also a different type of uncertainty from the one in Docquier and Rapoport (2007). In Docquier and Rapoport (2007), a potential migrant does not know if after taking education he/she will get a legal visa in the destination country. When the legal status is not granted, a skilled individual abstains from migrating, therefore contributing for a brain gain. In our paper, instead, the uncertainty arises due to the possibility of brain waste. In other words, an individual is uncertain about his/her earnings in the destination country, but not about his/her migration decision. However, this uncertainty introduces a brain waste risk for skilled workers, which is not present in Docquier and Rapoport (2007).

It is then important to highlight that all our results come through even if we impose that the return to skills are always higher at the destination (see above) or if we introduce uncertain migration (see section 7). This proves our claim that the central mechanism in this paper, the brain waste risk, differs from those based on high returns to skill at the

¹²A higher return to skills at the origin than at the origin can conduces to: (i) a negative self-selection, once it reduces the incentives of skilled workers to migrate relatively to the unskilled (Borjas, 1987); (ii) a brain gain, since it lowers the education incentives (Egger and Felbermayr, 2009); (iii) a brain gain, because it encourages skilled migrants to return to the origin.

¹³Mountford (1997) observes that such an incentive can exist via the differential probability of illegal migration across various levels of education.

origin relatively to the destination or uncertain migration.

4 No Brain Waste Scenario

In this section, we analyze the no brain waste scenario, i.e.: $p_S = 1$.

Self-Selection. The skilled and unskilled workers' incentives to migrate is given by $S_{p_S=1} = I(S, MI) - I(S, NM)$ and $U_{p_S=1} = I(U, MI) - I(U, NM)$, respectively. The subscript $p_S = 1$ indicates no brain waste scenario. At the steady state (i.e.: $w_1 = w_2 \equiv w$), the relation between skilled and unskilled workers' incentives to migrate equals:

$$S_{p_S=1} - U_{p_S=1} = \gamma(\omega - 1)(h - 1) > 0. \quad (11)$$

Under the no brain waste scenario, therefore, a skilled worker has always more incentives to migrate than an unskilled worker. However, a positive self-selection of skilled workers is promoted if and only if $S_{p_S=1} = I(S, MI) - I(S, NM) > 0$ and $U_{p_S=1} = I(U, MI) - I(U, NM) < 0$, (i.e.: skilled workers migrate and unskilled workers do not migrate):

$$\begin{aligned} S_{p_S=1} : \gamma h(\omega - 1) &> k\omega \\ U_{p_S=1} : \gamma(\omega - 1) &< k\omega. \end{aligned} \quad (12)$$

A positive self-selection of skilled workers is then encouraged when the returns to skills (h) are high¹⁴. In order to follow the brain drain literature, in the rest of this section, we assume that equation 12 is always satisfied. This is necessary for two reasons. First, we eliminate corner solutions where all individuals migrate, i.e.: unskilled workers do not migrate, and only some skilled workers migrate, given that they are asymmetric on h . Second, and as we are going to prove below, migration increases the incentives of individuals to acquire education. As a consequence, this opens the door for a brain gain.

Education Incentives and Migration. Under the no brain waste scenario only the following individuals will acquire education (evaluate $I(S, MI)$ with $I(U, NM)$):

$$c < c_{p_S=1} \equiv \omega(\gamma h - k) + (1 - \gamma)h - 1. \quad (13)$$

To check if migration increases the education incentives of natives relatively to autarchy, we compare equations 13 and 8:

¹⁴Self-selection is just determined by h , since h is the only parameter that affects skilled and unskilled workers' migration decisions asymmetrically; all the other parameters (ω , γ and k) work symmetrically for the two groups.

$$c_{p_S=1} - c_{Aut} = \gamma h (\omega - 1) - k\omega > 0. \quad (14)$$

As long as the positive self-selection condition holds (equation 12), then as expected, the incentives to acquire education under the no brain waste scenario are higher than under autarchy.

Brain Drain or Brain Gain? In the no brain waste scenario, a brain gain emerges if the derivative of P with respect to γ (equation 10) is positive at the skilled workers' threshold level of migration, equation 12:

$$\left[\frac{dP_{p_S=1}}{d\gamma} \right]_{h\gamma(\omega-1)=k\omega} = \frac{(h-1)(h-2)+h(\omega-1)-k\omega}{(1-\gamma(h-1))^2}. \quad (15)$$

It is straightforward to note that: first, the sign of the previous expression depends only on the numerator since the denominator is always positive; and second, the sign of the numerator is determined by the parameters ω , k and h . In particular, and making $\Delta_{p_S=1} = (h-1)(h-2) + h(\omega-1) - k\omega$, we can show that:

$$\begin{aligned} \frac{d(\Delta_{p_S=1})}{d\omega} &= h - k > 0 \\ \frac{d\Delta_{p_S=1}}{dk} &= -\omega < 0 \\ \frac{d\Delta_{p_S=1}}{dh} &= \omega - 2(2-h) \leq 0. \end{aligned} \quad (16)$$

The skill premium (h) has an ambiguous effect on brain drain: h only contributes for a brain gain for high relative wage destination-origin (ω)¹⁵. In turn, high relative wage destination-origin (ω) and low migration costs (k) promote a brain gain.

5 Brain Waste Scenario

In this section, we analyze the brain waste scenario, i.e.: $p_S \in (0, 1)$.

Self-Selection. As for the no brain waste case, skilled and unskilled workers' incentives to migrate is given by $S_{p_S \in (0,1)} = I(S, MI) - I(S, NM)$ and $U_{p_S \in (0,1)} = I(U, MI) - I(U, NM)$, respectively. The subscript $p_S \in (0, 1)$ indicates brain waste scenario. At the steady state (i.e.: $w_1 = w_2 \equiv w$) the relation between skilled and unskilled workers' incentives to migrate is:

$$S_{p_S \in (0,1)} - U_{p_S \in (0,1)} = \gamma (p_S \omega - 1) (h - 1). \quad (17)$$

¹⁵The ambiguity arises in part from the fact that when $h = h^*$, the comparative static exercises on h refer to simultaneous changes on h and h^* . This should be kept in mind for the comparative static exercises on h below.

Skilled workers then do not necessarily have more incentives to migrate than the unskilled, since $S_{p_S \in (0,1)} \leq U_{p_S \in (0,1)}$. This contrasts with the no brain waste scenario where skilled workers always have higher incentives to migrate than the unskilled (equation 11). In particular, under the brain waste scenario skilled workers have lower incentives to migrate than the unskilled if the probability of working as skilled is low (low p_S) and the relative wage destination-origin is low (low ω).

The result in equation 17 therefore should affect self-selection. To investigate this, we need to define when a positive self-selection of skilled workers arises in the brain waste scenario, i.e.: when $S_{p_S \in (0,1)} = I(S, MI) - I(S, NM) > 0$ and $U_{p_S \in (0,1)} = I(U, MI) - I(U, NM) < 0$:

$$\begin{aligned} S_{p_S \in (0,1)} : \gamma (\omega (p_S (h - 1) + 1) - h) &> k\omega \\ U_{p_S \in (0,1)} : \gamma (\omega - 1) &< k\omega. \end{aligned} \quad (18)$$

Since under the brain waste scenario, skilled workers might not have more incentives to migrate than the unskilled (equation 17), then also the possibility of a positive self-selection is reduced relatively to the no brain waste case. This is particular so when the probability of skilled workers to suffer brain waste is high (low p_S). Furthermore, relatively to the no brain waste case, now the skill premium (h) has an ambiguous effect on self-selection. The reason for this is that under the brain waste scenario, a skilled worker has no guarantee that he/she will reap the benefits of h in the destination country, i.e.: the brain waste risk¹⁶.

In this way, developed countries gain with reductions in the brain waste risk (i.e.: increases in p_S), since when this is the case more skilled workers migrate. Therefore, developed countries also benefit from improvements in the quality of education systems in developing countries.

For the same reasons as for the no brain waste scenario, in the rest of this section we assume that equation 18 is always satisfied. We want to study education incentives and brain drain when the brain waste scenario supports a positive self-selection since the opposite case is not interesting, i.e.: with a negative self-selection of skilled migrants, migration cannot increase education incentives and promote a brain gain.

Education Incentives and Migration. With brain waste, only the following individuals acquire education:

$$c < c_{p_S \in (0,1)} \equiv \omega (\gamma (p_S (h - 1) + 1) - k) + h (1 - \gamma) - 1. \quad (19)$$

¹⁶From equation 18, we can also see that the remaining parameters (k , ω and γ) cannot affect self-selection, since they promote migration symmetrically for unskilled and skilled workers.

The first question we must ask is if migration increases education incentives relatively to autarchy. To do this we compare equation 19 with equation 8:

$$c_{p_S \in (0,1)} - c_{Aut} = \gamma (\omega (p_S (h - 1) + 1) - h) - k\omega. \quad (20)$$

As for the no brain waste scenario, then, as long as the positive self-selection condition holds (equation 18), the incentives to acquire education under the brain waste scenario are higher than under autarchy.

More interesting, however, is to evaluate the education incentives under the no brain waste and the brain waste scenarios. To check this we compare equation 13 with equation 19:

$$c_{p_S=1} - c_{p_S \in (0,1)} = (1 - p_S) \gamma \omega (h - 1) > 0. \quad (21)$$

Relatively to the no brain waste scenario, the brain waste scenario reduces the incentives of individuals to acquire education¹⁷. This is so, because brain waste diminishes the expected returns to education.

The disincentive to acquire education, which arises under the risk of brain waste (resulting from imperfect international transferability of skills), is central in this paper because: first, it is the main force operating in our model; and second, it is what makes our results robust to different assumptions (see section 7).

Brain Drain or Brain Gain? In the brain waste scenario, a brain gain emerges if the derivative of P in relation to γ (equation 10) is positive at the skilled workers' threshold level of migration, equation 18:

$$\left[\frac{dP_{p_S \in (0,1)}}{d\gamma} \right]_{\gamma(\omega(p_S h + (1-p_S)) - h) = k\omega} = \frac{(h-1)(h-2) - h + \omega(p_S(h-1) + 1) - k\omega}{(1 - \gamma(h-1))^2}. \quad (22)$$

To analyze the effects of the different parameters on brain drain under the brain waste scenario, note first that the sign of equation 22 depends only in the numerator since the denominator is always positive. By computing the derivative of the numerator of equation 22 we obtain the following relations (for the sake of notation, we represent the numerator of equation 22 as $\Delta_{p_S \in (0,1)}$):

¹⁷Note that this depends only on brain waste, since temporary migration does not play a role, i.e.: even for $\gamma = 1$ (permanent migration) the above conclusion holds.

$$\begin{aligned}
\frac{d(\Delta_{p_S \in (0,1)})}{dp_S} &= \omega (h - 1) > 0 \\
\frac{d(\Delta_{p_S \in (0,1)})}{d\omega} &= 1 + p_S (h - 1) - k > 0 \\
\frac{d(\Delta_{p_S \in (0,1)})}{dk} &= -\omega < 0 \\
\frac{d(\Delta_{p_S \in (0,1)})}{dh} &= p_S \omega - 2(2 - h) \leq 0.
\end{aligned} \tag{23}$$

Note first that relatively to the no brain waste scenario (equation 16), under the brain waste scenario, the skill premium (h) continues to have an ambiguous influence on brain drain: h only contributes for a brain gain for high ω and high p_S . In turn, high probability of not suffering brain waste (high p_S), high relative wage destination-origin (ω) and low migration costs (low k) promote a brain gain. The reverse happens for low p_S , low ω and high k , i.e.: when brain waste becomes more relevant, a brain drain might arise.

In this way, this result may help to explain the empirical evidence on brain drain by Beine et al. (2008). In particular, Beine et al. (2008) show that the countries with a brain drain are mostly located in Africa and Latin America. In addition, available empirical evidence also indicates that these two regions suffer more from low international transferability of skills due to a low quality of the education system at the origin (Mattoo et al., 2010). Then, if the brain waste mechanism presented in this paper is at work in Africa and Latin America, low international transferability of skills might be partially responsible for the brain drain observed in these regions.

Other central issue is to evaluate brain drain outcomes under the no brain waste scenario and under the brain waste scenario. To check this we compare equation 15 with equation 22:

$$\begin{aligned}
\left[\frac{dP_{p_S=1}}{d\gamma} \right]_{h\gamma(\omega-1)=k\omega} - \left[\frac{dP_{p_S \in (0,1)}}{d\gamma} \right]_{\gamma(\omega(p_S h + (1-p_S)\tau) - h) = k\omega} \\
= \frac{\omega(1-p_S)(h-1)}{(1-\gamma(h-1))^2} > 0.
\end{aligned} \tag{24}$$

We can then see that, relatively to the no brain waste scenario, brain waste reduces the chances of a brain gain. This is so, since under the brain waste scenario, education incentives triggered by migration are weakened relatively to the no brain waste scenario.

6 Education Policy

In this section, we analyze if an education policy can increase the chances of a brain gain relatively to a scenario with no education policy¹⁸. For simplicity, as in Docquier and Rapoport (2007), now we make migration costs equal to zero. The consequence of having $k = 0$ is that, independently of having or not an education policy, migration will always promote a brain gain. However, the important point for education policies is not if migration promotes a brain gain (since, as we have seen in the previous sections, this depends crucially on migration costs), but if an education policy can promote more brain gain than in the absence of such policy. Since results for this last issue are not affected by migration costs, we exclude them.

In the education policy scenario, following Docquier and Rapoport (2007), the government in the origin migration country collects an income tax on the educated and the uneducated adults that remain in the country¹⁹. The tax can be applied with two purposes: (i) to give a direct subsidy to each young that takes education; (ii) to improve the quality of the education system. In the former, the objective is to increase the enrolment rates and therefore the human capital stock in the country. In the latter, the aim is to reduce the uncertainty about education quality and to make skills more transferable internationally²⁰.

As in Docquier and Rapoport (2007), we express the tax in terms of skilled workers' wages, Thw , where T is the tax rate. The part of the tax directed to subsidies to students is denoted in relation to the local wage, Zw , where Z stands for the subsidy rate. In turn, the part of the tax targeting the quality of the education system makes that the probability of a skilled worker of not suffering brain waste at the destination changes from $p_S^{T=0}$ to p_S^T , with $p_S^T > p_S^{T=0}$. The upper-scripts T and $T = 0$ refer to the "education policy" and the "no education

¹⁸Similar to Docquier and Rapoport (2007), we assume that the government budget is balanced and that there is no need for fiscal adjustments due to migration. Introducing these issues would not qualitatively change the results.

¹⁹We do not consider the political economy of migration and taxation (see Epstein et al., 1999).

²⁰There are other available policies to accomplish this goal. First, a government can encourage individuals to take education in foreign countries with better education systems. This strategy can bring fiscal gains (if the government does not subsidize foreign education), but can also make access to education more unequal (see Rosenzweig, 2005). Second, a government can stimulate the export of skilled workers, via bilateral agreements with other countries: the origin migration country guarantees the quality of the professionals and the destination assures the recognition of the education credentials. A well-known example of this case is Philippines, which has simultaneously disengaged from higher education and promoted the emergence of private education institutions (Docquier and Rapoport, 2011).

policy" cases, respectively²¹. With an education policy, the life income for alternative migration choices is:

$$\begin{aligned}
I(S, NM)^T &= (1 - c + Z) w_1 + h w_2 (1 - T) \\
I(S, MI)^T &= (1 - c + Z) w_1 + \gamma w^* (h p_S^T + (1 - p_S^T)) + (1 - \gamma) h w_2 (1 - T) \\
I(U, NM)^T &= w_1 + w_2 (1 - Th) \\
I(U, MI)^T &= w_1 + \gamma w^* + (1 - \gamma) w_2 (1 - Th). \tag{25}
\end{aligned}$$

Under the education policy, the closed economy critical level of education becomes:

$$c < c_{Aut}^T \equiv h - 1 + Z. \tag{26}$$

In order to obtain interior solutions for the education policy case, we need to assume that $(h + Z) \in]1, 2[$. Otherwise all individuals would have incentives to acquire education.

For the no education policy scenario, in turn, the life time income for alternative migration choices is as in equation 9 with $k = 0$ and the closed economy critical level of education is as in equation 8.

Next we compare the education policy and the no education policy cases. This exercise is done for both the no brain waste and the brain waste scenarios.

Education Policy: No Brain Waste Scenario. For the no brain waste scenario, we start by defining the migration conditions for skilled and unskilled workers. In the education and the no education policy cases we have, respectively:

$$\begin{aligned}
S_{p_S=1}^T &: \omega > 1 - T \\
U_{p_S=1}^T &: \omega < 1 - hT \\
S_{p_S=1}^{T=0} &: \omega > 1 \\
U_{p_S=1}^{T=0} &: \omega < 1. \tag{27}
\end{aligned}$$

As a result, only the following individuals will become skilled in the education and the no education policy cases:

$$\begin{aligned}
c < c_{p_S=1}^T &\equiv \omega \gamma h + (1 - \gamma) h (1 - T) + Z + Th - 1 \\
c < c_{p_S=1}^{T=0} &\equiv h (\omega \gamma + (1 - \gamma)) - 1. \tag{28}
\end{aligned}$$

²¹In the no brain waste scenario, since $p_S = 1$, then, the education policy consists only of giving direct subsidies to students.

From here it is straightforward to find $P_{p_S=1}^T$ and $P_{p_S=1}^{T=0}$. To study brain drain, we compute the derivatives of $P_{p_S=1}^T$ and $P_{p_S=1}^{T=0}$ with respect to ω . In both cases, the derivatives are evaluated at the skilled workers' migration threshold level (equation 27):

$$\begin{aligned} \left[\frac{dP_{p_S=1}^T}{d\omega} \right]_{\omega=1-T} &= \frac{(1-\gamma)\gamma h}{(1-\gamma(h+Z-1))^2} > 0 \\ \left[\frac{dP_{p_S=1}^{T=0}}{d\omega} \right]_{\omega=1} &= \frac{(1-\gamma)\gamma h}{(1-\gamma(h-1))^2} > 0. \end{aligned} \quad (29)$$

Given that these two derivatives are positive, then irrespective of having or not an education policy, migration always promotes a brain gain. As discussed above, the reason for this result is that migration costs are zero. As such, the only interesting thing to analyze when $k = 0$ is if the education policy promotes a higher level of brain gain than under the no education policy case. Comparing the brain drain conditions under the education policy and the no education policy cases, we obtain:

$$\begin{aligned} &\left[\frac{dP_{p_S=1}^T}{d\omega} \right]_{\omega=1-T} - \left[\frac{dP_{p_S=1}^{T=0}}{d\omega} \right]_{\omega=1} \\ &= \frac{\gamma^2 h Z (1-\gamma)(1-\gamma(h+Z-1)) + (1-\gamma)(h-1)}{(1-\gamma(h+Z-1))^2 (1-\gamma(h-1))^2} > 0. \end{aligned} \quad (30)$$

In the no brain waste scenario, therefore, the education policy always reinforces the possibility of a brain gain relatively to the no education policy case.

Education Policy: Brain Waste Scenario. For the brain waste scenario, we also begin by deriving the migration conditions for skilled and unskilled workers. For the education and the no education policy cases these are, respectively:

$$\begin{aligned} S_{p_S \in (0,1)}^T &: \omega (p_S^T (h-1) + 1) > h(1-T) \\ U_{p_S \in (0,1)}^T &: \omega > 1 - hT \\ S_{p_S \in (0,1)}^{T=0} &: \omega (p_S^{T=0} (h-1) + 1) > h \\ U_{p_S \in (0,1)}^{T=0} &: \omega > 1. \end{aligned} \quad (31)$$

In the education and the no education policy cases, then, only the following individuals will become skilled:

$$\begin{aligned} c < c_{p_S \in (0,1)}^T &\equiv \omega (p_S^T \gamma h + (1 - p_S^T) \gamma) + (1 - \gamma) h (1 - T) + Z + Th - 1 \\ c < c_{p_S \in (0,1)}^{T=0} &\equiv \gamma \omega (p_S^{T=0} h + (1 - p_S^{T=0})) + (1 - \gamma) h - 1. \end{aligned} \quad (32)$$

From these two equations we can derive $P_{p_S \in (0,1)}^T$ and $P_{p_S \in (0,1)}^{T=0}$ to study brain drain. As above, we compute the derivatives of $P_{p_S \in (0,1)}^T$ and of $P_{p_S \in (0,1)}^{T=0}$ with respect to ω and we evaluate them at the skilled workers' migration threshold level (equation 31):

$$\begin{aligned} \left[\frac{dP_{p_S \in (0,1)}^T}{d\omega} \right]_{\omega = \frac{h(1-T)}{p_S^T(h-1)+1}} &= (1-\gamma) \gamma \frac{p_S^T(h-1)+1}{(1-\gamma(h+Z-1))^2} > 0 \\ \left[\frac{dP_{p_S \in (0,1)}^{T=0}}{d\omega} \right]_{\omega = \frac{h}{p_S^{T=0}(h-1)+1}} &= (1-\gamma) \frac{p_S^{T=0}(h-1)+1}{(1-\gamma(h-1))^2} > 0. \end{aligned} \quad (33)$$

As such also under the brain waste scenario, and due to the absence of migration costs ($k = 0$), a brain gain is promoted independently of the education policy. Therefore, again what is important to analyze is if the education policy increases the brain gain relatively to the no education policy case. To study this, we compare the brain drain conditions under the education policy and under the no education policy cases:

$$\begin{aligned} \left[\frac{dP_{p_S \in (0,1)}^T}{d\omega} \right]_{\omega = \frac{h(1-T)}{p_S^T(h-1)+1}} - \left[\frac{dP_{p_S \in (0,1)}^{T=0}}{d\omega} \right]_{\omega = \frac{h}{p_S^{T=0}(h-1)+1}} = \\ (1-\gamma) \left(\gamma \frac{p_S^T(h-1)+1}{(1-\gamma(h+Z-1))^2} - \frac{p_S^{T=0}(h-1)+1}{(1-\gamma(h-1))^2} \right). \end{aligned} \quad (34)$$

If $p_S^T > p_S^{T=0}$ (i.e.: the education policy raises the quality of the education system), the education policy can increase the possibility of brain gain relatively to the no education subsidy case. However, if $p_S^T = p_S^{T=0}$ (i.e.: there are only direct subsidies to students), the education policy do not necessarily increases the possibility of a brain gain relatively to the no education policy case. In particular, when $p_S^T = p_S^{T=0}$, equation 34 tends to be negative when Z is sufficiently high²². Then, if the education policy does not target p_S , the education policy runs the risk of becoming ineffective the higher the education subsidy, because the opportunity costs of subsidization become very large.

The brain waste scenario therefore might reduce the success of education policies. So far, however, we do not know how the brain waste scenario does relatively to the no brain waste scenario. Comparing the effectiveness of the education policy under the no brain waste and the brain waste scenarios, we obtain:

²²To see this note that the sign of equation 34 depends only on the term in the numerator inside the large parenthesis (all other terms are positive). The derivative of the numerator in relation to Z when $p_S^T = p_S^{T=0}$ equals $2\gamma(\gamma(Z+h-1)-1) < 0$.

$$\left[\frac{dP^T_{p_S \in (0,1)}}{d\omega} \right]_{\omega = \frac{h(1-T)}{p_S^T(h-1)+1}} - \left[\frac{dP^T_{p_S=1}}{d\omega} \right]_{\omega=1-T} = -\frac{(1-\gamma)\gamma(1-p_S^T)(h-1)}{(1-\gamma(h+Z-1))^2} < 0. \quad (35)$$

The role of education policies is therefore unambiguously weakened under the brain waste scenario relatively to the no brain waste case. The rationale for this result is once more that brain waste reduces the returns to education, i.e.: since brain waste reduces the incentives of individuals to acquire education, it also renders education policies less efficient. However, as $p_S^T \rightarrow 1$ the two scenarios approach. This shows that, in our set-up, for an education policy is more important to target the quality of the education system than subsidizing students directly²³.

7 Robustness of Results

In this section, we check if the results in our paper are robust to relaxing a series of restrictions in the parameters of our model. In particular, we test if our conclusions do not change when: (1) the skill premium differs at the origin and at the destination; (2) the migration costs are different for the skilled and the unskilled and for the migrants that suffer brain waste and those that do not; (3) the migrants employed as unskilled are also subject to wage discrimination relative to natives. We also discuss, though not mathematically, the robustness of our results to: (1) other brain gain channels than temporary migration; (2) temporary brain waste; and (3) a multi-country world.

The above assumptions are relevant because they influence the relationship between the (net) skill premium at home and abroad. In fact, if the foreign net skill premium is higher than the one prevailing at origin, we might expect that the odds for a positive self-selection and a brain gain increase, since skilled agents enjoy a higher return to skill at destination. In other words, we want to analyze that even in set-ups that promote a positive self-selection and a brain gain, our results in the central case still emerge.

Different Skill Premium. In this subsection, we look at a situation where $h^* \neq h$, with h^* and h representing the skill premium at the destination and at the origin, respectively. The most interesting scenario is when $h^* > h$, since when this occurs the returns to skill at the destination increase and therefore it is more likely that we obtain a positive self-selection of skilled workers and a brain gain.

²³If individuals were credit constrained, direct subsidies to students would potentially become more central (Phan, 2012). In any case, the only way to reduce brain waste would continue to be via an increase in the quality of the education system at the origin.

With $h^* \neq h$, the life time income alternatives for a skilled individual are now (for the unskilled these are the same as in equation 9):

$$\begin{aligned} I(S, MI) &= (1 - c) w_1 + w^* (\gamma (1 + p_S (h^* - 1)) - k) + (1 - \gamma) h w_2 \\ I(U, MI) &= w_1 + w^* (\gamma - k) + (1 - \gamma) w_2. \end{aligned} \quad (36)$$

As before, the skilled and the unskilled workers incentives to migrate is given by $S_{p_S \in (0,1)} = I(S, MI) - I(S, NM)$ and $U_{p_S \in (0,1)} = I(U, MI) - I(U, NM)$, respectively. The relation between $S_{p_S \in (0,1)}$ and $U_{p_S \in (0,1)}$ can be shown to equal:

$$S_{p_S \in (0,1)} - U_{p_S \in (0,1)} = (h^* - 1) \gamma \left(\omega p_S - \frac{(h-1)}{(h^*-1)} \right). \quad (37)$$

Like in the central case ($h^* = h$), skilled workers have higher incentives to migrate than the unskilled for high ω and high p_S . Now however, skilled workers tend to migrate more than the unskilled for low h and high h^* , i.e.: when the skill premium is higher at the destination than at the origin. Note also that if $h^* > h$, under the no brain waste case ($p_S = 1$), $S_{p_S=1} > U_{p_S=1}$. However, as in the central case, in the brain waste scenario ($p_S \in (0, 1)$), and independently of the relation between h and h^* , $S_{p_S \in (0,1)} - U_{p_S \in (0,1)} \geq 0$.

We observe a positive self-selection of skilled migrants if:

$$\begin{aligned} S_{p_S \in (0,1)} &: \gamma (\omega (p_S (h^* - 1) + 1) - h) > k \omega \\ U_{p_S \in (0,1)} &: \gamma (\omega - 1) < k \omega. \end{aligned} \quad (38)$$

Similar to the central case, positive self-selection is promoted for high p_S . More interesting, a positive self-selection is encouraged when h is low and h^* is high. Remember that this differs from the central case where the skill premium (h) had an ambiguous effect. Again, this result is independent of brain waste, since it also arises with $p_S = 1$.

Different skill premium at the origin and at the destination also affect the education incentives. To analyze this, we compute $I(S, MI) - I(U, NM)$ and solve for c . From here we get that only the following individuals acquire education:

$$c < c_{p_S \in (0,1)} \equiv \omega (\gamma (p_S (h^* - 1) + 1) - k) + h (1 - \gamma) - 1. \quad (39)$$

Education incentives are therefore stronger for both high h^* and high h . Comparing the education threshold under autarchy (equation 8) and under migration (equation 39), we obtain:

$$c_{p_S \in (0,1)} - c_{Aut} = \gamma (\omega (p_S (h^* - 1) + 1) - h) - k\omega. \quad (40)$$

If the condition for self-selection holds (equation 38), then and as for the central case, education incentives increase with migration. Moreover, higher h^* and lower h contribute to increase the higher incentives to education that arise under the migration scenario relatively to autarchy.

Also, the difference in education incentives under the brain waste and the no brain waste cases is:

$$c_{p_S=1} - c_{p_S \in (0,1)} = (1 - p_S) \gamma \omega (h^* - 1) > 0. \quad (41)$$

Again as for the central case, we observe higher incentives to take education under the no brain waste scenario. Therefore, different skill premium at the origin and at the destination does not alter this result.

We can now look at brain drain. We first substitute equation 39 in equation 10. After, we evaluate the derivative of equation 10 in relation to γ , at the skilled workers' migration threshold level (equation 38):

$$\left[\frac{dP_{p_S \in (0,1)}}{d\gamma} \right]_{\gamma(\omega(p_S(h^*-1)+1)-h)=k\omega} = \frac{(h-1)(h-2)-h+\omega(p_S(h^*-1)+1)-k\omega}{(1-\gamma(h-1))^2}. \quad (42)$$

It can be easily checked that, as in the central case, brain gain is more likely for higher p_S , higher ω and lower k . However, different from the central case where the skill premium (h) had an ambiguous effect on brain drain, now a brain gain is promoted for higher h^* and lower h .

In addition, the relation between brain drain in the brain waste and the no brain waste scenarios is:

$$\begin{aligned} \left[\frac{dP_{p_S=1}}{d\gamma} \right]_{\gamma(\omega((h^*-1)+1)-h)=k\omega} - \left[\frac{dP_{p_S \in (0,1)}}{d\gamma} \right]_{\gamma(\omega(p_S(h^*-1)+1)-h)=k\omega} \\ = \frac{(1-p_S)(h^*-1)\omega}{(1-\gamma(h-1))^2} > 0. \end{aligned} \quad (43)$$

As for the central case, therefore, under the no brain waste scenario there are higher chances of a brain gain than under the brain waste scenario. We can then see that in spite of a higher skill premium at the destination than at the origin increases the chances of a positive self-selection, it does not cancel the negative effects of brain waste on education incentives and brain gain.

Different Migration Costs. In this subsection, we look at the case where the migration costs are different for the migrants that end up working as skilled (k_S) and as unskilled (k_U), i.e.: $k_S \neq k_U$. Again the most interesting scenario is when $k_S < k_U$, because if this occurs the

returns to skill resulting from migration increase (and therefore there are higher chances of a positive self-selection and brain gain)²⁴.

The alternative life time income paths for a skilled individual when $k_S \neq k_U$ are (for the unskilled these are the same as in equation 9):

$$\begin{aligned} I(S, MI) &= (1 - c) w_1 + w^* (p_S (\gamma (h - 1) - k_S + k_U) + \gamma - k_U) + (1 - \gamma) h w_2 \\ I(U, MI) &= w_1 + w^* (\gamma - k_U) + (1 - \gamma) w_2. \end{aligned} \quad (44)$$

The difference between the migration incentives for skilled and unskilled workers is then:

$$S_{p_S \in (0,1)} - U_{p_S \in (0,1)} \Rightarrow \gamma (h - 1) (p_S \omega - 1) + p_S \omega (k_U - k_S). \quad (45)$$

Skilled workers have more incentives to migrate than the unskilled for larger k_U and lower k_S . Also higher ω and higher p_S only contribute positively for higher migration incentives for the skilled, if $k_U > k_S$.

A positive self-selection of skilled workers arise if $S_{p_S \in (0,1)} > 0$ and $U_{p_S \in (0,1)} < 0$, this is so for:

$$\begin{aligned} S_{p_S \in (0,1)} : \gamma (\omega (p_S (h - 1) + 1) - h) &> \omega (p_S k_S + (1 - p_S) k_U) \\ U_{p_S \in (0,1)} : \gamma (\omega - 1) &< k_U \omega. \end{aligned} \quad (46)$$

Equation 46 shows that a positive-self selection of skilled workers is encouraged for low k_S . In turn, low k_U promotes both skilled and unskilled workers migration, and therefore, the effects on self-selection are neutralized. Furthermore, higher p_S only contributes for a positive self-selection if $k_S < k_U$. These results are independent of brain waste, since they also arise with $p_S = 1$. The only difference when $p_S = 1$ is that k_U stops to affect skilled workers, and therefore low k_U , by supporting more unskilled migration, can undermine a positive self-selection.

In terms of education incentives, we obtain that only the following individuals acquire education:

$$\begin{aligned} c &< c_{p_S \in (0,1)} \\ &\equiv h (1 - \gamma) + \omega (\gamma (p_S (h - 1) + 1) - k_U (1 - p_S) - k_S p_S) - 1. \end{aligned} \quad (47)$$

²⁴We then assume that a skilled worker that suffers brain waste (i.e.: that works as unskilled) have the same migration costs as an unskilled worker. However, results are very similar if the migration costs are based on the skill level, and not in employment, i.e.: if all skilled workers have migration costs k_S .

The education incentives, then, decrease with both k_U and k_S . Comparing this threshold level with the one under autarchy (equation 8), we arrive at:

$$c_{p_S \in (0,1)} - c_{Aut} = \gamma (\omega (p_S (h-1) + 1) - h) - \omega (p_S k_S + (1-p_S) k_U). \quad (48)$$

If the condition for self-selection holds (equation 47), then as in the central case, education increase with migration. Note, however, that k_U and k_S depress the higher incentives to education that arise under the migration scenario relatively to autarchy.

Furthermore, evaluating the case with no brain waste ($p_S = 1$) against the one with brain waste ($p_S \in (0,1)$), we have:

$$c_{p_S=1} - c_{p_S \in (0,1)} = (1-p_S) \omega (\gamma (h-1) - (k_S - k_U)). \quad (49)$$

When $k_S < k_U$, and as in the central case, more individuals take education under the no brain waste scenario than under the brain waste one. Interesting, though, while higher k_S reduces the advantage of the no brain waste case relatively to the brain waste one, the opposite occurs with k_U . This is so because under the no brain waste case, skilled individuals always incur in migration costs k_S . However, under the brain waste case skilled workers can either pay k_U or k_S depending on if they suffer brain waste or not, respectively.

For studying brain drain, we proceed in the same fashion as before. In particular, the possibility of a brain gain is the following:

$$\begin{aligned} & \left[\frac{dP_{p_S \in (0,1)}}{d\gamma} \right]_{\gamma(\omega(p_S(h-1)+1)-h)=(p_S k_S + (1-p_S) k_U) \omega} \\ &= \frac{(h-1)(h-2)-h+\omega(p_S(h-1)+1)-\omega(p_S k_S + (1-p_S) k_U)}{(1-\gamma(h-1))^2}. \end{aligned} \quad (50)$$

It can be shown that brain gain is encouraged for low k_S and low k_U . Relatively to the central case, brain gain continues to increase with ω , and h has an ambiguous effect. In addition, as long as $k_S < k_U$, higher p_S also promotes a brain gain.

Furthermore, the relation between brain drain under the brain waste and the no brain waste case is:

$$\begin{aligned} & \left[\frac{dP_{p_S=1}}{d\gamma} \right]_{\gamma(\omega((h-1)+1)-h)=k_S \omega} - \left[\frac{dP_{p_S \in (0,1)}}{d\gamma} \right]_{\gamma(\omega(p_S(h-1)+1)-h)=(p_S k_S + (1-p_S) k_U) \omega} \\ &= \frac{(1-p_S)((h-1)-(k_S-k_U))\omega}{(1-\gamma(h-1))^2} > 0. \end{aligned} \quad (51)$$

Again brain gain is more likely under the no brain waste scenario than under the brain waste one. This result illustrates that even when migration costs promote a positive self-selection of skilled workers (i.e.: for $k_S < k_U$), still, brain waste can reduce education incentives and the chances of a brain gain.

Unskilled Workers and Wage Discrimination. In this subsection, we look at the case where the migrants working as unskilled also incur a wage penalty in the destination country. In particular, for unskilled workers we have now that their wage at the destination is $\theta_U w^*$, with $0 < \theta_U < 1$ and for skilled $\theta_S w^*$, with $0 < \theta_S < 1$. In order to have a scenario that promotes a positive self-selection of skilled workers, we assume that $\theta_S > \theta_U$, i.e.: the wage penalty is larger for unskilled workers than for the skilled²⁵. In other words, higher wage discrimination for unskilled workers relatively to skilled ones can work as a migration deterrent for the former comparatively to the latter.

The life time income alternatives for a skilled individual are then (for the unskilled these are the same as in equation 9):

$$\begin{aligned} I(S, MI) &= (1 - c) w_1 + w^* (\gamma (\theta_S (1 - p_S) + p_S h) - k) + (1 - \gamma) h w_2 \\ I(U, MI) &= w_1 + w^* (\theta_U \gamma - k) + (1 - \gamma) w_2. \end{aligned} \quad (52)$$

Again, we start by comparing the migration incentives of the skilled and the unskilled workers:

$$S_{p_S \in (0,1)} - U_{p_S \in (0,1)} \Rightarrow \gamma (\omega (p_S (h - \theta_S) + \theta_S - \theta_U) - (h - 1)) \lesseqgtr 0. \quad (53)$$

Relatively to the central case, skilled workers continue to have higher incentives to migrate than the unskilled for higher p_S and higher ω . Similarly the effect of h , as in the central case, is ambiguous. In turn, while high θ_S (lower wage penalty for skilled workers) increases the incentives of skilled workers to migrate in relation to the unskilled ones, the contrary occurs with θ_U .

The previous effect can also be seen when analyzing self-selection. A positive self-selection of skilled migrants occurs if:

$$\begin{aligned} S_{p_S \in (0,1)} &: \gamma (\omega (\theta_S (1 - p_S) + h p_S) - h) > k \omega \\ U_{p_S \in (0,1)} &: \gamma (\theta_U \omega - 1) < k \omega. \end{aligned} \quad (54)$$

²⁵We can think that this is so, because skilled workers have some special skills (like language knowledge) that can give them an advantage over the unskilled in the destination country labor market.

It can be checked that, as for the central case, higher p_S contributes for a positive self-selection, and h has an ambiguous effect. In turn, higher θ_S works in favor of a positive self-selection of skilled workers, while high θ_U promotes unskilled migration and therefore it reduces the possibility of a positive self-selection of skilled workers.

We now look at the education incentives. We obtain that only the following individuals take education:

$$c < c_{p_S \in (0,1)} \equiv \omega (\gamma (hp_S + \theta_S (1 - p_S)) - k) + h (1 - \gamma) - 1. \quad (55)$$

Higher θ_S , hence, increases the education incentives of the skilled. The relation between the threshold level of education under autarchy (equation 8) and migration (equation 55) is:

$$c_{p_S \in (0,1)} - c_{Aut} = (\gamma (\omega (\theta_S (1 - p_S) + hp_S) - h) - k\omega). \quad (56)$$

If the condition for self-selection holds (equation 54), then, education incentives are higher under migration than under autarchy. Furthermore, lower wage discrimination against the skilled (higher θ_S) makes it more likely that the incentives to take education increase in the migration scenario relatively to autarchy.

In turn, comparing the incentives to take education under the brain waste and the no brain waste scenarios, we have:

$$c_{p_S=1} - c_{p_S \in (0,1)} = \omega \gamma (h - \theta_S) (1 - p_S) > 0. \quad (57)$$

In this sense, once again, individuals have higher incentives to acquire education under the no brain waste scenario than under the brain waste one. Note that under the no brain waste scenario the skilled workers, not only do not suffer brain waste, but are also not subject to wage discrimination (i.e.: when $p_S = 1$, θ_S is canceled out from the equations). Therefore, for high θ_S , the disincentive effect for taking education that occurs under the brain waste scenario relatively to the no brain waste one is reduced.

In terms of brain drain, we proceed as before, and we obtain that:

$$\left[\frac{dP_{p_S \in (0,1)}}{d\gamma} \right]_{\gamma(\omega(\theta_S(1-p_S)+hp_S)-h)=k\omega} = \frac{(h-1)(h-2)-h+\omega(\theta_S(1-p_S)+hp_S)-k\omega}{(1-\gamma(h-1))^2}. \quad (58)$$

Now contrary to the central case, ω has an ambiguous effect. Brain gain only increases with ω if θ_S , h or p_S are high relatively to k . In turn, high θ_S contributes for a brain gain, since it reduces the wage penalty for skilled worker that end up working as unskilled.

Finally, the relation between the potential brain drain/gain under the no brain waste and the brain waste scenarios is:

$$\begin{aligned} \left[\frac{dP_{p_S=1}}{d\gamma} \right]_{\gamma h(\omega-1)=k\omega} &- \left[\frac{dP_{p_S \in (0,1)}}{d\gamma} \right]_{\gamma(\omega(\theta_S(1-p_S)+hp_S)-h)=k\omega} \\ &= \frac{(1-p_S)(h-\theta_S)\omega}{(1-\gamma(h-1))^2} > 0. \end{aligned} \quad (59)$$

As for the previous cases, there are higher chances of a brain gain under the no brain waste scenario than under the brain waste one. Then, if the unskilled suffer higher wage discrimination than the skilled (which promotes positive self-selection), this does not cancel the negative effects of brain waste on education incentives and brain gain.

Other Extensions. In this subsection, we discuss (but do not analyze in formal terms) the effects of three additional extensions: other brain gain channels besides temporary migration (uncertain migration and remittances); temporary brain waste; and a multi-country world.

Start with uncertain migration. In the central case analyzed in this paper, when a potential migrant decides to migrate, he/she does so independently of his/her brain waste situation. Suppose, instead, that if a skilled individual suffers brain waste, he/she decides with probability q_S to not migrate and with probability $(1 - q_S)$ to migrate. As expected, the skilled individuals that suffer brain waste and that give up of migrating will contribute for a brain gain. However, this new formulation does not prevent the brain waste risk to arise. Therefore, since the main mechanism in this paper is not affected, results are also not going to be qualitatively altered.

Consider now remittances. Assume that each individual that decides to take education in the origin country receives a remittance R to finance his/her education. This case is somewhat similar to the education policy above. The only difference is that now who pays for the education of the young are not the taxes from those that remain in the country, but emigrants' transfers. As such remittances will also contribute to increase the education incentives of individuals in the origin country. However, as for the education subsidy case, remittances also do not eliminate the brain waste risk that skilled individuals face. Then, again results from our central case are going to be basically the same.

Next, we look at a situation where the brain waste is temporary, due for instances to changes in legislation that conduce to a more open skill equivalence policy²⁶. Imagine that a skilled individual that suffers brain

²⁶An example of legislation favorable to international skill equivalence is agreements at the EU level that oblige EU countries to recognize diplomas from other

waste spends a share $\delta \in (0, 1)$ of his/her working life in the destination country as unskilled and a share $(1 - \delta)$ as a skilled. In this case, the brain waste risk will be reduced, but not totally eliminated. As such, once more our results are not going to be changed substantially.

To close, we think of a multi-country world. Suppose that individuals can migrate to $i = 1, 2, \dots, n$ destinations, which are symmetric in every respect, except the brain waste risk²⁷. When this occurs, skilled workers will prefer to migrate to countries with lower brain waste risk. As a result, relatively to other countries, a country with a lower brain waste risk will find it simpler to attract skilled workers and therefore to achieve a positive self-selection. In addition, a brain gain will more easily arise in source countries, given that, as we have seen above, a lower brain waste risk increases education incentives. In this sense, a portfolio of countries with different brain waste risks can contribute to a reduction of brain waste amongst skilled workers, and therefore promote education and brain gain. In the end, however, as long as the brain waste continues to persist, education incentives and brain gain will be lower than in scenarios with no brain waste. Hence, our results are also going to be robust to a multi-country world.

8 Discussion

In this paper, we have argued that since brain waste affects the returns to education, then, it also influences education incentives, brain drain and self-selection. In this sense, we have compared a scenario with no brain waste with another one with brain waste. We have focused in the case where the brain waste arises due to a low international transferability of skills, resulting from a low quality of the education system at the origin.

We have showed that, relatively to the no brain waste scenario, the brain waste scenario has several negative effects. For the origin country of migration it reduces the incentives of individuals to acquire education and it weakens the possibility of brain gain to arise. For the destination country of migration, it undermines the chances of a positive self-selection of skilled migrants.

We have also discussed that these results are robust to different assumptions from the central case. For instances, the brain waste story still holds if we consider that the skill premium differs at the origin and

member countries (Hiris, 2004). These agreements, however, usually exclude EU members from Eastern Europe.

²⁷With this simplification, we want to focus on brain waste. It is well known that asymmetries between countries affect migration choices. Empirical evidence shows that migrants prefer countries with higher wages, with more job opportunities, and that are closer in terms of geographical and cultural distance (World Bank, 2006).

at the destination; the migration costs are different for the skilled and the unskilled; the migrants employed as unskilled are subject to wage discrimination; the brain gain channels are uncertain migration and/or remittances; the brain waste is temporary; and the world consist of several migration destinations.

Our model can in addition carry out some interesting policy implications. For developing countries, the most effective education policies are not the ones that subsidize students directly but that aim at improving the quality of the education system.

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